Automotive Megatrends and Their Impact on Memory and Storage

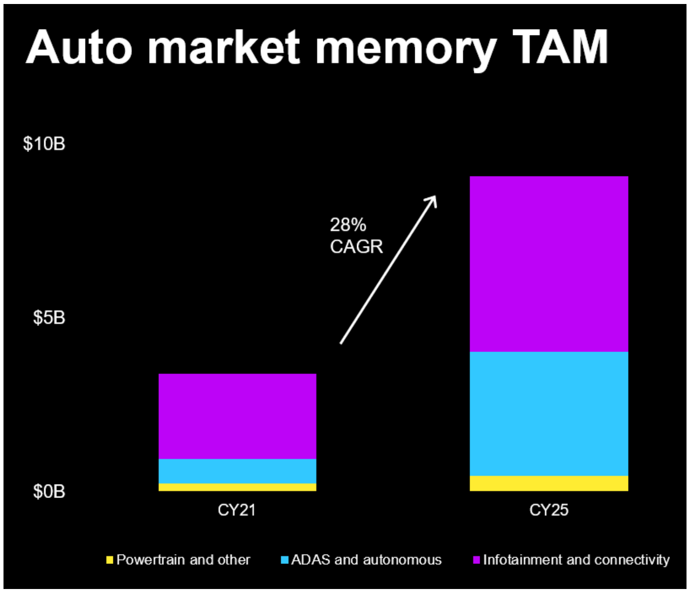

Figure 1: Automotive Market Memory and Storage TAM ($) (Source: Micron estimates)

Automotive is one of the fastest-growing segments in the semiconductor industry with the total market for memory (DRAM) and storage (NAND/NOR) in this segment growing from $4 billion in 2021 to $10 billion in 2025.

Over 97 million cars are projected to be sold in 2025 with an average of 16 gigabytes (GB) of DRAM and 204GB of NAND in each car. In other words, by 2025, a typical car will have three times more DRAM and four times more NAND compared to a car sold in 2021[1].

This article discusses the megatrends in automotive, as shown in Figure 2, and how they impact memory and storage growth.

Figure 2: Automotive megatrends; Enriched cabin image courtesy of Li Auto

Megatrend #1: Autonomy

The Society of Automotive Engineers (SAE) defines six levels of autonomy, from Level 0 (L0) to Level 5 (L5), where L0 has no driver assistance features while an L5 car can drive on its own in all scenarios without a driver, as shown in Figure 3.

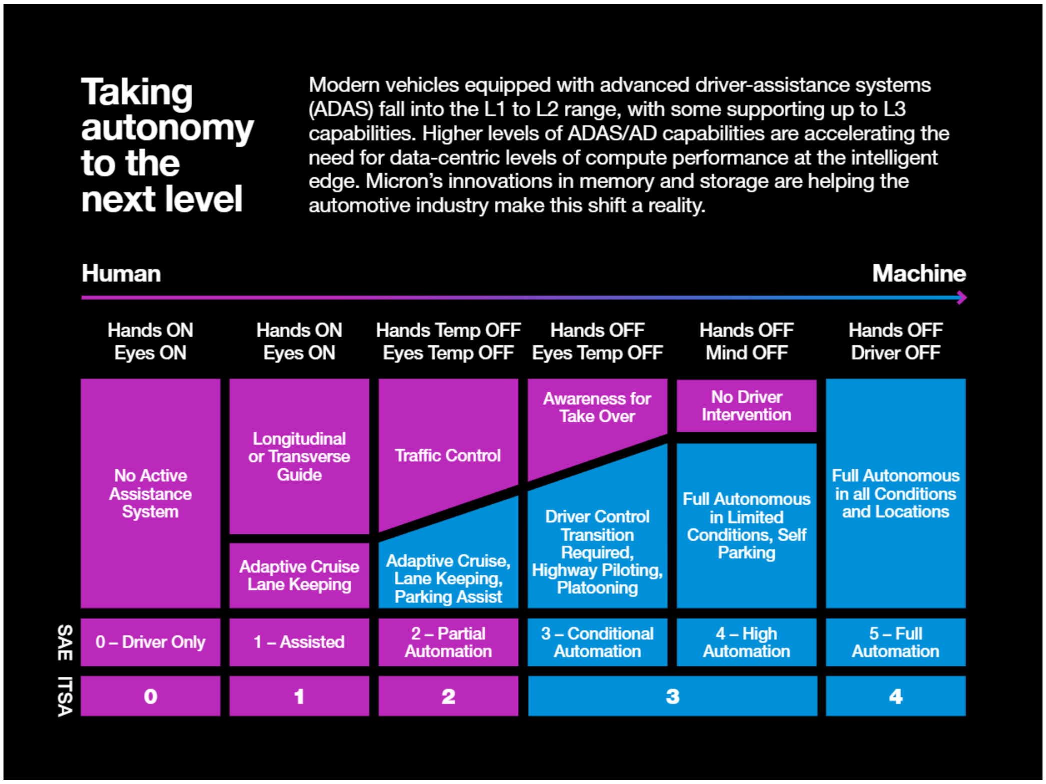

Figure 3: Autonomy levels

Companies such as Waymo and Cruise have put a great deal of focus on achieving L4 or L5 autonomy for robo-taxis, which require significant amounts of memory and storage to make critical decisions without driver intervention. Similarly, implementing even more limited L2+/L3 autonomy requires more memory and storage for advanced driver assistance and safety (ADAS) features, such as blind spot monitoring, adaptive cruise control, lane departure warnings, emergency braking, limited hands free driving and driver monitoring systems. As shown in Figure 4, by 2030, almost 3 million cars are expected to be fully autonomous and more than 15 million cars are expected to support at least L2+/L3 autonomy.

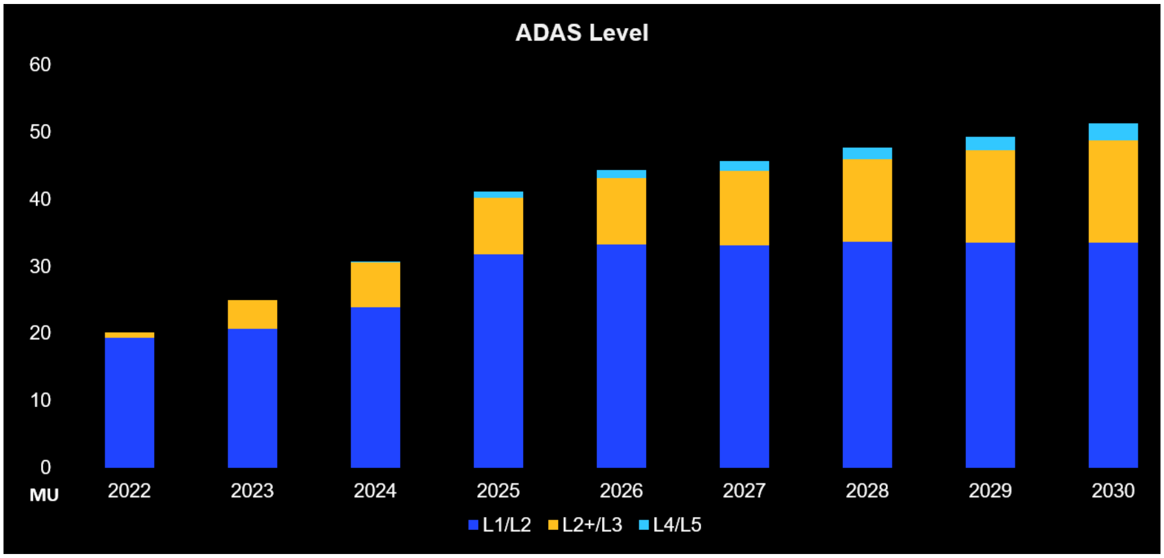

Figure 4: Car sales by autonomy level (millions of units) (Source: Micron estimates)

With increased autonomy, the reliable operation of electronic components becomes important because malfunction can lead to hazardous situations. Automotive industry standards, such as ISO 26262, with functional safety, aim to ensure a car can navigate or safely come to a stop on its own when a critical system error is detected. The different levels of functional safety are known as Automotive Safety Integrity Levels (ASIL), where ASIL A is the least stringent (for example, for rear lights) and ASIL D is the most stringent (for example, for braking).

Software is also becoming increasingly important in automotive. Today's high-end cars can have up to 100 million lines of code, and in the future, an L4/5 car could have between 300 million to a billion lines of code[2]. In addition to the system software, products like eMMC, UFS, and SSDs have embedded software (also known as firmware) to manage the functionality of the storage device. To ensure that software development methodology meets best-in-class practices, Automotive Software Process Improvement and Capability Determination (ASPICE) is increasingly being requested by automotive customers. ASPICE has five levels, from L1 to L5. L5 is the most demanding while L3 is widely accepted as the standard for excellence.

Memory and Storage Implications to Support Increased Autonomy

Memory Requirements

- Greater than one terabyte/second (TB/s) memory bandwidth to support the compute performance needed for self-driving cars (L4/L5)
- Higher interface bit width for improved throughput
- Significant increase in DRAM capacity with greater than 128GB needed for L4/5 autonomy
- Highest level of functional safety (ASIL D) for DRAM

Storage Requirements

- Increased endurance for L4/L5 event-based data logging applications (black box), potentially requiring 150 petabytes[3] (PB) of total bytes written
- Significantly increased densities with greater than 1TB of storage for L3+ autonomy
- Functional safety level ASIL B or higher with ASPICE L3

Megatrend #2: Electrification

Tesla was the trendsetter for electric vehicles (EVs), but now every major car OEM has announced significant investments into EVs on the order of tens of billions of dollars over the next five to ten years. By 2030, roughly one-third of all vehicles sold are expected to be electric according to consulting firm Deloitte[4] with roughly 30 million EVs sold, as shown in Figure 5. In addition to the carbon emission reduction with EVs, the design and manufacturing of battery-powered vehicles are simpler due to fewer moving parts compared to traditional internal combustion engine (ICE) cars. Although EVs today are more expensive to manufacture than ICE cars due to the higher cost of battery packs, improvement in battery technology over the next seven years to less than $60 per kilowatt-hour (KWH) is projected to bring cost parity between EV and ICE vehicles[5].

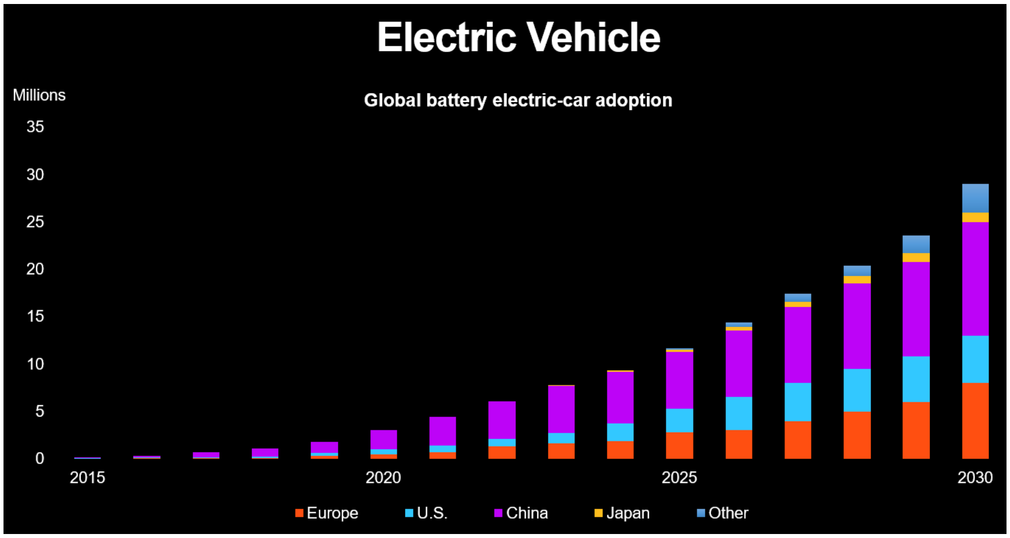

Figure 5: Electric vehicle sales by region (Source: Industry and Micron estimates)

Battery capacity/mileage and charging time are also key considerations for EVs. With new 350KW chargers, the charging time for 250 miles of driving can be reduced to 15 minutes or fewer. Additionally, with new battery technologies, companies are demonstrating vehicles with an effective range of greater than 500 miles[6]. Advances in solid-state batteries are expected to further reduce charging time, offer more range, and improve reliability with less risk for fires compared to today's lithium-ion based EV batteries.

Although the direct impact of the electrification trend on memory and storage is less significant than the other megatrends, EVs typically have higher levels of ADAS/autonomy features and more advanced infotainment systems requiring more memory and storage.

Memory and Storage Implications of Trend Toward Electric Vehicles

Memory Requirements

- An ICE vehicle's active memory usage is typically about 22,000 hours (four hours per day for 15 years). In comparison, an EV can have more than 60,000 power-on hours where the memory is active during charging over the vehicle's lifetime[7]. There is also a vision that EVs will serve as a power source for the home. This means that during times when the electric grid is under stress, a house could draw power directly from the vehicle's battery, which would further increase power-on hours when the memory is in active mode. Memory used in EVs will need to meet these extended power-on times, which will require longer qualification timelines.

- Increased memory capacities from advanced infotainment systems used in EVs will be required to justify the price premium over ICE vehicles as described in the enriched cabin megatrend below.

Storage Requirements

- EVs are also expected to have higher (more than 60,000) active-on hours for storage with bidirectional communication during charging, which requires extended qualification timelines.

- Advanced infotainment systems used in EVs require higher performance and larger storage capacities, as shown in the enriched cabin megatrend below.

- There is also potential for quad-level cell (QLC) NAND storage adoption for infotainment. This would result in lower storage costs with nearly 100% power-on time in EVs allowing background media management during idle time/charging.

Megatrend #3: Enriched Cabins

Figure 6: Enriched cabin; image courtesy of Li Auto, trademarks may be the property of others

Automotive in-vehicle infotainment (IVI) systems have increasingly become more advanced. Premium models can have up to 12 displays with 4K resolution and features such as voice, gesture, and facial recognition. Larger screen sizes and support for technologies such as Apple CarPlay and Android Auto are now increasingly part of the consumer's wish lists when buying a new car. Some surveys have indicated that 25% of consumers would not buy a car without Apple CarPlay or Android Auto[8]. In addition, the use of Android as the operating system for IVI is gaining traction with full functionality for apps and gaming and recreating the mobile experience in the car. IVI systems are also typically required to boot up in less than one second to display the video from a rear-view camera so that users can start driving (safely) immediately after the car is turned on.

Memory and Storage Implications of Trend Toward Enriched Cabins

Memory Requirements

- Lower standby power in suspend-to-RAM mode for instant-on/reduced boot-up time
- Expanded low-power DRAM (LPDRAM) capacity up to 64GB, migration to LP5/6, and increased bandwidth up to 400 GB/s. The DRAM components are soldered along with the system-on-chip (SoC) on a small PCB in a system-in-package (SIP) configuration to achieve signal integrity as data rate requirements continue to increase.

Storage Requirements

- Faster adoption of Universal Flash Storage (UFS) 3.1/4.0 and PCI Express® (PCIe®) Gen 4/5 interfaces due to increased bandwidth requirements for faster boot-up
- Increased storage capacities with up to 512GB of UFS or SSD storage

Megatrend #4: Connectivity and Software-Defined Vehicle

Most new car models offer connectivity to the outside world via a cellular network. This enables over-the-air (OTA) updates to improve functionality and resolve software issues, stream video, and audio content, and upload telemetry data for vehicle diagnostics. Connectivity also enables vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication which can help to reduce accidents and traffic congestion by alerting drivers of potential dangers. OEMs are also interested in OTA for after-market sales including feature upgrades and new applications, which can be more profitable than the actual vehicle sale. For example, Tesla is currently selling Full Self-Driving (FSD) capability for a $199 monthly subscription[9]. Connected cars are also increasingly being called software-defined vehicles with new features enabled via software as opposed to hardware.

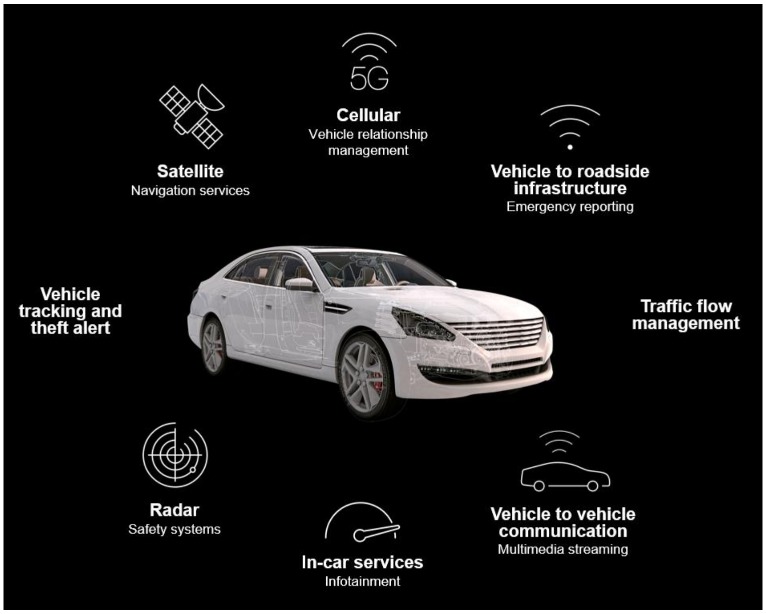

Figure 7: Connected car

Unfortunately, connectivity also brings an increased risk of cybersecurity vulnerabilities. According to a report published by Upstream, automotive cybersecurity vulnerabilities increased by over 3X from 2020 to 2021[10]. In some worst-case automotive incidents, hackers were able to remotely turn on wipers, increase the volume of the radio, and turn off the engine to bring the vehicle to a complete stop[11].

New cybersecurity standards, including International Organization for Standardization (ISO) 21434 and United Nations Economic Commission for Europe (UNECE) WP.29, aim to bolster automotive security to prevent malicious hackers from taking advantage of connected cars.

Memory and Storage Implications for Connected Cars Trend

Memory Requirements

- 1GB to 4GB LPDRAM in multichip packages (MCPs) for 5G connectivity — up from 0.5GB needed for 4G

Storage Requirements

- Higher sustained write performance requirements to support fast OTA software updates
- Increasing security requirements and compliance to ISO 21434
- 1GB to 32GB of storage along with LPDRAM for 5G connectivity in an MCP due to space savings

Megatrend #5: Zonal Architectures

The automotive industry is transitioning from domain-based architecture to zonal architecture. In a domain architecture, systems are grouped by function, whereas in a zonal architecture, systems are grouped by physical location. Each zone is responsible for electronic control units (ECUs), sensors, actuators, etc., in its area, and the zones are connected via a high-speed ethernet network using a zonal controller or gateway. The zonal gateway is located near the ECUs that are controlled by it. This approach significantly reduces cable lengths by more than 50%[12] and results in significant cost savings and improved fuel efficiency as the wiring harness is the third-heaviest subsystem in a luxury car with over a mile of cable length[13].

The zones connect to a central high-performance compute cluster resembling an enterprise server, which has given rise to the "data center on wheels" analogy. A scalable enterprise blade architecture for the central compute cluster also allows premium, mid-, and low-end cars to share the same fundamental design — with premium cars utilizing up to four SoC blades while low-end cars may have one or two SoC blades. The adoption of zonal architecture is also expected to accelerate the trend towards software-defined vehicles as zonal gateways and the central compute cluster can be easily updated with software to improve functionality or add new features[14].

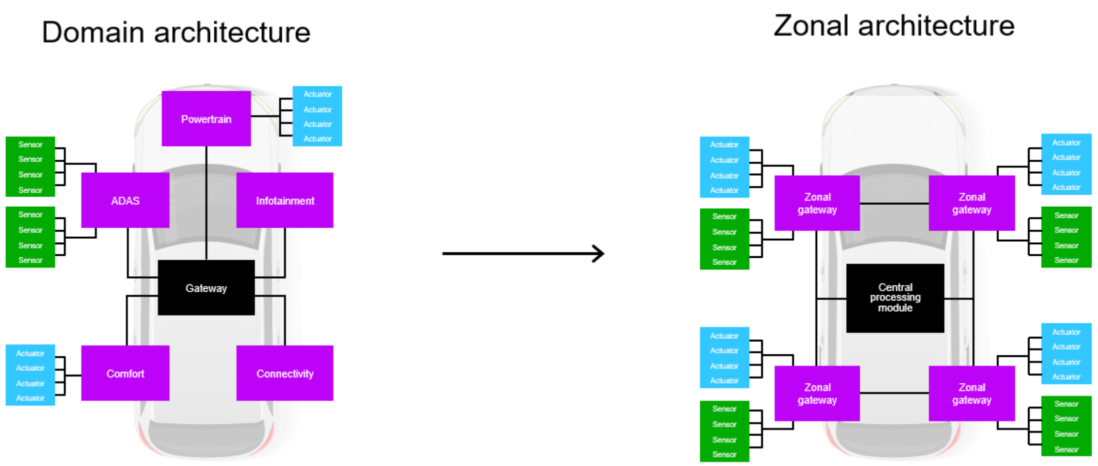

Figure 8: Domain versus zonal architecture

Memory and Storage Implications for Trend Toward Cars With Zonal Architecture

Memory Requirements

- Increased DRAM capacity and higher performance needs for central compute and zonal gateways

Storage Requirements

- Increased use of shared storage where SoCs connected to the same SSD using single-root I/O virtualization, also known as SR-IOV. SR-IOV can significantly improve virtual machine (VM) performance compared to para-virtualized drivers and emulated access with a hypervisor. SR-IOV also provides hardware isolation of data between VMs, improving security for applications/VMs sharing the same storage device.
- Use of multiport SSDs to reduce overall system costs in a shared storage configuration
- Shared namespaces and file system optimization to ensure that multiple host CPUs can access the same data on the SSD

Summary

The five automotive megatrends — autonomous, electrification, enriched cabins, connectivity, and zonal architectures — are transforming the automotive industry with a significant impact on memory and storage requirements for use in vehicles. Higher-performing memory and storage with increased capacities, functional safety, SR-IOV, and enhanced security features are needed to support these megatrends. For more than 30 years, Micron's leadership in automotive-qualified memory and storage has enabled automotive innovations through an industry-leading solutions portfolio, global customer labs, and unmatched ecosystem collaboration. Micron is partnering with tier-one automotive suppliers, OEMs, and chipset partners to develop innovative solutions to address these five automotive megatrends. For more information, visit www.micron.com/automotive.

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Author's Biography

Aravind Ramamoorthy is the Senior Director of the NAND product line in the Embedded Business Unit at Micron. He is responsible for product line management, product architecture, and applications engineering for eMMC, UFS, SSD, memory cards, and discrete components servicing automotive, industrial, and consumer segments. His team has launched several industry-first products like 1TB automotive BGA SSD, automotive UFS 3.1, and more recently the world's first 1.5TB microSD for video security. Aravind has worked in the semiconductor industry for over 20 years in various roles in engineering, business development, and marketing. He has a master's degree in mechanical engineering from the University of Maryland and an MBA from the University of California, Berkeley.

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