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Compact, shock- and error-tolerant SSDs offer auto infotainment storage options

"Industrial-strength" solid-state drives eliminate time-consuming seek processes, provide write/read performance up to 30 MBytes/sec, as well as error checking and correction circuitry

By Yuping Chung, Silicon Storage Technology (SST)

Remember when a state-of-the-art car entertainment system was one that could play multiple CDs? Those days are long gone. Today's automotive infotainment systems are complex embedded subsystems that bring together such diverse functions as MP3 music playback, GPS navigation, voice recognition, hands-free cellular connectivity, DVD video, and even Internet browsing.

As the auto infotainment system expands into a wider range of multimedia applications, its storage subsystem plays an increasingly crucial role. Music and video files must be stored and quickly accessed. Large mapping data files for 3D GPS systems must be rapidly searched and displayed, and audio files for voice recognition must be synthesized and stored.

HDDs are cost effective

Most auto infotainment systems in use today rely on a ruggedized hard disk drive (HDD) for data storage. These devices typically offer 40 to 50 GBytes of capacity. As a well-established, proven technology, HDDs offer a number of attractive advantages. On a dollar-per-GByte basis, they present designers with a cost-effective solution. In applications that can overcome the HDD's inherent seek and rotation latencies, where the majority of read accesses are sequential for example, HDDs can stream large amounts of data in a short period of time.

Reliability questions

In today's increasingly complex auto infotainment systems, however, other factors play an ever more important role in the selection of a storage subsystem. In many applications, the large quantities of data storage available on HDDs offers little benefit to auto infotainment system designers. Most systems only require four to eight GBytes of memory to adequately serve today's multimedia applications. Moreover, the automotive industry's high expectations for reliability and demanding requirements for ruggedness place a premium on storage subsystems that can offer high levels of shock, vibration, temperature, and moisture tolerance.

Given these trends a new generation of industrial-grade, small form factor solid-state drives (SSDs) offer designers of auto infotainment systems a highly attractive storage option. These new storage products come in either integrated or discrete versions. Integrated NAND modules, such as the "industrial grade" NANDrive™ line from Silicon Storage Technology (SST), combine an integrated ATA controller with one or more NAND flash die in a single package (see figure below). These devices offer complete IDE (Integrated Drive Electronics) flash disk drive functionality and compatibility in a compact BGA package as small as 12 x

18 x 1.4 mm. The designer simply mounts the BGA on the system motherboard. On boot-up, the system recognizes the NANDrive via the ATA or IDE interface as a system drive.

As an entirely silicon-based storage solution with no mechanical moving parts, small form factor SSDs such as NANDrive offer the designer the ability to meet the automotive industry's stringent shock and vibration specifications. From a performance standpoint, small form factor SSDs not only eliminate the time-consuming seek process a disk-based storage system must perform, which can take on average 13 ms, they also offer sustained write and read performance of up to 30 MBytes/sec. The current generation NANDrive devices from SST are qualified across the industrial temperature range and offer up to 8 GBytes of storage.

Smaller footprint
What is often overlooked are the major advantages small form factor SSDs offer in terms of footprint and performance. Over the past decade as automotive manufacturers have introduced a growing number of electronic subsystems into their vehicles, reducing the electronics footprint has become an increasing priority. For example, today's average automobile integrates anywhere from 30 to 50 microcontroller-based systems.

While HDD manufacturers have achieved continual advances in their ongoing effort to shrink the footprint of their products, today's drives still require much more space than silicon alternatives. As an example, a standard size 40 GByte HDD measures 70 x 100 x 9.5 mm. The NANDrive occupies 12 x 24 x 1.4 mm, or 1/120th that of the HDD. Weight savings are also impressive. At 0.8 grams, NANDrive weighs less than 1/100th of the HDD.

Data integrity and endurance are the most crucial storage subsystem considerations. Today's small form factor SSDs offer a wide array of features designed to extend IC endurance and ensure data integrity. To compensate for the random read errors that sometimes occur when using NAND flash, for example, SSDs offer embedded error checking and correction (ECC) circuitry designed to ensure the accuracy of data as it passes in and out of memory. NANDrive, for example, offers an 8-bit hardware ECC engine.

Bad-block management presents an additional challenge. Unlike NOR flash, NAND ICs are designed to allow a number of bad blocks. To manage these defects, firmware-based bad block management functions, activated when the small form factor SSD is initialized, identify the location of these bad blocks and map them out of the memory array. The firmware then directs the controller not to use those specified blocks. As additional bad blocks are identified, the firmware updates the map to ensure they are not used.

Write endurance poses another potential obstacle to the use of small form factor SSDs in the automotive market. Flash memory ICs are subject to write endurance limitations. After repeated erase and write cycles, the memory no longer retains data. The more complex the IC architecture and smaller the memory cell size, the lower the IC's endurance level. For example, single-level cell (SLC) flash memory devices are typically specified at 100k cycles. Devices using more complex multi-level cell (MLC) architectures, such as those commonly used today in portable consumer devices, are typically specified at 10k cycles.

Wear leveling

One way that small form factor SSD manufacturers are mitigating this risk is by using only SLC flash memory in SSDs for the automotive market. In addition, extended endurance is achieved by adopting wear-leveling functions in the SSD's firmware. As the name implies, wear-leveling algorithms track memory usage by block or page by matching an "age counter" to a map of the logical and physical sectors on the flash media. With each write and erase the age counter is incremented. These complex algorithms automatically balance memory usage by instructing the controller to rotate memory writes to blocks with lower usage. This technology utilizes all sectors of the flash memory to maximize endurance by reaching their write limit at the same time.

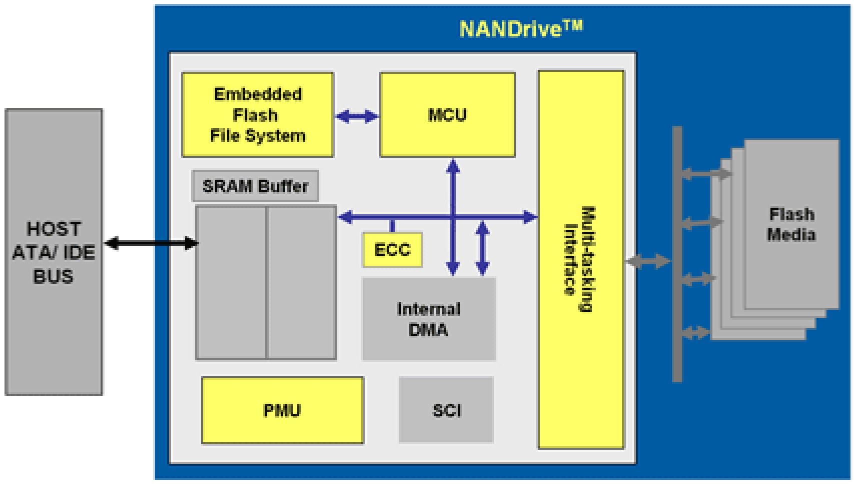
Discrete vs. integrated SSDs

Automotive manufacturers that decide the small form factor SSD offers a more attractive option than a HDD face another decision. They can buy plug-and-play integrated solutions or build their own discrete small form factor SSD using ATA flash controllers.

Many factors will play into that decision. In a discrete solution, the automobile manufacturer or subsystem supplier will purchase controllers and NAND memory ICs from different suppliers and mount the ICs on a board. Each system relies on an embedded flash file system block to manage the handshake mechanism between the host and the flash memory.

This approach offers a wider variety of suppliers and more flexibility when flash memory is in short supply; however, it also brings with it a more complex inventory management challenge. Moreover, as NAND flash memory technology evolves and the number of suppliers grows, compatibility issues between the controller and the memory present another potential issue.

Integrated solutions simplify the procurement and design process by combining an integrated ATA controller with one or more NAND flash die in a multi-chip package and optimizing the controller for the memory ICs in the drive. These plug-and-play solutions simplify the inventory management process by sourcing from a single vendor. Moreover, they can take advantage of stacked packaging techniques to offer substantial space savings. Discrete solutions using ICs from multiple vendors can occupy as much as twice the space of an integrated small form factor SSD.



Integrated solutions offer an advantage from a reliability standpoint as well. With NANDrive (see figure above), for example, the entire small form factor SSD fits into a single package. Since there is only a single chip on the board, the integrated SSD offers fewer points of failure than a discrete solution and better ability to meet the shock and vibration requirements of the automotive environment.

Conclusion

As automotive infotainment subsystem designers add a seemingly endless array of exciting, and exacting, new functions, they are placing increasing demands on the storage subsystem. These storage subsystems not only must deliver high performance at low cost, but must also ensure data integrity under severe environmental conditions. By combining the performance advantages of NAND flash with the footprint and reliability advantages of proven silicon technology, small form factor SSDs, such as NANDrive, offer automobile manufacturers an exciting new opportunity to build smaller and more reliable solutions that are better suited to the requirements of today's automotive infotainment systems.

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