How Solid-state Drives Work

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**History**

In 1956, IBM shipped the world's first **hard disk drive**, or **HDD**. The drive used 50 24-inch platters, stored a meager 5 megabytes of data and took up more room than two refrigerators. The cost was $50,000 ($421,147 in 2012 dollars).

Since then, hard drives have grown smaller, with larger capacity and less expensive. A new kind of computer drive, has arrived, known as a **solid-state drive**, or **SSD**, it uses semiconductor chips to store data. The chips used in a solid-state drive is flash memory, meaning the data stays put even without power.

If flash memory sounds familiar, then you probably have at least one or two thumb drives. These devices are officially called USB flash drives. They use the same flash technology and can be thought of as the predecessors of today's solid-state drives.

**Why Called Solid-state?**

Solid-state drives are built from transistors which are semiconductors. As a result, they enjoy a label, **solid-state,** reserved for devices that take advantage of semiconductor properties.

**How Solid-state Drives Save Data**

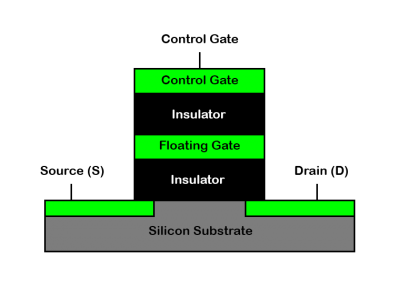
On the outside, solid-state drives look just like HDDs. They're rectangular in shape, covered in a metal shell and sized to match industry standard for hard drives, typically 2.5 and 3.5 inches. But beneath the metal shell, you'll find an array of chips organized on a board. The chips could fit into a smaller space, but SSD manufacturers dress up their components in extra "housing" to make sure they fit into existing drive slots of laptops and desktop PCs.



**IMAGE COURTESY blackmagicdesign.com**

SSD flash memory is called NAND. NAND flash has transistors arranged in a grid with columns and rows. If a chain of transistors conducts current, it has the value of 1. If it doesn't conduct current, it's 0. At first, all transistors are set to 1. But when a save operation begins, current is blocked to some transistors, turning them to 0. This occurs because of how transistors are arranged. At each intersection of column and row, two transistors form a cell. One of the transistors is known as a **control gate**, the other as a **floating gate**. When current reaches the control gate, electrons flow onto the floating gate, creating a net positive charge that interrupts current flow. By applying precise voltages to the transistors, a unique pattern of 1s and 0s emerges.

For a quick review, a single NAND flash cell stores an electrical charge on a floating gate which is isolated by oxide insulating layers above and below. In its simplest form when there is a charge on the floating gate it is programmed and recognized as a binary 0. When the floating gate has no charge it is erased and recognized as a binary value of 1.



**IMAGE COURTESY CACTUS-TECH.COM**

The NAND flash used in SSDs can only be used for a finite number of writes. SSDs can't write a single bit of information without first erasing and then rewriting very large blocks of data at one time. Each time a cell goes through an erase cycle, some charge is left in the floating-gate transistor, which changes its resistance. As the resistance builds, the amount of current required to change the gate increases. Eventually, the gate can't be flipped at all, rendering it useless. This decaying process doesn't affect the read capabilities of SSD, because reading only requires checking, not changing, the voltages of cells. As a result, NAND flash can "rot" into a read-only state.

Because they have no moving parts, SSDs can deliver improved reliability. They can rate up to 2.5 million hours MTBF, which probably means a few more years added to the lifespan of the device. They're also super quiet, with none of the whirring and clicking you get with HDDs.

An even bigger deal is the performance of solid-state drives compared to HDDs. With no moving heads and spinning platters, SSDs can access one piece of data as quickly as any other piece, even if they aren't in the same proximity. The speediness of the device manifests itself in all key CPU tasks, from booting up system software to opening files to reading and writing data.

SSDs consume far less power than traditional hard drives, which means they preserve battery life and stay cooler.

Even a casual user will notice a significant increase in the performance of a computer equipped with an SSD. But a power user will really feel the difference.  Today, gamers, photographers and anyone editing graphics or video files will appreciate the boost in speed a solid-state drive delivers.

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