What's New in Computers

Flash Memories

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Flash memories are not very new. Products based on flash memory have been around for more than 4 years now after the basic technology was introduced in 1988. Although flash-memories were initially thought of as replacements for magnetic storage, this has not happened. Instead, what is new are the different applications in which flash memory is being putting to use. What is flash memory? What are its features ? What are its advantages as compared to conventional memories? Where is it used ? This is what we'll take a look at in this article. The actual internal structure of flash memory is illustrated at the end of the article.

Magnetic Storage, RAM and EPROM

Disk memory and RAM memory are two types of read/write memories which we are all familiar with. We also know that this disk memory is non-volatile i.e., the data stored on the disk does not vanish when the power goes off (due to properties of the magnetic medium). The disk memory consists of several platters of magnetic medium rotating at a certain speed and a read/write head moves across the disk, reading and writing data. Currently, the size of such magnetic disks is in the range of 1–2 Gigabytes for PCs. RAMs are solid-state Integrated Circuits (chips), much faster than magnetic disks and are typically installed in sizes of 8–16 Mega bytes on desktop PCs. These RAMs are however, volatile. There is a type of commonly used non-volatile, solid-state memory called EPROM (Erasable Programmable Read Only Memory). But EPROMs need to be erased (using UV-light erasers) in order to be written into. They cannot be written into *in-situ*. Their structure is similar to that of flash memory

cells except that the oxide layers are thicker than those in flash memory cells. Various types of memories and their main features are summarized in the *Box*.

Types of Read /Write Memories

Magnetic Disks

- Typical capacity is 1-2 Giga bytes of storage (for PCs), Rs 9 per Mbyte, access time is in the order of 20 ms.
- Not very rugged due to moving precision mechanical components.
- Typical read rate is 5 Mbytes/s, write rate is about 3–4 Mbytes/s.
- Power consumption is about 3 W.

RAM (Random Access Memory) is of two types: DRAM and SRAM

- *DRAM*
  - Dynamic RAM, High Density (1 transistor per memory cell), access time is 40–70 ns, Rs 300 per Mbyte. PCs are now equipped with 16–32 Mbytes of DRAM.
  - Disadvantage is that it must be *refreshed* periodically. This implies that it is not available for access by the processor for read/write cycles during refresh. DRAM is volatile (no-power implies memory gets erased).
- *SRAM*
  - Static RAM, Low density (6 transistors per memory cell), used in low-capacity applications such as buffers, caches and FIFOs (Typical capacities: 256–512 kbytes). It is volatile.
  - Access time is 10–100 ns (depending on type) and does not need refresh cycles.

EPROM (Erasable Programmable Memory)

- Has to be erased (by UV light) and can be written into using special circuitry. It is non-volatile. Typical capacities are 32–128 kbytes.

Flash Memory

- Solid-state (and hence rugged) high density (one transistor per memory cell) relatively low-power (350 mW–max).
- Rs 700 per Mbyte.
- Typical capacities are 2 Mbyte (for digital cameras) to 80 Mbytes (PCMCIA card) for portable computers. PCMCIA card is the size of a credit card and is less than 3.5 mm thick.
- Read rate is 5 Mbytes/s and write rate is 700 kbytes/s.

Flash Memory — Solid-state Yet Non-volatile

Flash memories are solid-state chips but are non-volatile. These properties immediately made designers think of them as substitutes for magnetic disks in portable laptop and notebook computers. Flash memories are built from transistors (using one transistor per memory cell) — the same basic element of RAM chips. But they differ in their structure and operation from RAM to give them their above mentioned characteristic.

Designers produced flash memory PCMCIA (Personal Computer Memory Card International Association) cards, the size of a credit card, in the range of 20 MB–80 MB for portable computers hoping that one day such cards would replace magnetic disks in these machines. However this has not happened and magnetic disks are still being used in portable PCs.

The characteristics of flash memory and magnetic disks are given in the *Box*. Flash memories offer advantages of ruggedness, high density (one transistor per memory cell or bit) and low-power consumption due to their solid-state structure as opposed to magnetic disks which are built from several complex, moving mechanical components. However the storage capacities of magnetic disks have been doubling every year for the past 4–5 years (and continue to do so) for the same volume of storage. They offer an unbeatable price of about Rs 9 per MB, in terms of storage costs as against flash memories with Rs 700 per MB price tag. Further, flash memories have a disadvantage that a limited number of writes are possible as explained in the next paragraph.

Flash memories have the disadvantage that the number of write operations are limited to about 100,000. This meant that designers had to build in lots of spare cells which would increase the life of these memories. They took advantage of the fact that applications do a lot more reads than writes. When a memory cell reaches its write-limit, a spare cell is allotted to take its place. The write to

a flash memory is a complex operation requiring voltages of 10 V (above the normal 5 V) for a specified duration. All these make controllers for such flash memories complex and flash memories themselves expensive.

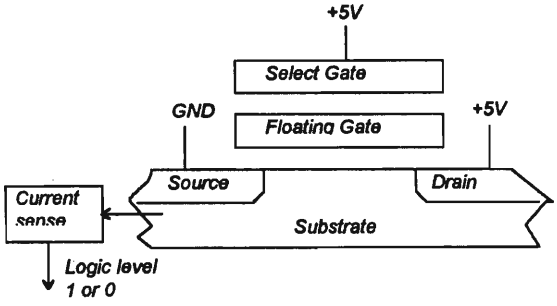
Thus flash memories never took off (as their protagonists hoped) in the storage scenario for portable machines. But they are being used in several other applications– especially in digital cameras, which are expected to be the launching pads for flash memory — as we'll see in the following paragraphs.

How Do They Work?

Flash memory transistors have an extra *floating gate* in addition to the gate that is present in normal transistors (see *Figure*). The floating gate is the charge-storage element which gives flash memory its non-volatile characteristic. However, charging or discharging the floating gate is slightly complex and is illustrated in the *figure*. The complex charging process results in the abnormally long write cycles of flash memory. Hence the write rate is very much less (700 k bytes/s) than the read rate (5 M bytes/s).

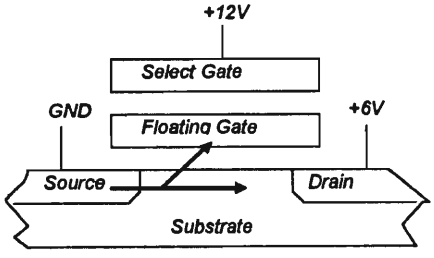
EEPROM

A slight variant of flash memory technology has been used to make highly successful EEPROM chips. EEPROM stands for Electrically Erasable Programmable ROM. These chips are replacing all applications where traditionally EPROMs are used. EPROMS are generally used to store firmware. Firmware (also called BIOS – Basic Input Output System – in a PC) is the name given to software which normally is executed first in the PC, when it is powered on. Firmware initializes all the peripheral devices of the PC such as disk, display and the keyboard and enables further loading of the operating system from disk to RAM to take place. Products such as fax machines, laser printers, telephone answering machines, cellular phones, digital exchanges and electronic cash registers require a microprocessor (or



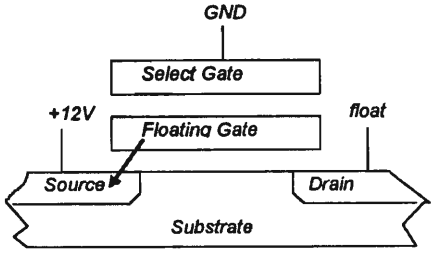
Read Operation
if Select Voltage (5V) > Threshold
Drain to source current flows (Logic level 1)
else
no current flows (Logic Level 0)

Difference in Threshold voltage (between select and source)occurs due to differing amounts of charge in the floating Gate



Program Operation (Logic level 0)

Done through hot-electron injection process Application of voltages Causes accumulation of electrons on floating gate, thus increasing the select gate to source potential difference and causing an increase in threshold voltage.



Erase Operation (Logic level 1)
Electrons flow out of the floating gate (due to applied voltages) reducing potential difference between select and source thus reducing the threshold voltage.

microcontroller) to manage the machine. The programs for these controllers (while certainly not as complex and large-sized as PC operating systems such as DOS or Windows 95) do require storage, and traditionally a combination of EPROM and battery-backed up RAM are used to meet the demands of these programs. The latter type was used for data that needs to be changed from time to time but needs to be non-volatile. EEPROM is now replacing this combination of memories since it offers non-volatility of storage. A further advantage of using EEPROMs is that if there are bugs in a program they can be corrected without

removing the chip from the machine unlike EPROMs which have to be removed from the system in order to be re-programmed.

Digital Cameras

Recently, flash memories are being used in digital still-picture cameras – replacing films. In appearance, these digital cameras look exactly like the normal camera. They acquire the image through their CCD (Charge Coupled Device) cell array and transfer the image to a flash-memory card – which serves as the *film*. The image can then be viewed on a TV or transferred to a PC for archiving into electronic *photo albums*. Some of the more sophisticated models even have a LCD screen to view the image instantly after the photograph is taken. The photographer can review his work 'on-line' (and do a re-take if necessary). In their digital form these images can be easily processed using image processing techniques for either efficient storage or for feature extraction. The implications of these are enormous. This has a wide variety of applications in fields such as medical databases, advertising, police crime records, voter identity card preparation and verification etc. This is especially true if this technology is combined with simple magnetic card storage technology which has even been used for producing bus and train tickets. In future, (when prices permit) low-capacity flash-memory cards may also be used in place of these magnetic cards. Another major advantage of these digital images is that they can be easily transmitted over modem or the internet to a remote location without distortion or delay. This is especially useful to journalists who just need a simple portable PC with a modem to transmit images to the main office. Thus the possibilities are many, the applications are exciting and flash memory will have a powerful impact in these areas. This explains why all the major photographic companies which have concentrated on film-based photography for decades, have now moved in a major way to the digital camera arena.

The negative point is that these digital cameras are still very expensive. A model recently released in India, which can store

about 100 images costs about Rs. 22,000. This is still prohibitively expensive. However, prices are expected to reduce with about 20 vendors entering the market — including the major photo companies.

In this article we have focused on the new applications of a not-so-new device – flash-memory. Flash memory is still searching for the application that will increase its demand to high levels in the mass market. Many believe that the digital camera is that 'killer' application. Manufacturers of flash memory hope that the expected high demand in the consumer market for flash memories will bring down its current high price and will enable it to compete in the PC market as well. They even predict that with improvements in technology that will overcome its current limitations, flash memory could even replace DRAM (Dynamic-RAM) in computers. This is because flash memory cells have the same density as DRAM cells and would occupy the same volume as DRAM. Time, and the response of the consumer will tell if flash memory will really make the big splash it's protagonists want it to make.

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Suggested Reading

- **Brian Dipert and Lou Herbert.** ***Flash memory goes mainstream.*** **IEEE Spectrum, October 1993.**
- **Gary Legg.** ***Flash Memory Challenges Disk Drives.*** **EDN February 1993.**
- **Rick Cook.** ***The way of all flash.*** **Byte Magazine, June 1996.**

Science is facts; just as houses are made of stones, so is science made of facts; but a pile of stones is not a house and a collection of facts is not necessarily science. *Henri Poincare*

The most exciting phrase to hear in science, the one that heralds new discoveries, is not Eureka! (I found it!) but That's funny...

Isaac Asimov