Silicon Motion Automotive SSD Controller Supports SR-IOV

WHITE PAPER

Saving cost and reducing CPU usage in the next generation of ADAS

In recent years, the concept of the digital cockpit has been proposed, including integrated dashboard, navigation, audio, and video, and higher transmission rates will be required at this time. High-end CPU and storage will be needed as well.

Market context : growing sophistication of ADAS places new demands on data storage systems

Led by premium vehicle marques such as Audi, Mercedes, BMW and Lexus, the automotive industry has entered a fast-moving phase of innovation in driver assistance functions (see figure 1).
The automotive industry's accelerating implementation of ADAS (Advanced Driver Assistance Systems) in premium vehicles is driven by two strong motivating factors:

- **Consumer appeal** – features such as highway collision avoidance and automatic lane-keeping are highly attractive to drivers, and make for a more enjoyable, effortless driving experience.

- **Safety** – the implementation of ADAS functions is one of the most effective ways in which car manufacturers can meet the increasingly stringent safety requirements of standards such as the European New Car Assessment Programme (NCAP) scheme.

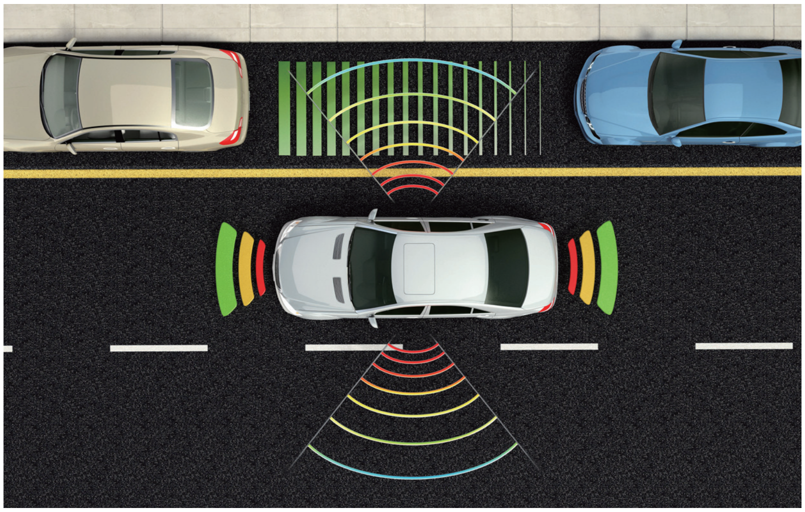


fig. 1:The automotive industry is transforming at lightning speed with the rise of connected vehicles. A higher-end transmission system and larger storage will be required.

Common ADAS functions in use in vehicles today include adaptive cruise control on the highway, automatic stop-and-go control in traffic jams, and lane-keeping assistance. Car makers are actively developing even more advanced functions, such as full auto-pilot operation on the highway.

ADAS equipment consists of arrays of sensors which send millions of signal outputs per second to a powerful processor. These sensor-rich systems may generate vast amounts of data as much as 4 terabytes of data per day. According to Intel's newsroom [1], "In an. autonomous car, we have to factor in cameras, radar, sonar, GPS and LIDAR – components as essential to this new way of driving as pistons, rings and engine blocks. Cameras will generate 20-60 MB/s, radar upwards of 10 kB/s, sonar 10-100 kB/s, GPS will run at 50 kB/s, and LIDAR will range between 10-70 MB/s. Run those numbers, and each autonomous vehicle will be generating approximately 4,000 GB – or 4 terabytes – of data a day."

And every ADAS implementation has to provide for storage of at least some of this information: data logging supports diagnosis and troubleshooting in the event of a fault in the ADAS function itself, and enables the gathering of evidence in the event of an accident. It also enables the vehicle to contribute its data to the training data sets for machine learning held centrally by car makers (see Figure 2).

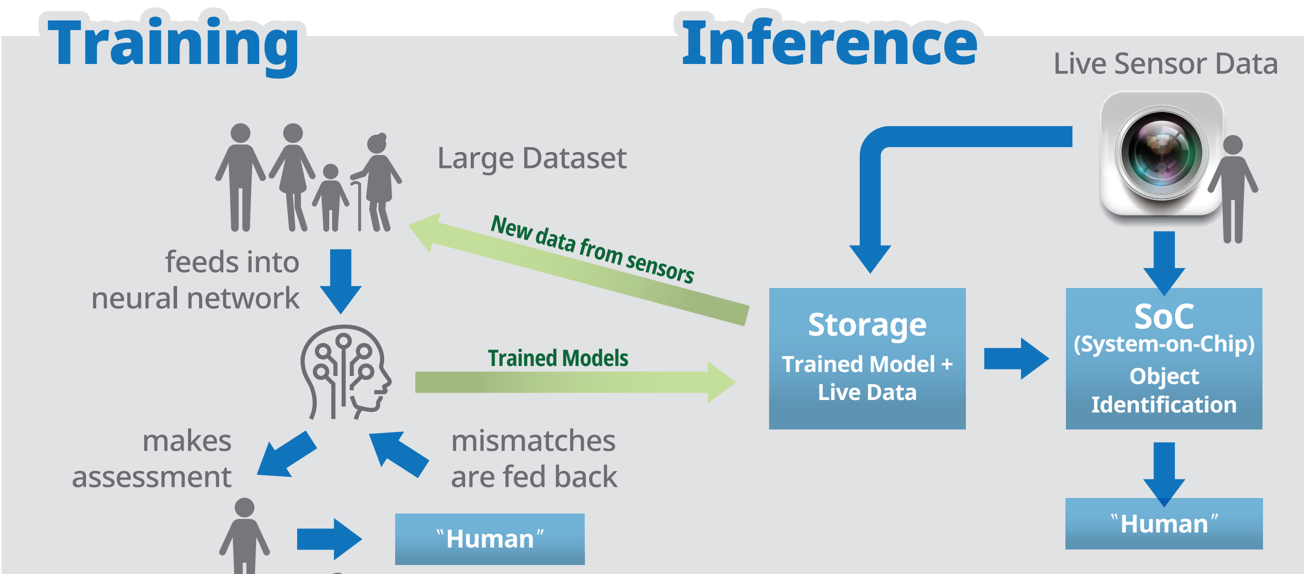


Fig. 2: Machine learning systems require local storage of sensor signals captured by a vehicle's ADAS equipment.

This local storage provision today is often comprised of relatively low-performance eMMC or UFS (Universal Flash Storage) memory devices, a low-cost option for mid-density data storage which can operate at relatively slow rates of data transfer between the storage device and the host processor. In future, ADAS implementations will increasingly require the large memory capacity and high speed offered by solid-state disks (SSDs), which are based on dense arrays of 3D NAND Flash managed by an integrated SSD controller.

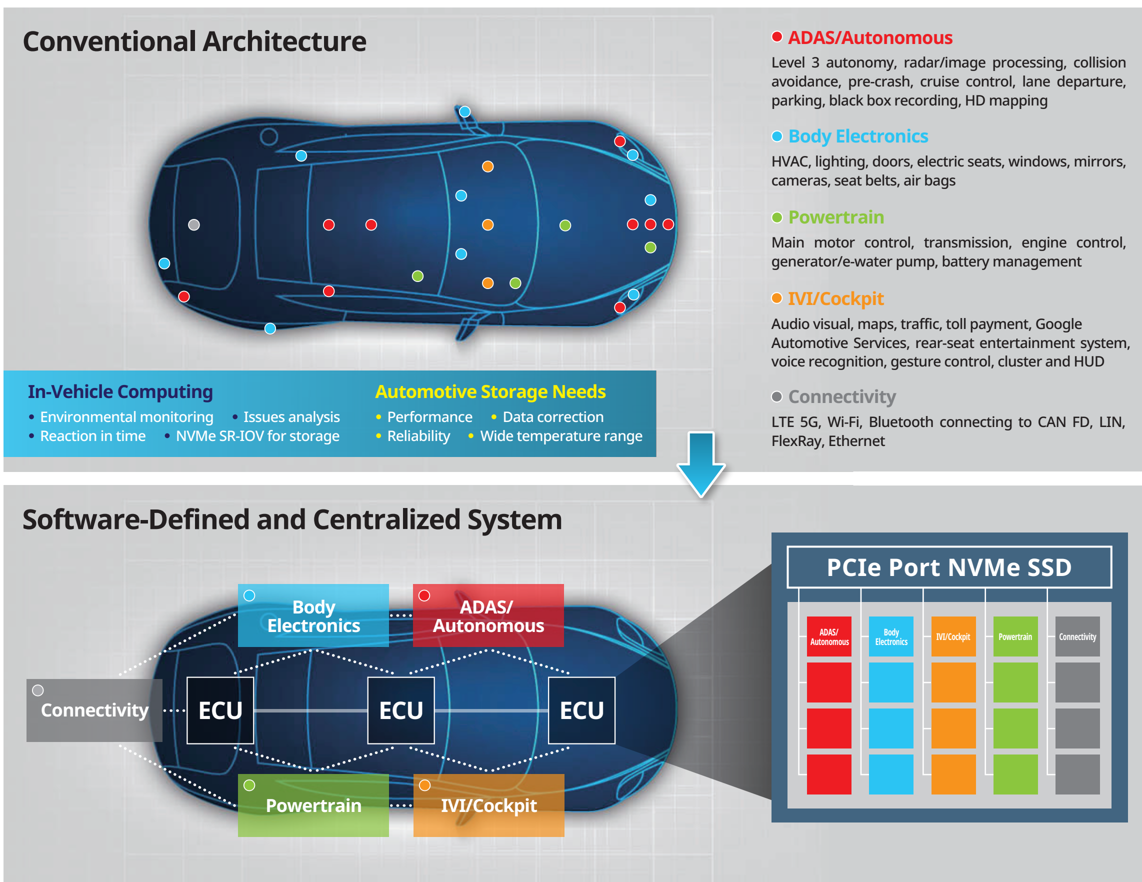
As ADAS features become more sophisticated, the number of sensor systems in a vehicle increases. This creates a problem for the conventional automotive computing architecture, in which each computing sub-system (an Electronic Control Unit, or ECU) is associated with its own, dedicated data storage device.

The advantage of a dedicated SSD at each ECU is speed: a direct interface between a sensor system and its dedicated storage unit can be configured to provide enough bandwidth to meet minimum system requirements for Read and Write speeds.

But the adoption of this architecture might mean, for instance, that a front and rear collision avoidance system could include four separate data storage units – one each for the RADAR/LiDAR sensor at the front left, front right, rear left and rear right of the vehicle. Additional storage devices might also be associated with other ADAS sensors, such as lane-keeping assistance sensors and park-assist sensors, so the number of discrete eMMC, UFS or SSD devices in an ADAS-equipped vehicle could eventually be ten or more.

This proliferation of SSDs in premium vehicles would have highly undesirable consequences: in particular, a high bill-of-materials cost, and increased size and weight. As a result, the automotive industry is looking to the concept of virtualization – a technique successfully adopted in the telecoms and networking equipment sector some years ago – to enable the sharing of data storage hardware across multiple ADAS modules.

With the introduction of complex functions such as ADAS and even self-driving in cars, the design of car computers also needs to meet this requirement, so that the data received by the car can be optimally processed and calculated. Many car manufacturers are already moving toward a new concept.



The idea of Centralized Architecture is to integrate all electronic systems into a centrally controlled platform, covering major components, including assisted driving and self-driving systems. E-mirrors, digital dashboards, audio-visual navigation systems, car networking systems, etc. At the same time, a higher-end transmission system and various storage applications will be required. This model allows for greater software functionality and easier remote management.

Fortunately, a proven technology already exists for implementing virtualization in high-speed data networks operating on a PCI Express (PCIe) bus: Single-Root I/O Virtualization, or SR-IOV.

SR-IOV : sharing a storage resource across multiple ECUs at near native speed

In telecoms and networking settings such as data centers, virtualization technology allows for the sharing of a server (computing) resource across multiple, independent 'virtual machines' (VMs), each of which runs its own instance of platform software such as the Linux® operating system. The key component in a computing system's virtualized architecture is the hypervisor, a software layer which governs access by each VM to the server's resources, including to its hard disk drive (HDD) or SSD (see Figure 3).

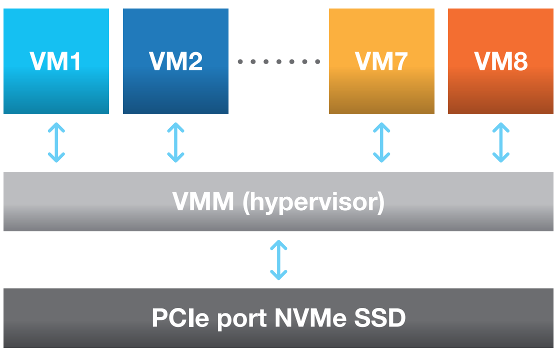


Fig. 3: A conventional virtualized computing architecture uses a hypervisor as a virtual machine manager. (Image credit: Silicon Motion)

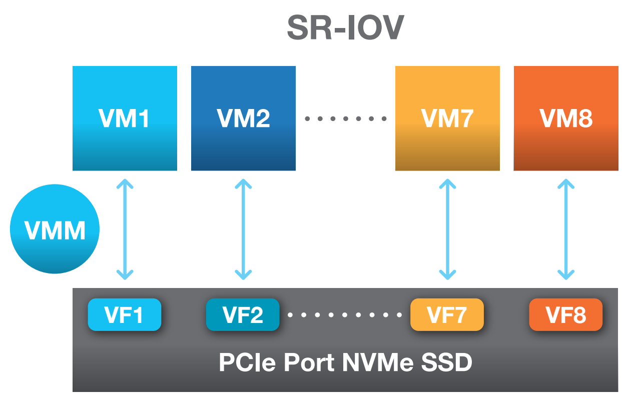


Fig. 4: The SR-IOV architecture provides for direct connection of multiple ADAS modules to a SSD via PCIe channels. (Image credit: Silicon Motion)

This virtualized architecture gives flexibility to run a VM on any supported hardware 'target', and thus optimizes the usage of the available hardware resources. The ultimate effect is to reduce hardware costs: a data center which implements a virtualized system can perform more computing operations with fewer servers than an older, non-virtualized system.

The SR-IOV architecture applies this same concept of virtualization, but to network resources rather than to computing resources. Its implementation is as an extension to the PCIe specification, and is an industry standard ratified by the PCI Special Interest Group (SIG).

In the context of ADAS in a premium car, discrete physical functions such as front collision detection sensors and rear collision detection sensors would be exposed as multiple VMs on the PCIe bus via a PCIe network switch. Silicon Motion's SSD Controller offering built-in SR-IOV capability can interface directly, at high speed and independently to each VM via a dedicated 'virtual function' (VF) implemented in the SSD controller.

To the VM – the ranging system, satellite positioning system or visual camera, each supporting a different ADAS function – the SSD looks as though it is a discrete hardware unit dedicated to that one function. But in fact, SR-IOV allows a SSD to be shared across as many as eight VMs.

The advantage of this virtualized network architecture is clearly shown in Figure 4: data transfers no longer have to be routed via the hypervisor (virtual machine manager, or VMM), thus eliminating the delay caused by the translation of software code from PCIe format into hypervisor format, and from hypervisor back into PCIe format. This also reduces the burden on the CPU in which the hypervisor runs.

Benefits of virtualization: speed and cost

The SR-IOV network architecture thus produces two, highly valuable benefits for the automotive manufacturer:

- **Reduced cost :** a sophisticated ADAS implementation which might before have required three, four or more discrete SSDs dedicated to each separate ADAS function can now use just one SSD for data storage, shared across all ADAS functions. This dramatically reduces bill-of-materials cost, as well as saving space and weight.

- **High performance :** in a conventional, hypervisor-based virtual machine architecture, a sophisticated ADAS implementation could share a SSD via a hypervisor as shown in Figure 3. But by implementing virtualization of data storage capacity in an SR-IOV architecture, automotive manufacturers benefit from near-native data-transfer speed – I/O operations are almost as fast as they would be when using a local PCIe NVMe SSD directly attached to the ECU. In typical ADAS implementations, the delay in performing a Read or Write operation caused by the hypervisor in a conventional virtual architecture is around 700ms. By contrast, in an SR-IOV architecture, this delay typically falls to just 10ms.

So advantageous is SR-IOV technology to the operation of automotive data storage systems that, as of mid-2020, the JEDEC standards organization is understood to be intending to make it mandatory in automotive SSDs housed in a BGA package.

Even before this JEDEC specification has been made mandatory, SR-IOV technology is available for deployment in automotive data storage applications, thanks to the introduction of automotive-grade SSDs from Silicon Motion which support SR-IOV functionality.

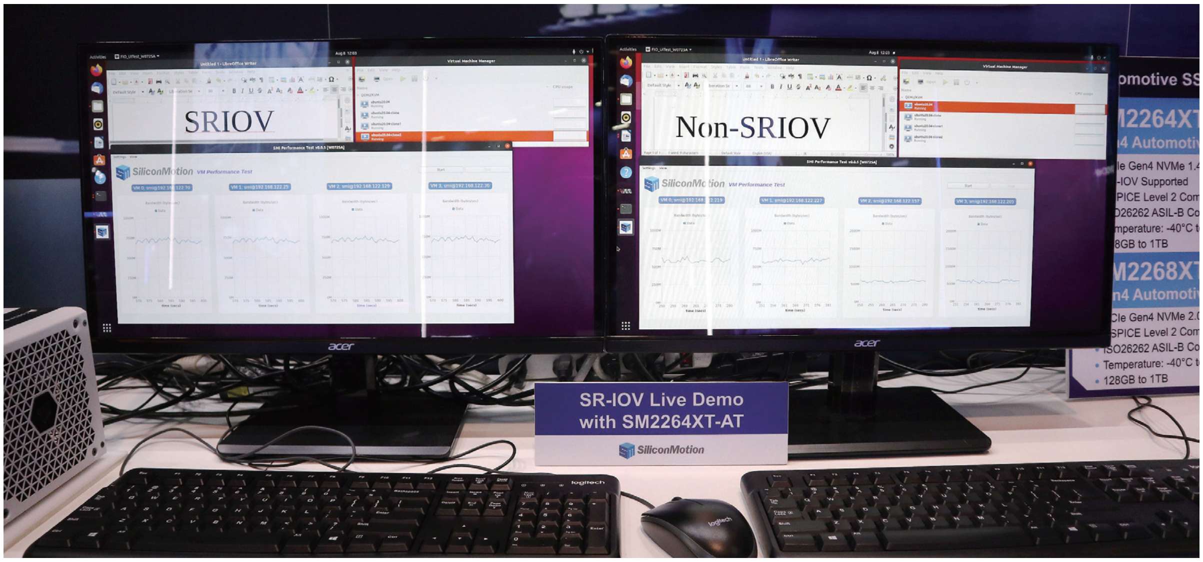
The World's First Automotive PCIe Gen4 SSD Controller Solutions: High Quality, High Data Integrity, and Built-in SR-IOV Capability

Silicon Motion SM2264XT-AT is an automotive-grade PCIe Gen4 NVMe SSD controller designed to provide exceptional performance and reliability for emerging automotive central computing and ADAS/autonomous architectures. It is equipped with a quad-core ARM R8® CPU, supporting four lanes of 16Gb/s per lane. SM2264XT-AT features built-in SR-IOV capability, supporting up to eight Virtual Machines (VMs), which is an excellent fit for future vehicles requiring centralized storage architecture implementation.

Designed with state-of-the-art PCIe Gen4 technology and innovative hardware features, the SM2264XT-AT ensures optimal speed and efficiency. Its advanced architecture, built on 12nm process technology, guarantees robust data protection, ultra-high quality of service (QoS), and unparalleled reliability.

Automotive PCIe Gen4 SSD Controllers Live Demonstration Results

Silicon Motion Introduced and demoed the SM2264XT-AT at the Flash Memory Summit. The SM2264XT-AT SSD controller with SR-IOV showcased unmatched SSD performance, seamless VM management, boosted speed, and reduced CPU load.



A side-by-side demonstration comparing SR-IOV and Non-SR-IOV configurations on two separate PCs revealed significant advantages for SR-IOV

Stability - The SR-IOV setup showed more stable performance, a crucial factor for automotive applications where even minor inconsistencies can have significant repercussions.

Resource Allocation - The SR-IOV system demonstrated lower CPU usage, allowing for more tasks to be performed concurrently essential for modern, multi-functional automotive systems.

This demonstration underscores SR-IOV as a more reliable and robust solution, ready for immediate implementation and offering immediate benefits. From performance gains and reduced CPU usage to better scalability and future-proofing, SR-IOV presents a compelling case for being the architecture of choice for next-generation automotive systems.

Full automotive qualification

The SSD storage device satisfies the strict requirements of automotive system designs for quality, reliability and safety.

Quality – the SSD controller is fabricated in TSMC's automotive-qualified wafer production process and complies with AEC-Q100 Grades 2/3. Silicon Motion offers flexible longevity support to guarantee long-term availability to match long automotive product lifetimes. Silicon Motion holds an Automotive SPICE® process assessment certificate.

Reliability – SSD storage products are renowned for their data integrity, providing bit-perfect data transfers into and out of their NAND Flash array thanks to unique End-to-End Data Path Protection technology. The SSD incorporates full data error detection with recovery engines to provide enhanced data integrity throughout the entire Host-to-NAND- to-Host data path. A data recovery algorithm can detect any error in the SSD data path, including hardware (ASIC) errors, firmware errors and memory errors arising in SRAM, DRAM or the main NAND Flash array.

Safety – Silicon Motion supports the SSD controller product with a Failure Modes, Effects and Diagnostic Analysis (FMEDA) to facilitate automotive manufacturers' compliance with the ISO 26262 functional safety standard.

Use of the automotive-grade SSD controller with built in SR-IOV capability is the perfect solution for high-speed storage and read-out of the high volumes of data generated by next-generation ADAS equipment. Automotive manufacturers which base their ADAS development plans on an SSD device will benefit from:

- High performance – the SR-IOV capability provides for near-native performance in a flexible virtualized architecture
- Reduced CPU utilization thanks to the elimination of the hypervisor layer between virtual machines and an SR-IOV enabled SSD.

Reference

[1] Brian Krzanich, Intel, at https://newsroom.intel.com/editorials/ krzanich-the-future-of-automated-driving/#gs.96s0oi

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

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