HIGH prep

JLR

CHIPLET CHALLENGE

INTER IIT TECH MEET MADRAS

BACKGROUND Automotive Industry

Revolution in the automotive industry has well and truly begun!

With the advent of Electric Vehicles, Autonomous Driving, Connected Cars, Shared Mobility, and Software Defined Vehicles, present-day automobiles are much more than a metallic box that can drive you around. Cars are becoming more complex, intelligent and connected due to the increasing use of advanced electronics and software. As a matter of fact, a modern car is powered by nearly 100 million lines of code! And electronics are responsible for 40% of a new car's total cost, with thousands of chips going under the hood. Compare that to just a couple of decades ago – lines of code have increased over 10x and the percentage of electronics cost has doubled.

Owing to this transformation, the importance of semiconductors in the automotive space has exploded in recent years. And to ensure that we continue to build ultra-modern, luxurious and the best cars in the world, JLR has partnered with numerous semiconductor companies like NVIDIA for ADAS and autonomous driving capability and Wolfspeed for Silicon Carbide (SiC) chips used in EVs for powertrain efficiency and extended driving range.

Similar to what happened with smartphones a decade ago, the automotive industry is poised for massive disruption growth on the back of high-performance semiconductors. *Exciting times ahead!*

Trends in the Automotive industry & Moore's Law

Due to this revolution, three major trends are shaping the automotive and semiconductor industry –

1. OEMs are packaging more-and-more features in their cars, creating a high demand for performance, leading to a large number of processors getting packed inside modern vehicles.
2. OEMs are moving towards a centralized vehicle architecture with one or two giant high-performance computers that are exceeding 1000 TOPS and DMIPS in performance. Towards the periphery, the number of sensors are increasing rapidly, their resolution is going up and the data generated in a car is exploding!
3. OEMs are developing Software Defined Vehicles (SDV) whose features are enabled, controlled, and updated by software over the lifetime of the car. This can be achieved by minimizing the hardware in the car, adopting a cloud first approach, seamless connectivity between ECUs and the car and cloud, SOA containerisation and orchestration and data processing capability (on-board, edge and cloud).

Till now, the semiconductor industry has evolved according to Moore's law. Transistors have gotten smaller, allowing more of them to fit on ICs, thus exponentially increasing compute capability. For instance, IBM's 2-nanometer (nm) chip technology puts 50 billion transistors, each the size of roughly five atoms, on a space no bigger than your fingernail. TSMC, on the other hand, has started large-scale production of **3 nm chips**!

SYSTEM-ON-CHIP: Advantages & Limitations

A system-on-chip (SoC) is a popular method to package an IC. Simply put, it is an IC design that combines elements of an electronic device onto a single chip instead of using separate components. There are many advantages of an SoC, such as small size, high-performance capability, enhanced security and low latency.

But now, with the three major trends taking shape, die sizes must be large enough to accommodate more IP. While this happens, process sizes are shrinking further down the nm scale with latest technologies. The rate at which die sizes need to increase to support an ever-increasing list of features however, is much greater than reduction achieved through technological advances. And as the die size increases, yield begins to decline.

SoCs have a few other technical limitations and business problems associated with them –

1. Development and manufacturing cost of lower nm nodes is extremely high. The cost grows exponentially with reduction in node size. This cost is passed down to automotive OEMs.
2. Owing to prohibitive costs and lack of research capabilities, very few suppliers have the technology to manufacture low nm nodes. This could create an oligopoly in the market dominated by players such as TSMC and Samsung.
3. High-performance compute SoCs are power hungry devices. This is a problem especially in EVs, where power is a scarce resource and can be better utilized to extend driving range.
4. As these chips are packaged very compactly, they suffer from overheating. Cannot afford that, especially with safety critical features.
5. Common chips provide little possibility for OEM feature differentiation for the end customer

CHIPLETS: A Promise for the Future?

There are forces at work that are driving the industry to start exploring approaches outside the traditional SoC structure. Moore's Law has started to slow, but there are many other reasons to design new chips today that would've been unimaginable just a few decades ago, from processing big data to supporting computation using massive AI models. One of the probable solutions is to simply split the dies!

Enter CHIPLETS!

Simply put, chiplets are segmented processors – instead of consolidating every part into a single chip (known as a monolithic approach), specific sections are manufactured as separate chips. These individual chips are then mounted together into a single package using a complex connection system.

The idea behind chiplets is to break apart the system on a chip into its composite functional blocks, or parts. Sub-elements of a complex-function chip could be made as chiplets, where these sub-elements might include a separate computational processor or graphics unit, an AI accelerator, an I/O function, or a host of other chip functions.

A system composed of chiplets is kind of like an SoC on a module, and, in the future, could be made using interoperable mix-and-match chiplet components sourced from multiple providers. This approach could lead to chiplets powering entirely new computing paradigms, creating more energy-efficient systems, shortening system development cycle time, or building purpose-built computers for less than it would cost today.

Advantages of Chiplets & Automotive Operating Conditions

Chiplets can offer many advantages –

1. Achieve high scalability by having multiple dies in a single package
2. Not all types of components benefit from a shrinking process node size. For instance, reducing die size doesn't create much of a difference for analog IPs. Logic elements, on the other hand, benefit immensely from the scale of shrinking die sizes. Chiplets allow the flexibility to have a logic component on 3 nm and an analog one on 12 nm in the same package, helping save cost.
3. Chiplets provide great flexibility – one can build a custom package with chiplets in Lego style! Whereas if an OEM buys an SoC from a particular semiconductor company, they must accept the package as is. There is no scope for customizing the individual components – you cannot get more GPU than is offered by the vendor, although it is very important to run ML algorithms and make real-time decisions
4. Among CPU, GPU and NPU, the former changes the least over time. Whereas the latter two have very frequent and fast updates. With chiplets, one has the option to simply replace the GPUs and NPUs and install the latest ones, while keeping the CPU the same.

Although chiplets seem to offer great promise, its adoption in the automotive sector has been tricky. Some of the areas of concern are reliable die-to-die communication technology, latency and security. While designing chiplets, one also needs to be wary of the automotive operating conditions.

Although there are some similarities in the transformations of smartphones and cars, the Automotive Industry is inherently unique. Because of its highly safety critical nature, there is a lot of emphasis on quality and reliability. We need semiconductor chips and electronic hardware that can withstand the wide-ranging and adverse operating conditions of a car and perform their functions spotlessly.

Some examples of the operating conditions are adverse weather (heavy rains, fog, inadequate or improper lighting), wide-ranging temperature (extremes of driving in a desert or in snow), patches of poor network or connectivity enroute, rough terrain, heavy traffic, high-speeds, variable loading, etc.

JLR'S PROBLEM STATEMENT

Are you ready to shape the future of the automotive industry by breaking up the system-on-a-chip model, and accelerating adoption of chiplet technology in cars?

Part 1

1. First, do a comprehensive analysis on why JLR should adopt chiplet technology and where. Be very specific about the applications or components in a car where use of chiplets will add the most value (at least 2 major applications). Explain your rationale.

2. For each of the above applications, draw a detailed micro-architecture diagram of the chiplet-based processor keeping optimal throughput as the main priority. Clearly show all the interconnects between the chiplets.

3. Which parts of the complete chiplet architecture / package should JLR design and which ones we can just buy them off-the shelf? Keep in mind the end-user applications and what would help JLR differentiate itself from other OEMs.

Part 2

1. Summarize the leading communication technologies in the semiconductor industry in general and chiplets in particular. What are the IPs needed to communicate between chiplets?

2. Which interconnect technology should be used? Keep in mind automotive applications and operating conditions when designing a fast and secure die-to-die communication technology for chiplets.
    a. In the solution, talk about your technology's latency and communication efficiency and back it up with data in literature or experimental or simulated results.
    b. Explain your strategy for ensuring secure (from a cyber security standpoint) and reliable communication – this a major difference between automotive and other sectors. Chiplets are used in the server market as well, but the life of a person does not depend on a server's communication tech. Instead, Automotive has safety critical applications that need reliable communication.
    c. 2.5D / 3D interconnect technologies are the talk of the town these days. But, think out of the box for solutions! Remember, IITians do not conform to existing norms. They set new norms!

3. Apart from throughput, thermal management is another key aspect when it comes to packaging of chips. How should we package this chiplet solution? Devise a cooling solution that will efficiently suck the heat out of the package.

Evaluation Criteria:

Mid-term Submission:

- Mid-term submission due by: November 9, 2023
- Weightage: 20%
- What to submit: Part I (1), Part II (1)

Final Submission & Presentation:

- Final submission due by: December 12, 2023
- Presentations will happen offline during the Inter IIT Tech Meet 12.0.
- Weightage: 80%
- What to submit: All other sections
- **Submission Format**: A .zip file containing a detailed report along with your final presentation (and other documents supporting that) and simulation files.

References

Here are some references to get you started on chiplets. They are by no means comprehensive. Do not restrict yourself to these!

1. https://www.imec-int.com/en/articles/automotive-industry-ready-confront-its-greatest-challenge-yet
2. https://www.imec-int.com/en/articles/why-are-chiplets-attracting-attention-automotive-industry
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