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Future Aspects Based Survey of Electronic Flash Memory and Magnetic Memory

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Abstract: The basic concept of using the square hysteresis loop of certain magnetic memory as storage devices was known from the earliest days of computer development. Magnetic hard drives were the world's most common means of memory storage. In this mechanically based memory system, information was stored on magnetic platters and read with magnetic heads, which hover over the disks. Hard drives were very susceptible to breakage from shaking, bumps, and falls. Data access can be slow; the magnetic reader must scan the disk magnetic section by magnetic section, looking for often-dispersed data stored on the disk.

Flash memory is an alternative storage source. It stores data in solid-state transistors without moving parts. This makes the memory hardy and much less in size inclined to damage than traditional forms of storage. It also uses less power and works faster than other forms of storage. When a computer utilizing Flash is turned on, all data used in the last session reappears quickly, and without danger of corruption, as it is stored to the non-volatile, incorruptible Flash RAM. This feature makes virtually instant startup time possible, which is the reason this device majorly use on future aspects.

The future of Flash technology looks bright. Less than a year ago, it was impractical due to technological and economic restrictions. However, the price of Flash memory has dropped significantly and is now rather competitive with other forms of storage but the today's price is not competitive.

The purpose of this paper is to detail the current and future technology of Flash and discuss the uses, features, and flaws of the technology. The information within this paper has been culled from professional papers, magazines, and internet sources. It also contains personal knowledge of Flash technology.

Keywords: Control Gate, Flash Memory, Magnetic Memory, Floating Gate, MOSFET, RAM, ROM, Transistors

1. Future Aspects of Flash Memory Devices

Smart Cellular phones, MP3, MP4 players, digital cameras, handheld digital organizers, "jump-drives," all of these items used in everyday life are made possible by a revolutionary technology: "Flash" memory in the manner of size reducing day by day. This type of electronic storage, based on the simple transistor and CMOS solid state technology based, is sweeping the personal computing and electronics world. The marked durability of Flash memory drives makes it perfect to fulfill jobs that its predecessor, the notably bulkier magnetic hard drive, was incapable of filling due to its mechanical limitations. While a Flash drive can be shaken, dropped, and drenched in liquid and still function perfectly, the previous style of hard drives will just stop working due to a number of problems caused by such rough handling. The durable design of Flash memory drives opens to product manufacturers a completely new realm of design options, ranging from new MP3 players with large amounts of storage packed into tiny cases to laptop and tablet computers much smaller and more capable than currently existing models in size for users.

Technology behind Flash requires deep knowledge of transistor and CMOS technology. It has implications in quantum tunneling, electron theory, printed circuits, and transistors. Flash of any type is based on transistor technology generally called MOSFETs. These transistors have electrons channeled through them, thereby changing the base voltage required to start an electrical current flowing through the circuit. The computer reads and interprets this threshold voltage and translates it into the zeros and ones of a computer's binary languages. The process used depends on the specific type of Flash memory, but the same common principal applies, and all Flash cells have the same basic structure.

This revolutionary form of storage manages all of these remarkable capabilities of transistors; we must understand how the technology works and how the technology is different from older forms of storage.

2. Past of Magnetic HDD Disk Device

The technology behind Flash memory is based on the transistors, FET, MOSFET and CMOS, a key part of any electronic device's printed circuit. These small semiconductors revolutionized the computer world, doing away with the long outdated vacuum tubes that were necessary in the earliest computing devices. They use a minute voltage, or electrical current to control a larger change in voltage or current. Transistors are an integral

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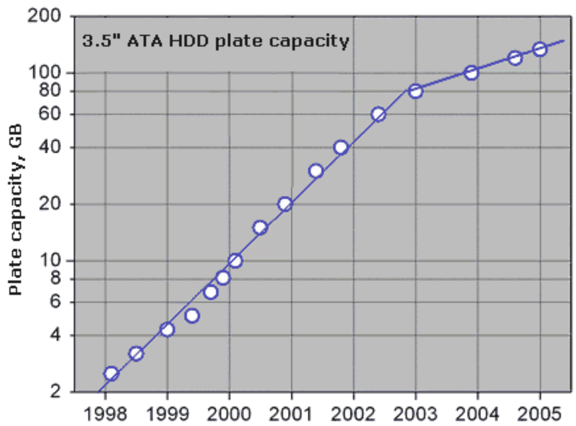
part of modern circuitry and already govern the worlds of computing, cellular phones, and other modern electronics. Now they are sweeping another area of the computer industry, the crucial area of storage. To understand how revolutionary the transistor is to this area of the market, it is crucial to first understand the current technology behind hard disk drives, or HDDs.

It should be noted that HDDs are a type of storage called non-volatile by the industry, which means that when a device using a disk loses power, all information that was written to the disk stays there. A typical HDD consists of a central spindle holding one or more flat, circular, magnetic disks called platters, usually made from a non-magnetic material such as glass and coated in a fine layer of some type of magnetic material, commonly either iron or a cobalt alloy. Platters are spun at extremely high speeds under "read-write heads" that fly across their surface reading from the platters or writing data to them. Floppy was the proper manner example to specify for this type of memory devices. Data is written to a platter by magnetizing the magnetic coating into a pattern that computers recognize as data. Reading a disk is simply the reverse of the process, with a computer detecting and deciphering a magnetic pattern and turning it into visual data for the end-user. For each platter on a spindle, there exists one head. All heads are commonly mounted on an actuator arm that grazes the surface of the drive and detects and modifies its magnetic makeup. The actuator arm moves the heads across the spinning platters allowing each head virtually limitless access to its specific platter. The size and speed of the common HDD have skyrocketed, leading to its quick acceptance as a cross-market standard for everything from MP3 players and laptops to digital video recorders. The common hard drive, as of December 2006, can hold from anywhere between 160 GB (1,073,741,824 bytes = 1 GB) to 1 TB of data and its platters can rotate at rates anywhere from 7,200 to 10,000 rotations per minute. According to the past survey the following graph is showing the usage of



the memory devices:

FIGURE 1: The common HDD was accepted into the market for its average reliability and ever-increasing size [1].

At first glance, the average person would expect that such a large amount of space, at such a high speed, would be more than able to remain the market standard for the long-term future. The statistics are staggering until the shortcomings implicit in HDD technology are considered. First, it should be understood that hard drives are machines and suffer all the requirements and burdens of that classification. They have moving parts, which require power and can degrade over time [1]. The power required is generally not an excessive amount, but it is large enough to affect the usage of HDDs in devices that need to be more compact and cannot afford to lend space to a battery pack. The moving parts also generate friction and, in turn, heat [2]. They are extremely fragile devices that must exist in an exact environment to function properly; they exist in a mostly sealed enclosure that protects the platters and heads from dust and other types of external contaminants. The heads glide on an air bearing only nanometers above the platter surface; therefore, the internal environment of the device and the surface environment of the disk must be kept perfect to prevent severe damage from fingerprints, dust, smoke particles, or anything else capable of closing the sub-microscopic void between the head and the platter. The critical requirements for so perfect an environment are the leading contributors to the downfall of hard drives. They cannot stand up to the wear and tear that the user of today puts onto their devices. For example, cell phones and MP3 players are dropped by careless users on a regular basis. This kind of motion is deadly to hard drives, where the slightest jolt can send a stable environment on the nano-metric scale into disarray. A quick jolt to a laptop or computer tower can send the read-write head of its hard disk straight through one of the thin magnetic platters, ruining it and destroying all of the data stored on it.

3. The Important Aspects of Flash memory

3.1. A Brief Description of Memory Devices

The electronic Flash drive overcomes the mechanical features of the common HDD and features much fewer flaws than its older brother, while adding new advantages into the mix. Flash memory was invented in 1984 by Dr. Fujio Masuoka while he was working for Toshiba. He invented two types of Flash at the time, NOR and NAND. Dr. Masuoka presented his invention at the 1984 IEEE International Electron Devices Meeting, where it was recognized by Intel as an invention with massive potential. Intel introduced their first commercial NOR type Flash device in 1988 [3].

NOR-based Flash has long read, write, and erase times, but it also has a full memory interface that allows random access at any location. NAND-based Flash, which was announced by Toshiba in 1989 at the International Solid State Circuits Conference, followed closely behind. It has much faster read, write, and erase times, offers a higher density, and comes at a lower cost per bit than its NOR-based counterpart. However, whereas NOR has a full memory interface, NAND only supports sequential access, meaning that its elements can only be accessed in

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a predetermined, ordered sequence. This type of access is also used on cassette tapes; data can only be accessed in the order it is recorded. It can be “fast-forwarded” through to a desired point, but it is still accessed in the order that it appears on the tape. These characteristics make NAND Flash desirable for mass-storage such as in PC cards and various memory cards, but much less useful for computer memory [3].

3.2. Working Methodology: Flash Memory

Flash memory is a non-volatile form of memory. However, the likeness ends there. Flash has better kinetic shock resistance than an HDD and offers faster read times over the HDD. Current Flash technology can generally be broken up into two classifications—NOR Flash and NAND Flash [2]. The typical Flash memory cell consists of a type of transistor known as a MOSFET, or metal-oxide semiconductor field-effect transistor and two transistor gates. To understand a MOSFET, one must understand its components, generally consisting of a channel of n-type or p-type semiconductor material, named nMOSFET or pMOSFET respectively. The purpose of n-type doping is to produce carrier electrons in the material, and the purpose of p-type doping is to produce an abundance of holes.

A MOSFET is based on the modulation of charge caused by a MOS capacitance. It includes two terminals, each connected to a highly doped region that can be of either the n or p type, but the two terminals must both be of the n type or both be of the p type. The regions are denoted by the symbol of the doping process followed by a plus sign, “+.” The two regions are generally divided by a body region doped of the opposite type. The active region is a MOS capacitance with a third electrode, the Gate, located above the body of the transistor and insulated from all of the other regions by an oxide.

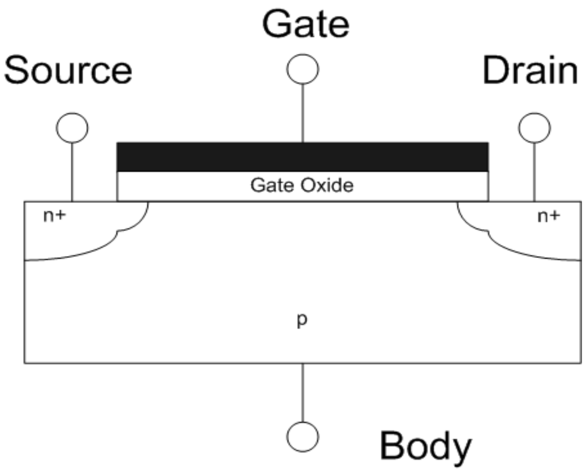

FIGURE 2: Field-Effect Transistor [4]

3.3. NOR Logic Flash Memory

The NOR version of a Flash cell, there are two gates, as opposed to a MOSFET's one. One gate, the Control Gate, is exactly like the gate mentioned above in other MOS transistors. However, the second gate, or Floating Gate, is situated between the control gate and the transistor's substrate, and is totally isolated in the oxide layer. Because of this isolation, any electrons placed on it get trapped there and store information. Electrons on the Floating Gate modify the electric field coming out of the Control Gate, which modifies the threshold of the cell. When an attempt to read the cell is made, a specific voltage is placed on the Control Gate, and electric current will either flow or not, depending on the threshold of the cell. The presence or absence of current is translated into the zeros and ones of binary language, and represents the stored data.

NOR Flash cells are programmed by starting electrons flowing from the Source Terminal to the Drain Terminal. A large voltage is then placed on the Control Gate providing a strong enough electric field to pull the electrons up through the Floating Gate in a process sometimes called Hot Electron Injection. Also known as Hot Carrier Injection, this is a phenomenon specific to solid-state devices and occurs when an electron gains enough kinetic energy to overcome a potential barrier, becoming what is known as a “hot carrier”, and moving to a different area of the device. In a MOSFET, the carrier is injected from the substrate to the gate dielectric. A NOR cell is erased by a large voltage differential placed between the Control Gate and the Source Terminal, which pulls electrons off in a quantum-mechanical process known as quantum tunneling, the effect of transitioning through a classically forbidden energy state [5]. The high voltage required for both processes is generally generated by an on-board charge pump.

3.4. NAND Logic Flash Memory

NAND Flash also features a MOSFET transistor, a Control Gate and a floating gate. However, rather than using Hot Electron Injection to write data to the drive, a process called Tunnel Injection is used. The quantum tunneling effect that occurs when charge carriers, such as electrons or ions (in the case of Flash, electrons), are injected into an electric conductor through a thin layer of an electric insulator. A process called Tunnel Release is used to erase NAND Flash [6].

3.5. Flash Memory Specifications: ROM and RAM

Low-level access to Flash, or access to a physical Flash memory device by software such as a device driver, is different from accessing standard common memories. While common computer RAM, random access memory, simply responds to operations by returning the contents and altering them immediately, Flash requires certain special considerations, especially when it is programmed to be used as a type of ROM, Read Only Memory.

In NOR-based Flash, the read-only mode is similar to reading from a common memory, providing the address and data bus are mapped correctly, and can be used much like any address-mapped memory. NOR can also be partitioned with a file system and used as a storage

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device; however, as mentioned earlier, NOR suffers from slower read and write times than NAND-based Flash [6].

NAND-based Flash, memory is accessed much like block devices such as hard disks. It typically has software-based poor block management, meaning that when a logical block is accessed, it is mapped to a physical block. The device has a number of blocks set aside in its memory to compensate for bad blocks and for storing primary and secondary mapping tables. The error-correcting and detecting redundancy corrects errors where even one bit in the block is incorrect, marks the block as bad in a logical block allocation table, copies undamaged data to a new block, and updates the logical allocation table to reflect all changes. If any more than one bit is corrupted, however, data is no longer possible to reconstruct from the original contents. When executing software from NAND based Flash, virtual memory strategies are used. Memory contents are copied through a process called paging into system-memory-mapped RAM and executed from there [6].

4. Smart File Systems of Flash Memory

The characteristics of Flash memory, there are special requirements when it comes to its file systems. One of the first file systems in use in the early 1990s was the FFS2 format developed by Microsoft for use with its MS-DOS operating system. In 1994, the PCMCIA group approved the Flash Translation Layer specification (FTL) [7], the first file system to allow a Flash device to look like a FAT, or File Allocation Table, file systems, a file system that is supported by virtually all existing operating systems for personal computers. The first Linux Flash-specific file system was the JFFS, or Journaling Flash File System, which was quickly superseded by the JFFS2 format, and later the YAFFS, Yet another Flash File System, which was built specifically for NAND Flash [7].

5. Future Aspects of the development of Flash Memory

The Flash memory are being invented to greatly improve the reliability of Flash memory. One type, called Charge Trap Flash, was invented by Samsung in 2006. [8] The technology uses a SONOS, semiconductor-oxide-nitride-oxide-semiconductor, or MONOS, metal-oxide-nitride-oxide-semiconductor, structure and stores information in charge traps in the nitride layer.

A SONOS cell consists of an nMOSFET transistor with an additional layer of insulation on the gate.

When the gate is biased positively, electrons form an Emitter Circuit Tunnel though the oxide layer and get trapped in the silicon nitride layer. This has the same effect described for MOSFET structures and results in an energy barrier between the emitter and the collector raising the threshold voltage. Electrons can be removed or added by changing the charge bias on the gate.
Another new type of Flash Memory is called Serial Flash. It is a small, low-powered type of Flash that typically uses an SPI, or Serial Peripheral Interface Bus. Serial Flash requires fewer wires on the circuit board than Parallel Flash types require [8].

6. The Faults and Flaws of Flash

To say that Flash is flawless is presumptuous. While it suffers from far less negative qualities than magnetic HDDs, Flash is not without its drawbacks.

Flash is limited in that although it can be read or written to one byte at a time, it can only be erased one block at a time. In other words, Flash offers random-access read and programming operations, but it cannot do random-access rewrite or erasure operations. In addition, it is limited by its degradation cycles. Flash memory has a finite number of write/erase cycles, which can be attributed to degradation of the oxide layer in the transistor due to electrical field effects. This is barely offset by the promise that most commercial Flash drives come with, ensuring over 1 million cycles.

Data corruption is one of the most common problems with Flash drives during their recommended life cycle. This is most often caused by the removal of a drive while it is being written to, a common occurrence when one is in a hurry to get data off a Mac^{TM} computer. The situation is made worse by faulty formatting caused by unsuitable file systems that were never built to be used on removable devices. Data recovery can be achieved in few cases, using certain different methods based on the file system being used on both the drive and the accessing machine.

7. The Cost of Flash

Since its development, the major downfall of Flash technology has been its price. In the first few years of the current decade, Flash memory cost approximately double the price of a hard drive per gigabyte of memory. However, the price of Flash memory is on the decline. Because of price and durability, many companies are embracing Flash as the next great development in data storage. One of the great shortcomings of Flash is that NOR Flash, the type used to run software, has a lifespan of 100,000 write cycles and is slow to read big sections of data. However, NAND Flash can be rewritten up to one million times and is faster and more efficient at reading larger amounts of data. The cost per gigabyte reduced from 2005 to 2015 respectively $45 to $01 as per today's survey report. Flash memory will reduce the cost of memory expectedly according to based technological survey.

Moore's Law

Moore's Law states that at minimum cost, the number of transistors on an integrated circuit doubles every two years. Flash memory is actually outstripping Moore's Law because companies are seeing the importance of Flash technology and putting more money into development. Because of this, Flash is developing even more rapidly, allowing for even greater advances in technology.

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8. Major Applications of Flash Memory Technology

As the price of Flash memory has declined, more companies have begun working on ways to use Flash technology in their products. Samsung and Seagate expect to release hybrid hard drives sometime early this year. These hybrid drives combine the traditional magnetic hard drive with Flash memory and allow such possibilities as computers with lightning fast boot time, high-speed applications, and low power usage, as hard drives would not have to spin as frequently. The key to using these developing hybrid drives is the creation of operating systems that are compatible with the memory type.

Flash memory has many more applications. A number of them have already been realized. Cell phone manufacturers use Flash for their SIM cards, which store everything from phone numbers and ring tones to photos and video clips. Apple computers uses Flash in its iPods™ and may also use Flash memory in its computers in the near future. Digital cameras also make use of removable cards with Flash storage for photos and videos. One of the exciting possibilities for Flash is an exceedingly low energy requirement, which could end up extending battery life by a factor of four on such devices as MP3 players and cameras. Another intriguing prospect is that of using solely Flash memory in laptops in order to create ultra-portable computers.

9. Sustainable Flash Memory

lash memory has very few effects on the environment; indeed, the need for Flash is propagated by an increasing need for large storage space in a smaller physical body. In this sense, the sustainability of Flash is rooted clearly in the desired improvement of the quality of life of humanity.

That is not to say that Flash is without effect on the environment. Because of the system's
lack of moving parts, it uses significantly less power then today's hard drive devices. While this is not a significant difference, as generally hard drives do not exceed a 15 Watt power consumption, even at peek usage [10], the change over to Flash will mean that computers will have a much smaller energy footprint overall. Also, as processing power increases, the overall power requirements of a computer will increase; Flash's advantageously small power requirements will effectively reduce any future computer's overall wattage. Computers now can include power sources in excess of 500W.

This small boon aside, the sustainability of Flash rests on humanity's needs. As long as humans need a form of easily transportable storage or a form of low power storage, Flash will be the answer. Its survivability and ruggedness make it paramount to the previous options, and its lower power consumption makes it extremely useful in battery operated devices such as cameras or MP3 players.

10. New Age: Technology in development of Memory devices

Flash memory is the technology of the future. Many companies have already begun to embrace the advantages Flash has to offer, and this should continue over time until a new and better method of memory storage is developed. Gone are the days of relying on fragile magnetic hard drives to store important data. Now that Flash memory is available to the world, cellular phones, MP3 players, and "jump drives" can be dropped, shaken, and run through washing machines without sustaining any damage to the data they contain.

The durable design of Flash technology has opened a new realm of electronic possibilities to the world. Computers may become smaller, stronger and more power-efficient than they once were. Perhaps most importantly, they will be able to save data even if power is lost unexpectedly. With Flash technology still in development, the best part about it is seeing what technology will be reinvented next.

Glossary

- *Control logic Gate* – One of the primary components of a MOSFET, used to draw electrons through the oxide layer by either Hot Electron Injection or quantum tunneling.
- *File system* – In the devices, a method of storing files, and the data they contain, so that they can be easily accessed at a later point in time
- *Flash memory* – A form of non-volatile computer memory using transistors, it can be electrically erased and reprogrammed.
- *Floating Gate* – In a Flash cell, this body is part of the MOSFET completely encased in the oxide layer. This gate captures electrons being drawn towards the control gate, which are in turn translated into the ones and zeros of computer binary.
- *HDD* – Acronym: Hard Disk Drive. A non-volatile storage device that stores digitally encoded data on rapidly rotating platters with magnetic surfaces.
- *Hot Electron Injection* – occurs in solid-state semiconductors when electrons gain enough kinetic energy to overcome a potential barrier such as the oxide in a MOSFET, and migrates to a different area of the device.
- *MOSFET* – Acronym: metal-oxide-semiconductor field-effect transistor. A common field effect transistor that is the primary component of Flash memory's storage capability. Consists of a conductive gate surrounded by an oxide layer.
- *Quantum tunneling* – A process of quantum mechanics that occurs in NAND Flash. In this process, electrons physically pass through the energy state of the oxide to be trapped on the Floating Gate.
- *RAM* – Acronym: Random Access Memory
- *ROM* – Acronym: Read Only Memory
- *Transistor* – a small semiconductor device required in the world of circuitry that uses a small amount of voltage or electrical current to control a large change in voltage or current.

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BIOGRAPHIES

Sachin Tyagi received, Bachelor of Technology degree in Electronics and Communication Engineering from ICFAI Institute of Science and Technology, ICFAI University, Dehradun and Master of Technology in Electronics and Communication Engineering from MBU, Solan. In addition to working as faculty (Assistant Professor) he is pursuing research work in Roorkee College of Engineering, Roorkee. His areas of interest include VLSI Technology and Circuit designing, Signal Processing, MIMO systems and Wireless mobile communication.

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