Flash RAM

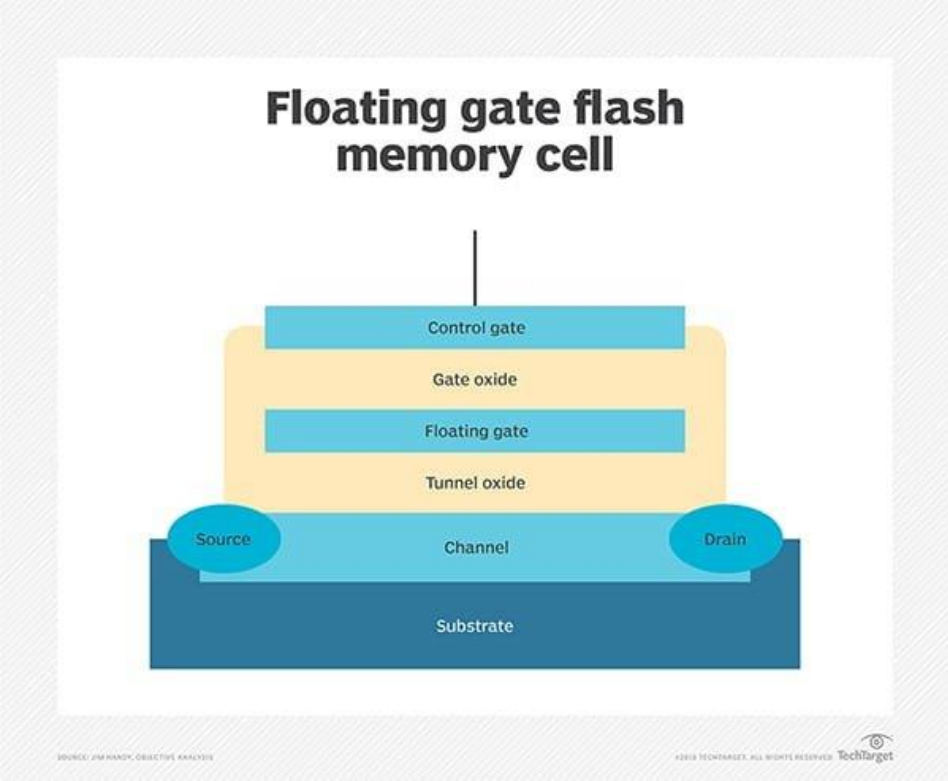
You have already seen that computers use RAM (Random Access Memory) to both write and read numbers, and ROM (Read Only Memory) to store and read numbers from, but not to write into.

RAMs can be dynamic or static RAMs, but both will have their contents erased whenever power is removed.

Some ROMs can be written into, like Programmable ROMs which can be written once by burning some connecting wires, Erasable PROMs, where contents can be erased using Ultraviolet light, or Electrically Erasable PROMs, which can be erased using a higher voltage.

Flash RAMs evolved from EEPROMs, and can be written into and erased. It works just like RAMs but can hold its contents even when electricity supply is removed.

A basic flash memory cell consists of a storage transistor with a control gate and a floating gate, which is insulated from the rest of the transistor by a thin oxide layer. The floating gate stores the electrical charge and controls the flow of the current.



Electrons can be forced through the thin oxide layer to the floating gate in the presence of a high electric field, with a strong negative charge on the cell's source and the drain and a strong positive charge on the control gate.

This allows easy flow of current in the p-doped channel between the source and the drain of the FET to represent the binary value ‘1’.

Data can be erased via a strong negative charge on the control gate. This forces electrons into the channel, where a strong positive charge exists. This removes most of the holes in the p-doped channel causing a big drop in conductivity. This represents a ‘0’.

Electrons trapped in the floating gate does not depend on whether the flash memory cell is receiving power because of electrical isolation created by the oxide layer. This means that flash memory can provide persistent storage.

A flash RAM can hold its contents for many years without the need for an electrical supply and hence can be used as a storage medium for computers.

NAND and NOR Flash RAMs

Flash RAMs can be divided into NOR and NAND flash memory. They differ in architecture and design characteristics.

NOR flash memory uses no shared components and can connect individual memory cells in parallel, enabling separate random access to all the data.

A NAND flash cell is more compact and has fewer bit lines, with the floating gate transistors strung together to increase storage density. NAND flash memory is better suited to serial rather than random data access.

NOR flash programs data at the byte level. NAND flash programs data in pages, which are larger than bytes, but smaller than blocks.

NOR flash is fast on data reads, but it is typically slower than NAND on erases and writes. NAND flash consumes less power than NOR flash for write-intensive applications. NOR flash memory is generally more expensive to produce.

Solid State Drive (SSD)

Flash-based media are based on a silicon substrate and therefore are known as solid-state devices. They are widely used in both consumer electronics and large data storage systems.

There are three SSD form factors widely used in personal computers:

- SSDs that fit into the same slots used by traditional hard disk drives (HDDs) and uses the standard HDD interfaces such as SATA or SCSI.
- Solid-state cards built on a printed circuit board and use a standard I/O interface, such as Peripheral Component Interconnect Express (PCIe).
- Solid-state modules that fit in a dual inline memory module (DIMM) or small outline dual inline memory module using a standard HDD interface, such as SATA.

An additional subcategory is a hybrid hard drive that combines a conventional HDD with a NAND flash module. The flash part provides very fast I/O while the HDD part can store a large amount of data.

The different form factors of SSDs are shown below.

2.5" SATA

mSATA

M.2

PCIe Add-In Card

All-flash SSD

SSDs offer advantages in performance and potentially reduced operational costs compared to disk-based storage devices. The chief difference, aside from the media, is in the underlying physical architecture used to write data to a storage device.

HDD-based drives have an actuator arm that enables data to be written to or read from a specific block on a specific sector on the platter. All-flash storage systems do not require moving parts to read or write data.

The ability to insert SSDs in x86-based personal computers and servers has increased the technology's popularity.

For individual users, SSDs cost more, and are generally used only on more expensive PCs. For companies, the drawback of placing flash in a server is that there is a need to build the hardware system internally, including the purchase and installation of a storage management software stack from a third-party vendor.

Pros and cons of flash memory

Here are some advantages of flash memory:

1. Flash is the least expensive form of semiconductor memory.
2. Unlike dynamic random access memory (DRAM) and static RAM (SRAM), flash memory is non-volatile, offers lower power consumption and can be erased in large blocks.
3. NOR flash offers increased random read speeds, while NAND flash is fast with serial reads and writes.
4. An SSD with NAND flash memory chips delivers significantly higher performance than traditional storage media, such as HDDs, compact discs and tape.
5. Flash drives are more reliable than HDDs as they have no moving parts.
6. Enterprise storage systems equipped with flash drives are capable of low latency, which is measured in microseconds or milliseconds.

The major disadvantages of flash memory are:

- SSDs are much more expensive compared to equivalent HDDs.
- Also, at the present, HDDs have a larger capacity. HDD of 12 TB can be obtained, but the largest SSD has a capacity of only 2 TB.
- The wear-out mechanism where memory cells can fail with excessively high numbers of program/erase cycles, which eventually break down the oxide layer that traps electrons.
- Once enough bits are lost, the whole drive can become inoperable.
- Unlike HDD where the magnetized patterns on the platters do not get destroyed when parts of the HDD break down, SSD memory cells become very difficult to read when random cells are destroyed.
- Thus, recovering data from spoilt HDD can be quite easily done, while data in an inoperable SSD is almost impossible to recover.

Thus manufacturers make sure that SSDs do not wear out without warning. They typically contain control circuitry that can be checked for possible breakdown.

Field Programmable Gate Array (FPGA)

FPGAs are solid-state devices that can be configured to have different functions. Unlike microcontrollers, which are fixed circuits that are controlled by a program to perform different functions, FPGAs can be programmed to become different digital circuits.

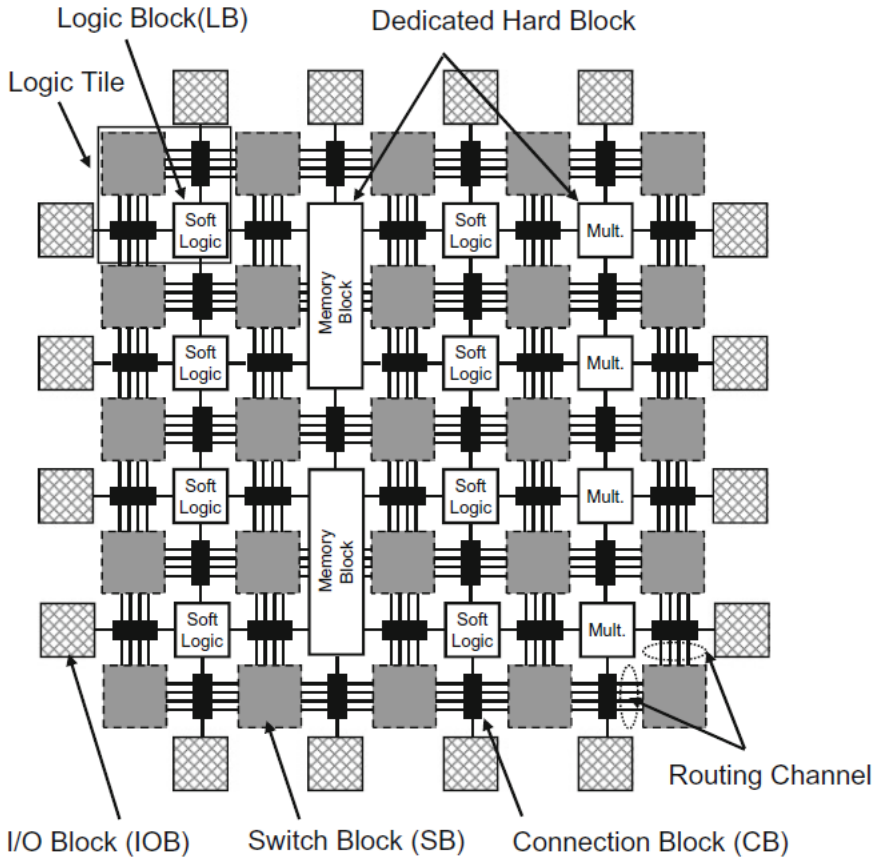
Just like a microcontroller, an FPGA can also be re-programmed to be another circuit that has a totally different function.

When prototyping a product, such as a microwave oven or a washing machine, engineers can write software for a microcontroller to control the functions of the system, or choose an FPGA and write a hardware description language (HDL) program to control the system.

For mass consumer products, it is cheaper to prototype using FPGA as the HDL program can be used to set up the mask to build an application specific integrated circuit (ASIC) chip which will be very cheap to produce.

FPGA Structure

A simplified diagram of an FPGA is shown below.



The I/O block allows the FPGA to be connected to the external world.

The soft logic block contains look-up table, multiplexers and shift registers. This allows any combinational or sequential circuits to be built using them.

The switch block, connection block and routing channel allow flexible connection of parts in the soft logic blocks, and between the different blocks.

The memory block and multiplier form the hard logic block in this illustration. In actual FPGAs, hard logic blocks may include communication blocks, digital signal processing blocks, or even a whole microprocessor.

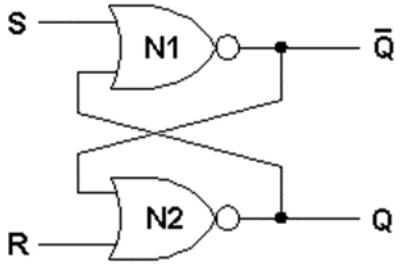
The HDL program sets up the connections between the different parts using flash ram to allow or block current from flowing between different parts.

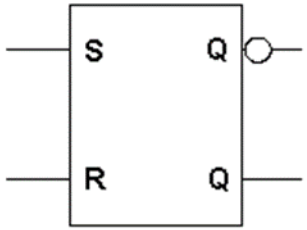
The links can be erased when needed, for example, during debugging, or when the project is finished and the FPGA can be used for another purpose.

Verilog

There are several HDLs, but the one most commonly used for teaching is Verilog. Unlike VHDL which is used in the industry, Verilog is a much simpler language to learn, and can perform almost all the functions that VHDL can do.

A simple structural description of an SR latch written in Verilog is given below.






```
module SRlatch(
    output Q, Q_bar,
    input  S, R);
    nor N1(Q_bar, S, Q);
    nor N2(Q, R, Q_bar);
endmodule
```

Structural description does not help the engineer to design the circuit, as the circuit diagram must be already available in order to write the Verilog program. The more powerful way to write the code is to use behavioural description of the circuit.

The Verilog code describing a D flip-flop is shown below.

```
module Dff(
    output reg Q,
    output Q_bar,
    input  D, clr, clk);
    wire Q_bar;

    assign Q_bar = ~Q;

    always @(negedge clr)
        Q = 1'b0;
    always @(posedge clk) begin
        if (clr != 0)
            Q <= D;
    end
endmodule
```