# How Flash Memory Works

by Jeff Tyson

Electronic memory comes in a variety of forms to serve a variety of purposes. Flash memory is used for easy and fast information storage in such devices as digital cameras and home video game consoles. It is used more as a hard drive than as RAM. In fact, Flash memory is considered a **solid state** storage device. Solid state means that there are no moving parts -- everything is electronic instead of mechanical.

Here are a few examples of Flash memory:

- Your computer's BIOS chip
- CompactFlash (most often found in digital cameras)
- SmartMedia (most often found in digital cameras)
- Memory Stick (most often found in digital cameras)
- PCMCIA Type I and Type II memory cards (used as solid-state disks in laptops)
- Memory cards for video game consoles

In this article, we'll find out how Flash memory works and look at some of the forms it takes and types of devices that use it.

**More Memory!**

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- How RAM Works
- How Virtual Memory Works
- How ROM Works
- How Removable Storage Works
- How BIOS Works

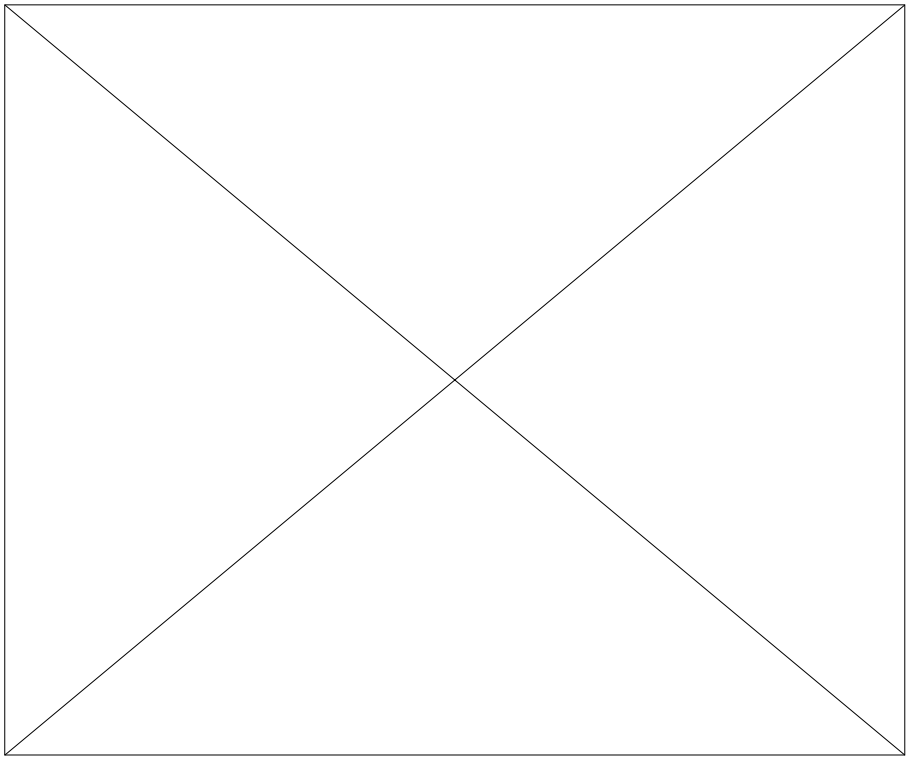
## The Basics

We discussed the underlying technology of Flash memory in How ROM Works, but here's a quick review:

Flash memory is a type of **EEPROM** chip. It has a grid of columns and rows with a cell that has two transistors at each intersection (see image below). The two transistors are separated from each other by a thin oxide layer. One of the transistors is known as a **floating gate**, and the other one is the **control gate**. The floating gate's only link to the row, or **wordline**, is through the control gate. As long as this link is in place, the cell has a value of 1. To change the value to a 0 requires a curious process called **Fowler-Nordheim tunneling**.

**Tunneling** is used to alter the placement of electrons in the floating gate. An electrical charge, usually 10 to 13 volts, is applied to the floating gate. The charge comes from the column, or **bitline**, enters the floating gate and drains to a ground.

This charge causes the floating-gate transistor to act like an electron gun. The excited electrons are pushed through and trapped on other side of the thin oxide layer, giving it a negative charge. These negatively charged electrons act as a barrier between the control gate and the floating gate. A special device called a **cell sensor** monitors the level of the charge passing through the floating gate. If the flow through the gate is greater than 50 percent of the charge, it has a value of 1. When the charge passing through drops below the 50-percent threshold, the value changes to 0. A blank EEPROM has all of the gates fully open, giving each cell a value of 1.



The electrons in the cells of a Flash-memory chip can be returned to normal ("1") by the application of an electric field, a higher-voltage charge. Flash memory uses **in-circuit wiring** to apply the electric field either to the entire chip or to predetermined sections known as **blocks**. This erases the targeted area of the chip, which can then be rewritten. Flash memory works much faster than traditional EEPROMs because instead of erasing one byte at a time, it erases a block or the entire chip, and then rewrites it.

You may think that your car radio has Flash memory, since you are able to program the presets and the radio remembers them. But it is actually using Flash RAM. The difference is that Flash RAM has to have some power to maintain its contents, while Flash memory will maintain its data without any external source of power. Even though you have turned the power off, the car radio is pulling a tiny amount of current to preserve the data in the Flash RAM. That is why the radio will lose its presets if your car battery dies or the wires are disconnected.

In the following sections, we will concentrate on removable Flash memory products.

## Removable Flash Memory Cards

While your computer's BIOS chip is the most common form of Flash memory, removable solid-state storage devices are becoming increasingly popular. **SmartMedia** and **CompactFlash** cards are both well-known, especially as "electronic film" for digital cameras. Other removable Flash memory products include Sony's **Memory Stick**, PCMCIA memory cards, and memory cards for video game systems such as Nintendo's N64, Sega's Dreamcast and Sony's PlayStation. We will focus on SmartMedia and CompactFlash, but the essential idea is the same for all of these products. Every one of them is simply a form of Flash memory.

There are several reasons to use Flash memory instead of a hard disk:

- Flash memory is noiseless.
- It allows faster access.
- It is smaller in size.

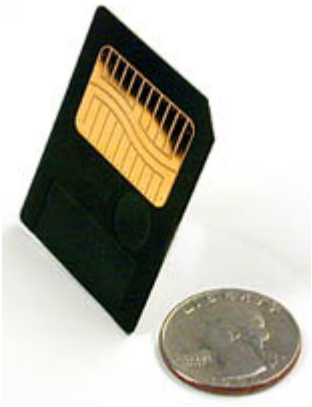
- It is lighter.
- It has no moving parts.

So why don't we just use Flash memory for everything? Because the cost per megabyte for a hard disk is drastically cheaper, and the capacity is substantially more.

# SmartMedia

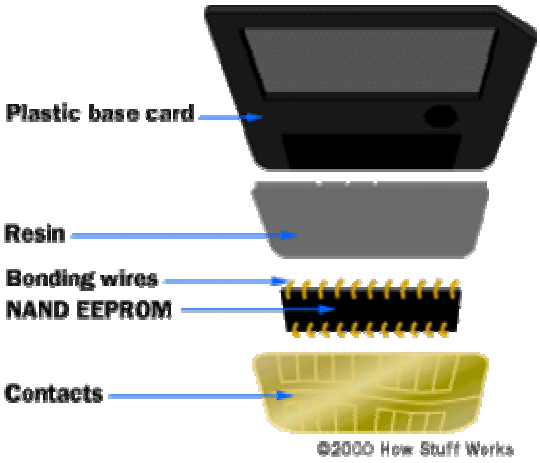
The **solid-state floppy-disk card** (SSFDC), better known as SmartMedia, was originally developed by Toshiba.

SmartMedia cards are available in capacities ranging from 2 MB to 128 MB. The card itself is quite small, approximately 45 mm long, 37 mm wide and less than 1 mm thick. This is amazing when you consider what is packed into such a tiny package!



**SmartMedia card**

As shown below, SmartMedia cards are elegant in their simplicity. A **plane electrode** is connected to the Flash-memory chip by **bonding wires**. The Flash-memory chip, plane electrode and bonding wires are embedded in a **resin** using a technique called **over-molded thin package** (OMTP). This allows everything to be integrated into a single package without the need for soldering.




The OMTP module is glued to a **base card** to create the actual card. Power and data is carried by the electrode to the Flash-memory chip when the card is inserted into a device. A notched corner indicates the power requirements of the SmartMedia card. Looking at the card with the electrode facing up, if the notch is on the left side, the card needs 5 volts. If the notch is on the right side, it requires 3.3 volts.

SmartMedia cards erase, write and read memory in small blocks (256- or 512-byte increments). This approach means that they are capable of fast, reliable performance while allowing you to specify which data you wish to keep. They are small, lightweight and easy to use. They are less rugged than other forms of removable solid-state storage, so you should be very careful when handling and storing them.

# CompactFlash

**CompactFlash** cards were developed by Sandisk in 1994, and they are different from SmartMedia cards in two important ways:

- They are thicker.

- They utilize a controller chip.

CompactFlash consists of a small circuit board with Flash-memory chips and a dedicated controller chip, all encased in a rugged shell that is several times thicker than a SmartMedia card.

As shown below, CompactFlash cards are 43 mm wide and 36 mm long, and come in two thicknesses: **Type I** cards are 3.3 mm thick, and **Type II** cards are 5.5 mm thick.

**CompactFlash card**

CompactFlash cards support dual voltage and will operate at either 3.3 volts or 5 volts.

The increased thickness of the card allows for greater storage capacity than SmartMedia cards. CompactFlash sizes range from 8 MB to 192 MB. The onboard controller can increase performance, particularly on devices that have slow processors. The case and controller chip add size, weight and complexity to the CompactFlash card when compared to the SmartMedia card.

Both of these types of removable storage, as well as PCMCIA Type I and Type II memory cards, adhere to standards developed by the **Personal Computer Memory Card International Association** (PCMCIA). Because of these standards, it is easy to use CompactFlash and SmartMedia products in a variety of devices. You can also buy adapters that allow you to access these cards through a standard floppy drive, USB port or PCMCIA card slot (like the one you find on a laptop computer). Sony's **Memory Stick** is available in a large array of products offered by Sony, and is now showing up in products from other manufacturers as well.

Although standards are flourishing, there are many Flash-memory products that are completely proprietary in nature, such as the memory cards in video game systems. But it is good to know that as electronic components become increasingly interchangeable and learn to communicate with each other (by way of technologies such as Bluetooth), standardized removable memory will allow you to keep your world close at hand.