About the production and application of flash drives

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Abstract— **Different kinds of semiconductor memory serve as a representation of the current dominating data storage technology. The article looks at the different types of flash drives and how they are made. Flash drive are commonly used for storage, data backup, and transferring files between devices. Multi-layer technologies are described as being fundamental in manufacturing. The write and read speeds, memory capacity, port type, and pricing are the key considerations when selecting flash drives. Examples of their use are provided.**

Keywords- flash memory, USB port/interface, read and write speeds

I. INTRODUCTION

A flash drive is a type of storage device used to store and exchange data with a computer or other device. It is a type of non-volatile, external computer memory with small dimensions. The many common names such as Stick memory and USB (Universal Serial Bus) memory sticks are actually trademarks of specific companies. Since August 2008, the name "flash drive" or "UFD" (USB Flash Drive) has emerged as the standard term for these devices, and since 2018 UFS (Universal Flash Storage), UFS 3.0 and UFS 3.1 since 2020. It is implemented on semiconductor chips using planar technology.

Simon Sze credited with being a non-volatile memory (NVM) pioneer and with playing a major role in the advancement of flash memory technology[1][2]. Robert H. Dennard is regarded as a pioneer in the field of semiconductor memory and is the inventor of Dynamic Random Access Memory (DRAM)[3]. While working at Intel in the 1970s, Dov Frohman is credited with creating the first commercial NVM technology, also known as Electrically Erasable Programmable Read-Only Memory[4].

The flash memory was invented by Fujio Masuoka, an engineer at Toshiba, in 1984 [5][1][6]. The name "flash" was proposed by his colleague Shoji Arizumi on the basis that the process of erasing the memory reminded him of a flash. Masuoka presented his development at the IEEE 1984 International Electron Devices Meeting (IEDM) held in San Francisco, California. The company Intel noticed the great potential of the invention and in 1988 produced the first commercial flash chip of the NOR type.

Two main types of flash memory are produced according to their storage logic structures: NOR (NOT OR logic) and NAND (NOT AND logic) (fig. 1). In both types of memory, integrated circuits (ICs) are used as elementary cells for storing information. NAND-type flash memory was first announced by Toshiba in 1989 at the International Solid-State Circuits Conference. It is characterized by higher write speed and smaller chip area. The three most common subtypes or classes on record are: SLC (Single Level Cell), MLC (Multi Level Cell), and TLC (Three Level Cell), with decreasing capabilities and prices, respectively. QLC (Quad-Level Cell) is a new type of MLC (Multi-level Cell) memory in which 4 bits of information are recorded in one cell. 64 layer 3D QLC flash memory is used.

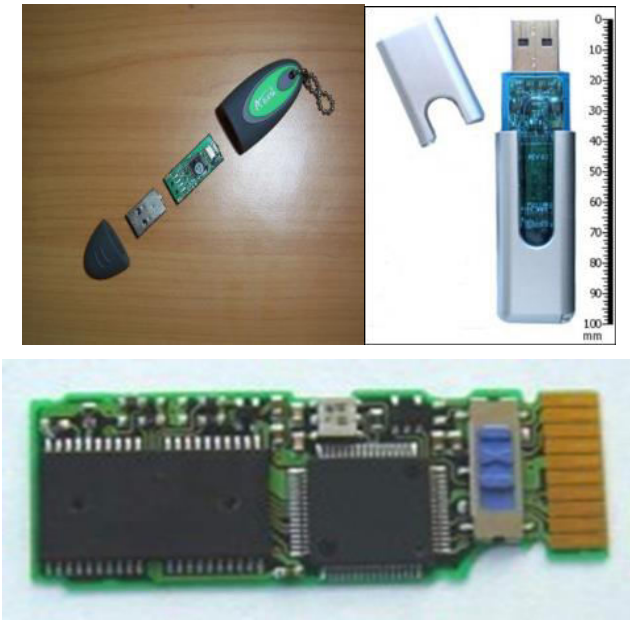

Figure 1. Flash memories - some applications

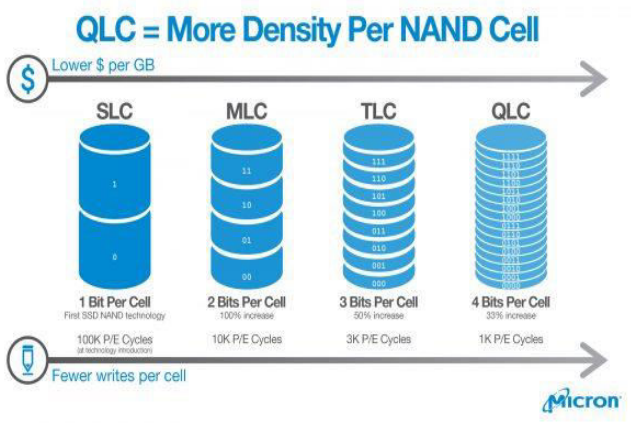

Figure 2. Functioning of the different types of flash memory

The diagram in fig.2 published by Micron shows very well how the different types of flash memory work (bits density per NAND cell). There is evidence of the introduction of these memories first in Israel. The patent for the first USB flash drive belongs to the Israel company M-Systems. Currently, the application of flash drives is ubiquitous.

II. EXPOSURE

A. Construction

The development of high-speed serial interfaces (buses) such as USB (Universal Serial Bus) made serial-access memory systems feasible for information storage for the first time. The USB computer bus standard is supported by modern operating systems (OS) such as Windows, Mac OS X, Linux, and other Unix-based OSes. Flash drives usually use the USB standard to communicate with the computer or similar device.

The simultaneous development of small, high-speed, low-power microprocessor systems allows this to be built into extremely compact systems that are the core components. On one end, the device is equipped with one male type-A USB 2.0, 3.0-3.1 (type C)-3.2, micro USB or even a combined connector, and inside a plastic case, there is a small printed circuit board with SMD (Surface Mount Devices) elements.

They have a capacity according type of memory cell that used for the chip used (Fig. 2) – 4, 8, 16, 32, 64, 128, 256, 512 GB, 1TB (at 232 multilayer technology) and more, read speed 10, 15, 16, 19, 40, 70, 75, 80, 90, 100, 130, 150, 200, 300, 333, 350, 370-380-390-400, 440, 625, 700-710-790, 1250 MB/s, 480 Mbps, 5Gbps and write speed 6, 7, 8, 10, 14, 18, 20, 25, 28, 30, 32, 35, 60, 80 MB/s. A USB drive's memory capacity can range from a few gigabytes to several terabytes, and the speed at which data can be transferred to and from the drive is influenced by a number of elements, including the type of memory chip used and the USB port's interface speed.

The memory controller and the memory chips themselves can be a limiting factor when it comes to overall performance. With a USB 2.0 flash drive, performance is limited and maximum speeds are around 40 MB/s. Accordingly, USB 3.0 flash drives can reach speeds of up to 625 MB/s, and USB 3.1 models up to 1250 MB/s. These speeds are theoretical and maximum, usually the real ones are lower, so for example a USB 3.1 flash drive has an average speed of 440 MB/s. In general, USB 3.0 and USB 3.1 flash drives are much more productive and faster than USB 2.0, which is already an old and slow interface. Depending on the components used, some flash drives even on USB 3.0 and USB 3.1 can reach speeds of up to 300MB/s, and sometimes even lower – up to 200MB/s and 100 MB/s for more than 64 GB of memory. There are also additional factors such as housing, availability of indicator light, dimensions and others. When choosing a flash drive, it is necessary to find an acceptable compromise between the mentioned factors and price according to its specific application.

A flash drive can be read any number of times, but writing to it is limited. The number of times data can be written to the memory chips in a USB drive before they begin to wear out is referred to as limited writing. Flash memory has a limited number of write cycles, which means it can only be written to so many times before the memory cells degrade and the data becomes unreliable. This is why USB drives have a limited lifespan, and it's critical to backup important data on a regular basis to avoid losing it. Depending on the type of memory cells used in the memory chips, it is able to withstand between 10,000 and 100,000 cycles during its lifetime.

The reason is that to perform a write, it is necessary to first erase the memory area, and the area can only withstand a limited number of erasures. Since erasing is done in whole sections, it is not possible to replace just one bit or byte without erasing the entire section (this limitation applies to the most popular type of flash memory - NAND). Most flash drives come reformatted with a FAT or FAT 32 file system. The versatility of this file system allows the flash drive to be accessible from almost any device that has a USB port. Some file systems are designed to spread the record over the entire memory, without crowding in a certain area a given part of the data (for example, directories); this extends the life of regular flash drives. Some flash drives have this functionality built into the controller itself. Additional components to flash drives are: bridge and test points, LEDs, write protect switch, blank space, USB connector cap, transport accessories, etc. Recently, there have been various varieties and individual design of the constructions such as card, key chain, pen, even car, etc.

In fig. 3. a basic construction of a USB flash memory is shown [8]:

1. USB connector - interfaces with the host computer;
2. USB storage and management controller - microcontroller with on-chip ROM and RAM;
3. Test points - used for loading code into the microcontroller;

4. Flash memory - used to store data;
5. Crystal oscillator - produces the clock signal and controls data output;
6. LED - indicates active data transfer;
7. Write protection switch (optional) - used to enable and disable writing of data;
8. Slot for second chip flash memory

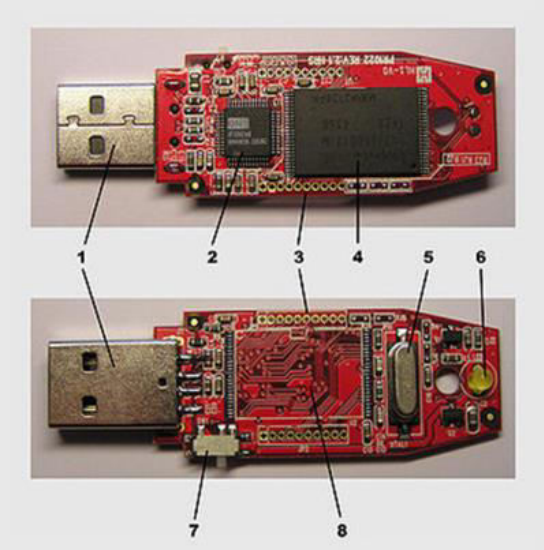

Figure 3. Flash memory construction

B. Technology

Flash memory initially combined some older technologies with low cost, low power consumption, and small size thanks to advances in microprocessor technology. The memory is based on the previous EPROM and EEPROM technologies [9]. They have very limited capacity, are very slow to read and write, require complex control circuitry and can only be rewritten after erasing the entire contents of the chip. Hardware designers later developed EEPROMs with an erasable region broken into smaller "fields" that could be erased individually without affecting the others. Changing the contents of a particular part of memory involves first copying the entire field into an off-chip buffer memory, erasing the field and then overwriting the information back into the same field, making the necessary change to that particular part of memory. This requires significant computer support and PC-based EEPROM flash memory systems often have their own microprocessor. Flash drives are a kind of miniature version of them. Subsequently, companies rely exclusively on multilayer technologies [9].

Flash drives with 2 TB memory appeared in 2018. Since 2019, the company Intel has introduced 114 multilayer, and SK Hynix - 96 layer 3D NAND with a trend towards 4D NAND technology; subsequently and Toshiba/Western Digital 128 multi-layer technology. In 2020, Samsung started the production of chips with 512 GB of UFS 3.1 flash memory, and in 2022, Micron started a new 232 multi-layer 3D NAND TLC flash memory technology, because the capacity of one of these chips reaches 1 Tb. During the Flash Memory Summit 2022 event, the Macronix company presented the FortiX Macronix flash memory, which, in addition to storing information, can perform calculations and primary data processing by including the specialized additional structure nvTCAM (non-volatile ternary content-addressable memory). Its IMS 3D NAND technology is also known. This could prove to be the beginning of a whole new computer architecture that is very different from the architecture of current classical computers.

C. Application

There are several advantages to using USB memory:

1. Portability: USB memory devices are small and lightweight, making them easy to carry around and use on the go. Protected from scratches and dust, mechanically very strong, easy to carry.
2. Large Storage Capacity: USB memory devices are available in a wide range of capacities, allowing for large amounts of data to be stored in a compact form factor.
3. High-Speed Data Transfer: USB memory devices are capable of transferring data quickly, making them ideal for backing up large amounts of data or transferring large files.
4. Wide Compatibility: USB memory devices are compatible with a wide range of devices, including computers, laptops, game consoles, and other electronics.
5. Easy to Use: USB memory devices are simple to use and do not require any special software or drivers to be installed on the computer.
6. Durable: USB memory devices are often more durable than traditional storage devices, such as hard drives, and are less likely to be damaged if dropped or bumped. Some flash drives retain their information after being immersed in water, and when the power is turned off or removed, the contents of the memory are preserved.
7. Affordable: USB memory devices are relatively inexpensive, making them an affordable solution for data storage and transfer.
8. Write-protected flash drives are suitable for repairing virus-infected computers without the risk of infecting the flash drive itself.

Overall, USB memory devices provide a convenient, portable, and affordable way to store and transfer data, making them an ideal choice for many different applications.

While USB memory devices have many advantages, there are also some disadvantages to using them:

1. Limited Lifespan: The memory chips in USB memory devices have a limited lifespan and can only be written to a certain number of times before they start to wear out. This means that data stored on a USB memory device may become unreliable over time.
2. Vulnerability to Data Loss: USB memory devices can be lost or damaged, resulting in data loss. This can be particularly problematic if important data is stored on the device and there is no backup.
3. Security Concerns: USB memory devices are susceptible to viruses and other forms of malware, which can compromise the security of the data stored on the device.
4. Slow Data Transfer Speeds: Depending on the type of USB memory device and the interface speed of the USB port, data transfer speeds may be slower than with other types of storage devices.
5. Limited Power Supply: Some USB memory devices require an external power source to operate, which can be inconvenient for some users.
6. Easy to lose: Because of their small size, they are easy to lose.

Overall, while USB memory devices offer many advantages, it's important to be aware of the potential disadvantages and take steps to minimize the risks associated with using them. This may include regularly backing up important data, using anti-virus software, and being careful about the types of data stored on the device.

In modern life, we can hardly imagine a number of activities without flash drives. They are used in the form of flash cards in portable battery-powered devices - digital cameras and camcorders, digital voice recorders, MP3 players, PDAs, car components and CD-cards, smartphones, artificial intelligence elements for voice recognition and various complex patterns, searching large data sets, searching for matches in DNA molecules in medical technology, voting machines and etc. In the form of USB, they are used to store and transfer information in computers. Embedded software in various network and peripheral devices (routers, printers, scanners) is also increasingly written to this type of memory. Flash drive is ‘’king’’ - more and more data centers are working with flash memory. Few people are interested in storage via "old-fashioned" hard drives anymore, especially after the directives to reduce electricity consumption. Leading manufacturers are SanDisk Ultra, Kingston Data, Hama Flash Pen, Transcend, Adata, Samsung, Philips, Adata, etc.

III. CONCLUSION

Flash memories have been a part of our lives since they first appeared on the market in the late 2000s. There are two main types of flash memory produced: NOR (NOT OR logic) and NAND (NOT AND logic). Their construction consists of basic and additional components. The production is based on the multi-layered technologies of micro-engineering. The most important factors when choosing a flash memory are write and read speed, memory volume, the type of port and of course the price. In the application, it is necessary to find an optimal option between them according to the specific activity. When buying a new USB flash drive, the user must first decide what the drive will be used for. If it is to be used to transfer personal or business financial documents, business proposals, presentations, or personal photographs, it is a good idea to use a device that has password protection. Development continues!

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