Advanced microprocessor systems
Microprocessor Evolution

First Transistor
Discrete Transistors

Bipolar

FET

N-channel FET
Planar Transistors

BJT

FET
1971

4004
2,300 transistors
10,000 nm

1972

8008
3,098 transistors
10,000 nm
1978
8086
29000 transistors
3000 nm

1985
80386
275000 transistors
1500 nm
1993

Pentium
3.1M transistors
800 nm

1995

Pentium Pro
5.5M transistors
500 nm
2006
Pentium D Presler
362M transistors
65 nm

2007
Core 2 Duo Wolfdale
411M transistors
45 nm
2011

- 8-core i7 Haswell
- 2.6B transistors
- 22 nm

2016

- 22 core Xeon Broadwell
- 7.2B transistors
- 14 nm
Microprocessor circuits on chip

Hi level Cross section
Advanced Microprocessor System Block Diagram

- Power
- Clock
- ROM/FLASH
- CPU
- RAM L1/L2/L3
- DDR1,2,3,4-SDRAM
- Hypertransport/PCI express

- Graphics
- Dual SLI
- PCI express

- Network Comm.
- 10/100bT/Gb/802.11
- Wireless, Ethernet, Optical

- Mass Storage
- SATA, RAID, DVD, Blu-ray

- I/O Control
- USB
- IEEE488
- Bluetooth

- A/V
- 3D sound, Joystick,

- Peripherals
- Keyboard, Mouse, scanner, USB

Up to 1KW, water cooling
1.8 – 3.8 GHz
CPU Advancement Mechanisms:

1) Advances in *processor architecture*:

   RISC
   Pipelining
   Superscalar
   Out-of-order execution
RISC - a system that uses a small, highly-optimized set of instructions that typically execute in one clock cycle, rather than a more specialized set of instructions that may require several clock cycles. There are many traits associated with RISC. For example, most machines are implemented with multiple internal buses similar to a Harvard architecture. Another common trait is that RISC systems use the load/store architecture, where memory is normally accessed only through specific instructions, rather than accessed as part of other instructions like an add.
Pipelining - a technique used in the design of computers to increase their instruction throughput. Rather than processing each instruction sequentially, each instruction is split up into a sequence of steps which are executed within a small offset from one another. Thus, different steps can be executed concurrently (by different circuitry), and almost in parallel.
Superscalar - a form of parallelism called instruction-level parallelism within a single processor. A CPU executes more than one instruction during a clock cycle by simultaneously dispatching multiple instructions to redundant functional units on the processor.
**Out-of-order execution** – A CPU technique involving:

- fetching instructions in a compiler-generated order
- The instructions are dynamically scheduled
- In between they may be executed in some other order
- Independent instructions behind a stalled instruction can pass it
- Instructions are reshuffled back into the correct order for writeback stage
CPU Advancement Mechanisms:

2) Advances in *processor manufacturing*:
   Lithography processes:
   
   - Optical
   - e-beam
   - X-ray
   - Extreme UV
Optical Lithography - a photograhic process used to pattern parts of a semiconductor film or the material of a substrate. It uses light to transfer a geometric pattern from a photomask to a light-sensitive chemical "photoresist", on the substrate. A series of chemical treatments then either engraves the exposure pattern, or enables deposition of a new material in the desired pattern.
**e-beam Lithography** - is the practice of scanning a focused beam of electrons to draw custom shapes on a surface covered with an electron sensitive film called a resist. The purpose, as with photolithography, is to create very small structures in the resist that can subsequently be transferred to the substrate material, often by etching. Using this technique, sub 10nm structures can be created.
X-ray Lithography - uses X-rays to transfer a geometric pattern from a mask to a light-sensitive chemical photoresist on a substrate. A series of chemical treatments then engraves the produced pattern into the material underneath the photoresist. Using this technique, sub 1nm structures can be created.
**Extreme UV Lithography** - a next-generation lithography technology using an extreme ultraviolet (EUV) wavelength, currently expected to be around 13.5 nm. Using this technique, sub 20nm structures can be fabricated.
CPU Advancement Mechanisms:

3) Advances in *processor implementations*:

- Semiconductor computing
- Optical computing
- Molecular computing
- Quantum computing
**Semiconductor computing** - Silicon is only one out of many different semiconductor materials. A combination of the elements gallium and arsenic forms crystals which permit electrons to move faster than in silicon, so that this material is sometimes used when extreme speed is important. The main reason that silicon is used in computers is because it is easier, and therefore less expensive, to make complicated circuits out of silicon than for any other material. Computer circuits also require some parts to be made out of insulators in addition to the parts that are semi conducting. With silicon, it is easy to make a good insulator by adding some oxygen to produce silicon oxide. The average cost is now much less than one penny per 10,000 transistors.
Optical computing - uses photons produced by lasers or diodes for computation. Photons promise to allow a higher bandwidth than the electrons used in conventional computers. Photonic logic is the use of photons (light) in logic gates (NOT, AND, OR, NAND, NOR, XOR, XNOR). Switching is obtained using nonlinear optical effects when two or more signals are combined.
**Molecular computing** - a form of computing which uses DNA*, biochemistry and molecular biology, instead of the traditional silicon-based computer technologies. It is in its infancy and is currently the subject of research.

* A bioengineer and geneticist at Harvard’s Wyss Institute have successfully stored 5.5 petabits of data — around 700 terabytes — in a single gram of DNA, smashing the previous DNA data density record by a thousand times.
**Quantum computing** - a computation device that makes direct use of quantum-mechanical phenomena, such as superposition and entanglement, to perform operations on data. Quantum computing is still in its infancy but experiments have been carried out in which quantum computational operations were executed on a very small number of qubits. Both practical and theoretical research continues to develop quantum computers for both civilian and national security purposes, such as cryptanalysis.
Advanced Microprocessor System Block Diagram

Color key:
Red = processor
Black = I/O
Lt. gray = single chip
Dark gray = contained on chip
Stacked memory package-on-package (POP) device

The OMAP4430 die uses flip-chip technology. The OMAP4430 package-on-page (POP) device supports memory stacking using a POP implementation. The OMAP4430 die provides two LPDDR2 interfaces. Each interface supports up to two chip-selects, so up to four LPDDR2 memory dies are supported. Those interfaces are available only on device top ball out.

The two stacked memory packages are directly connected to the two LPDDR2 EMIF4D interfaces of the OMAP4430 die.

Figure 1-3 shows the concept of the POP solution, and Figure 1-4 shows stacked memory package on the POP device.

Two types of LPDDR-SDRAM memories are supported in POP package: S4 and S2 with size up to 2GB and 32-bit data width.

The POP device includes feedthroughs. The feedthroughs are defined from the bottom ball-grid array (BGA) to the stacked memories. The purpose of some of the feedthroughs is to provide power supply to the stacked memories.

OMAP4430 Processor

Highlights:
- 1GHz Dual-Core ARM Cortex-A9 MPCore
- 1080p Video
- 3D Graphics Accelerator
- Memory: 1GB Low Power DDR2 RAM

Status LEDs
SD/MMC Card Slot
Serial /RS-232
Camera Connector
USB 2.0 OTG
Audio in/out
Power Supply 5V
Power/Reset Buttons
JTAG
WLAN/Bluetooth
Expansion Connector
LCD Expansion
DVI Out
HDMI Out (Type A)
10/100 Ethernet & 2xUSB 2.0 Host ports

Board Dimensions: W:4.0" (101.6 mm) X H: 4.5" (114.3 mm)
Intel® Atom™ x5 and x7 Processor Platform Block Diagram

Quad Core 14nm
1.6 GHz Base Frequency
2.4 GHz Burst Frequency
Figure 4. STM32F437xx and STM32F439xx block diagram