WHITE PAPER

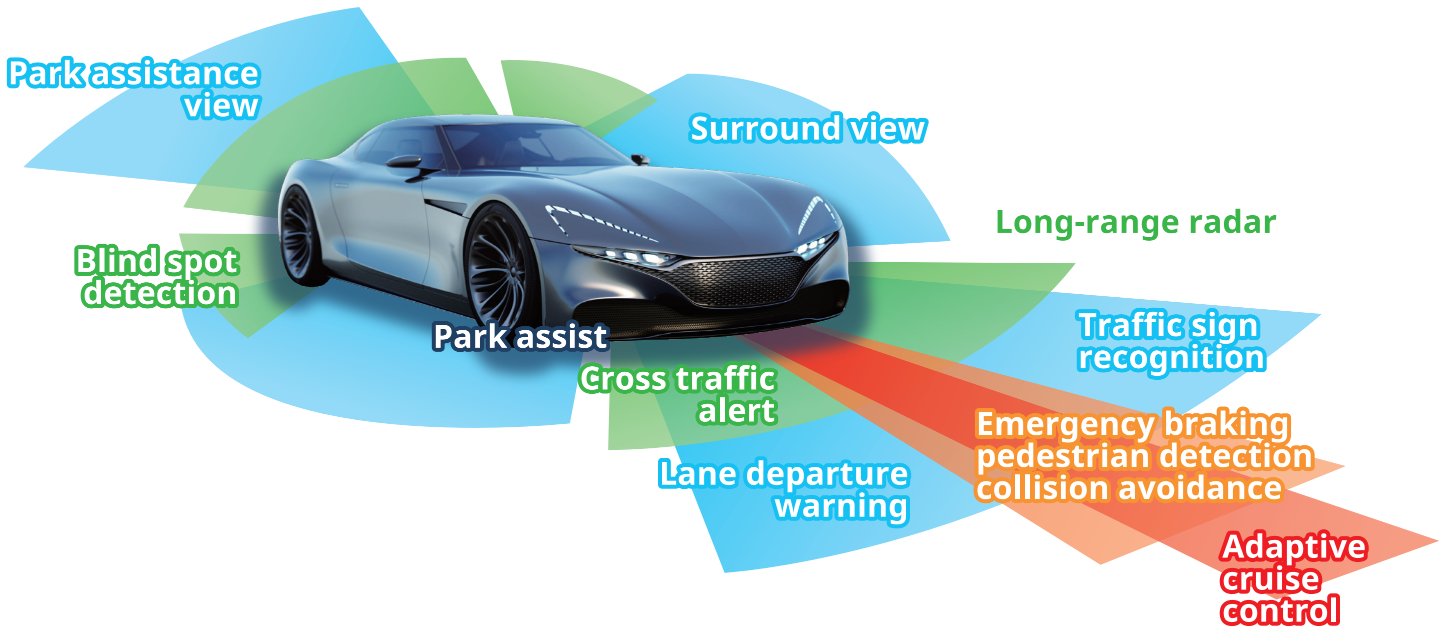
Silicon Motion NAND Memory Solutions

for Autonomous and Electric Automotive Applications

Supporting the explosive growth in automotive data requirements

Market context:
the migration to autonomous and electrically powered vehicles, along with the resulting transition to a centralized vehicle architecture requires high-performance, high-bandwidth, stable, secure memory in order to be successful.

According to a current research, roughly 90 million cars will be collecting data from sensors and making it available online by 2025. Today's vehicle brings many advanced "infotainment" features together in a single cockpit dashboard — screens that entertain and provide critical information to the driver to ensure safety and even help them drive. Screens are getting bigger; some stream music, video and even gaming for passengers, and the GPS is built right into the vehicle along with other Advanced Driver Assistance Systems (ADAS). Many ADAS features collect data from sensors, cameras, radar and lidar. Although the amount of data for each feature can be small, it adds up.



Autonomy, even if only partial, adds a great deal of data to the mix. ADAS features such as lane keeping, automatic breaking, and adaptive cruise control are data-dependent features, and fully autonomous driving that requires no human intervention at all will require data for the automatic decision making to happen.

Connectivity is also driving up data storage requirements on vehicles. Whether it's Wi-Fi or 5G, connectivity makes it easier to upgrade onboard software. When software becomes easier to upgrade, it's more likely to be added to a vehicle in the form of new features, bug fixes, and security patches.

The modern vehicle is also equipped with a great deal of diagnostics capabilities which could become remote accessible. Like a commercial aircraft, cars have their own black boxes to record what happens during an accident and the moments leading up to it. Storage is needed to capture data such as steering input, G-forces on the car, speed, telemetry, and even video and audio. Storage requirements become more specific because a large, sudden burst of data must be written to the device quickly. That storage device must be durable enough to survive a serious impact, and even fire or water damage.

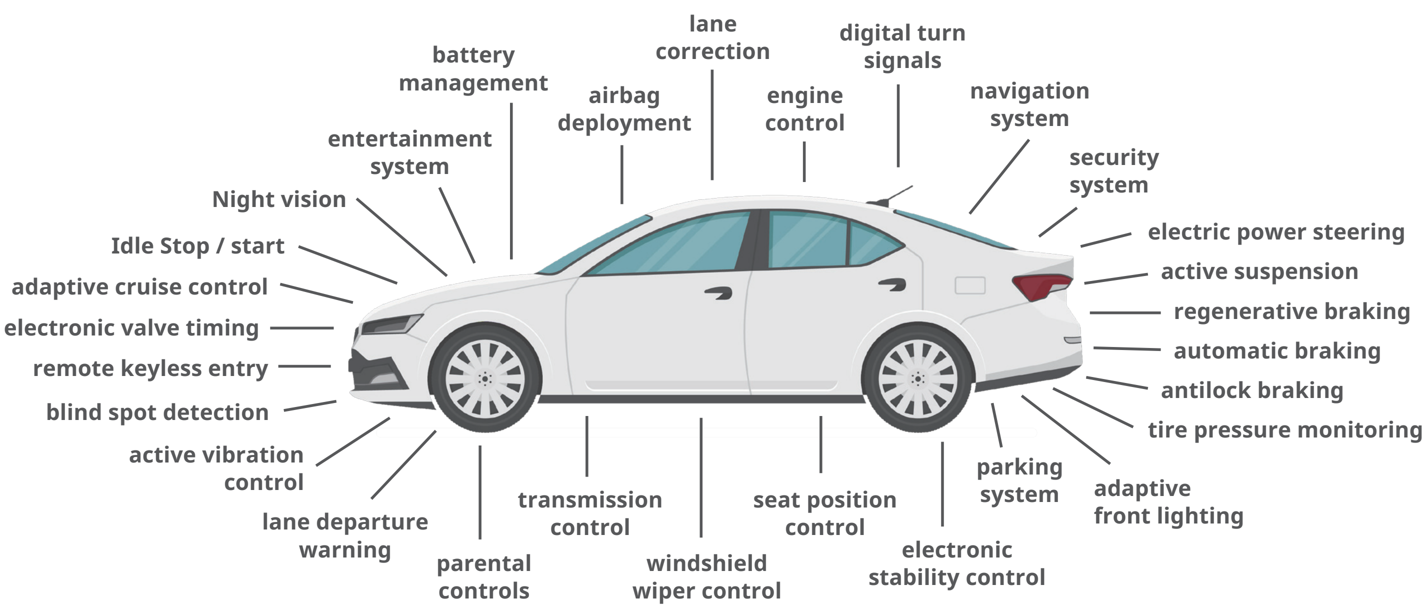
A key design trend in the architecture of intelligent vehicles is the consolidation of many computing capabilities so that the storage can serve a variety of applications in the functions of vehicles, while being smart enough to know what takes priority. For example, autonomous functions and entertainment applications might share the same storage pool.

Architecture

The move towards electrified and autonomous vehicles has forced manufacturers to rethink the whole philosophy of how vehicles are designed. Up until now, almost every function in the vehicle had its own ECU to perform measurements and take actions. Each of those ECUs also needs to communicate freely with any other ECU. However, the introduction of advanced functions and features, such as ADAS, has meant that the number of ECUs required for a vehicle to operate has increased dramatically, along with the bandwidth needed for the data that is generated.

That increase in the number of ECUs naturally leads to a rise in the number of parts required to manufacture those ECUs, which, in turn, has led to a corresponding increase in the complexity of vehicle systems, as well as their cost. Even worse for electric vehicles, the additional weight of the ECUs and wiring needed to implement the electrical system has a real negative impact on the range of the vehicle.

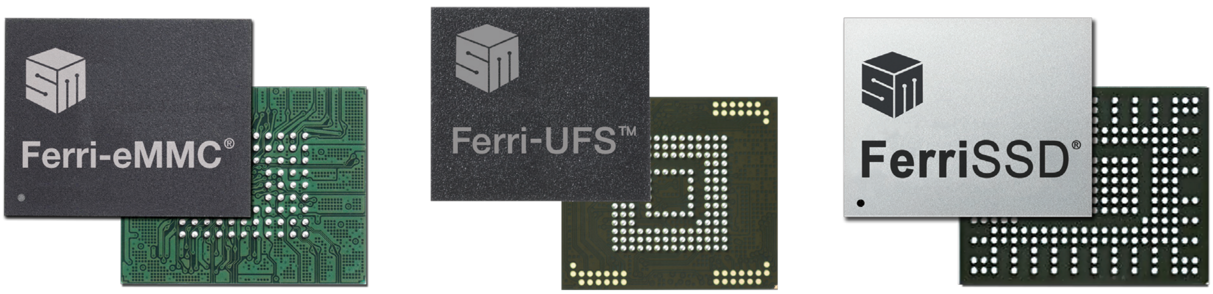
All of the new features in vehicles rely on producing, processing and storing vast amounts of data. The manufacturers of these vehicles see a centralized solution as the best way to be able to handle that data. From having separate ECUs for each function, designs are migrating to having a single ECU to take care of multiple tasks, for example to be in charge of all the functions in a single physical area of the vehicle. These multi-function ECUs are then controlled by a central gateway. In time, that central gateway will take on more tasks, cutting out more peripheral ECUs until there are only a few remote ECUs controlled by a very powerful central computer. The success of that transition relies on memory. As more features are consolidated into fewer ECUs. Those ECUs need to be faster and more powerful, and memory is shared by multiple functions. The central gateway and any other ECUs must be able to access the data they need from storage in a timely manner. Storage needs to be reliable, especially in the case of mission critical applications. It needs to be secure, and it needs to have the lifespan to match the vehicle’s own one.



Solutions

The ever-growing quantities of digital data that must be processed and stored, mean automotive system designers now prefer NAND flash devices over rotational media for mass storage because of their reliability and tolerance for wide temperature ranges as well as large capacities in small form factors. Any NAND flash storage device must keep pace with capacity requirements, low latency, and performance by delivering fast read and write speeds and high data throughput. Despite this consolidation, there will be a variety of different NAND storage types to support the required data storage demands in autonomous and electric vehicles.

In addition to meeting automotive grade qualifications, storage devices are expected to last for as long as the vehicle is on the road. NAND flash storage solutions such as embedded Multimedia Card (eMMC), Universal Flash Storage (UFS) and Solid-State Drives (SSD) are readily being adopted by automakers, Tier 1 systems designers, and other key stakeholders in the automotive supply chain for performance, reliability, longevity, and security considerations.



Multimedia Card (eMMC), Universal Flash Storage (UFS) and Solid-State Drives (SSD)

NAND Storage in Modern Automotive Designs

When NAND flash was still quite expensive and had not attained the densities and cost structures we see today, hard drives using rotational media were seen as the best solution to storing data in cars. Automotive-grade hard drives were designed to handle temperature extremes and vibration as well as withstand shock loads as high as 200 times the force of gravity and more. They were also inexpensive given the amount of data they could store in a small space. However, hard drives have relatively slow access times and are subject to shock and vibrational failures.

But as NAND flash cost came down and solid-state storage designs matured, they began to make more sense and replace rotational media. A clear advantage for NAND storage over hard drives is the lack of moving parts, which makes them less likely to fail due to shock and vibration. NAND storage is also much faster than a hard drive and can also handle the extreme temperatures ranges of automotive applications.

NAND flash finds its way into the modern vehicle in so many ways to support so many applications; the types of NAND flash storage in the vehicle is dependent on application performance and capacity requirements. CompactFlash and Secure Digital cards remain flexible options for automotive applications such as digital maps and dash cameras. These removable storage types enable the flexibility of after-market content upgrade and retrieval.

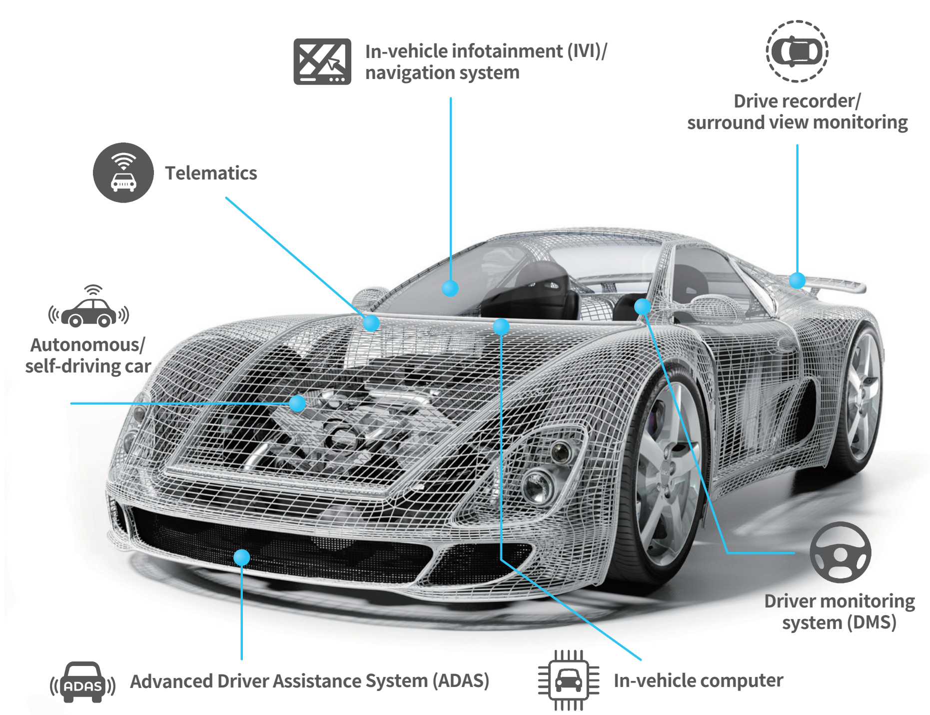
advantages of NAND flash

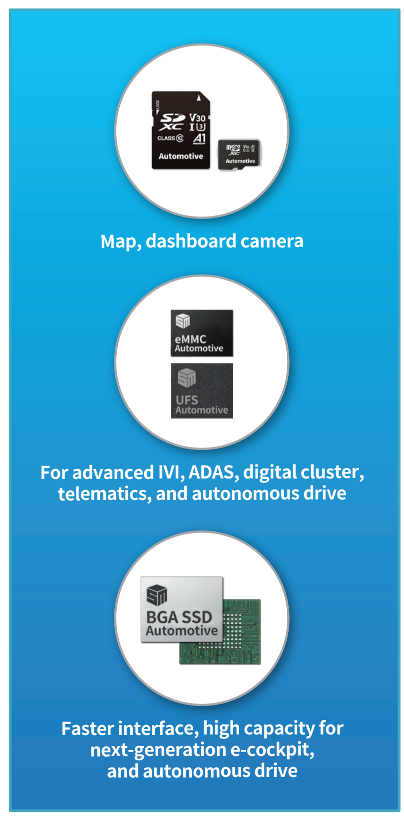
Advantage

- relatively faster access times compared to hard drive storage lack of moving parts
- less likely to fail due to shock and vibration
- can handle extreme temperatures ranges of automotive applications

NAND storage in the form of eMMC was the first type of solid-state storage to be widely adopted in automotive applications. Widely deployed in mobile phones, this non-removable memory card is soldered onto a circuit board, making it secure against constant vibrations. eMMC continues to be a viable choice for storing data related to many navigation and infotainment applications, including satellite radio, 3D maps, traffic monitoring, and weather information.

The emergence of the UFS interface has seen it usurp eMMC for newer automotive designs, as it was specifically developed to be a high-performance replacement to eMMC. It offers a faster interface, higher density, better power efficiency, and higher performance for reads and writes in comparison to eMMC. UFS also offers fast boot times, allowing for systems to start up as fast as it takes for the driver to turn the key in the ignition.





The more computational needs of an automotive design have pushed data storage requirements even further in terms of performance and storage capacity. This has led to the adoption of higher capacity NAND flash storage in the form of full-blown SSDs that are automotive grade, which means they're designed to handle enterprise equivalent performance and capabilities while supporting extreme temperature ranges. The larger capacities also allow for the consolidation of storage within the automotive system to reduce the overall number of storage devices required.

Automotive-grade SSDs are moving from SATA to the PCIe NVMe interface as more vehicles with advanced autonomous driving capabilities are sold. They require as much as 1TB of flash storage for 3D maps, 4K infotainment content, sensor data, and black box recording, all of which increase demands for more bandwidth, latency, and capacity.

Practical Memory Solutions for Automotive Applications

Silicon Motion provides a number of NAND memory solutions that are fully integrated and ideal for use in automotive applications. They are designed to allow vehicle manufacturers to easily transition to next-generation architectures with advanced functionality, while complying with applicable standards. The FerriSSD family provides reliable PCIe NVMe/SATA/PATA storage with fast access speeds. It integrates industry-proven controller technology, NAND flash and passive components to simplify automotive designs. The Ferri-UFS range offers a feature-rich flash controller compliant with the latest UFS2.1/3.1 standard and standard NAND flash memory. Its high-performance storage accessing, better power efficiency, and ease of system design make it ideal for automotive applications. Finally, the company's Ferri-eMMC range is fully compliant to the JEDEC standards for eMMC 4.5/5.0/5.1 protocols. The three families of NAND solutions also offer a wide range of features to ensure that the overall system design is as simple as possible, these include:

- AES-256bit full disk encryption support with Secured Password Protection for secure storage and over-the-air updates
- Dedicated hardware pin to trigger data flush to safely store user data during sudden power failure, for example in a vehicle collision
- SLCMode for enhanced performance and durability of the MLC and TLC NAND flash
- SSDLifeGuard software and commands to monitor SSD health status to ensure data integrity

Controllers Are "The Brains" of NAND Flash

NAND flash storage devices for automotive applications should be tailored for the functions found in the modern vehicle, and this is mainly enabled by the NAND controller technology designed with automotive applications in mind. The NAND controller is essentially the "brains" of a storage device, as it plays a key role in optimizing the various NAND flash storage for automotive applications by ensuring the performance, reliability, security as well as supporting the various 3D NAND flash technologies.

eMMC, UFS and SSD controllers share many same capabilities as those controllers for other applications. The controllers used for automotive, however, are usually manufactured on an automotive process by the semiconductor foundries, supports extended temperature, exhibits low Defected Parts Per Million (DPPM), and designed with the ASPICE standard compliance in mind.

Whether it's just a controller or full-blown storage device, any automotive-grade flash products must demonstrate they have undergone rigorous testing to meet the qualifications expected by automakers, including AEC-Q100 compliance and ISO 9000/9001, and ISO26262 certification.

Automotive designs are evolving for modern autonomous and EV vehicles and so are the respective storage systems. Because NAND flash finds its way into the modern vehicle in so many ways to support so many applications, automotive manufacturers expect their chosen NAND storage device to have the required performance and reliability with data retention to match life of the vehicle. As a practical example, Silicon Motion automotive-grade PCIe NVMe SSD controllers have have all the features mentioned above and also offer built-in SR-IOV capability to virtualize network resources and allow a single SSD to be shared across up to eight different functions to reduce cost, while increasing the performance and throughput of the network.

Summary

With the transition to electric power and autonomous driving happening at full speed, NAND memory offers the only storage solution that is fast, rugged and secure enough for the new architectures being implemented to accommodate the features necessary for tomorrow's vehicles. The automotive industry is already in the process of migrating to NAND memory as its price has dropped and its capabilities increased. This migration need not be difficult as currently available solutions integrate the many features required for a complete storage solution in a single package. Reliable vendors, such as Silicon Motion, have a robust portfolio of tailored flash storage and controller solutions that are optimized to support infotainment, navigation, ADAS, and self-driving applications, as well as being future-proofed to support the evolution of the data center on wheels.

For more information about Automotive-grade SSD controller products, please go to **www.siliconmotion.com**

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