ELE 414 Microprocessors
Section 21 & 22

Syllabus

Hacettepe University

Department of Electrical and Electronics Engineering

ELE 414 Microprocessor and Programming II
Spring 2003 2004 All sections

WEDNESDAY 09:10-12:00
Instructor: Asst.Prof. Dr. Ali Ziya Alkar
Office Hours: TBDe-mail: alkar@hacettepe.edu.tr

Prerequisite: In order to take this course you should have taken the prerequisite course ELE 413 in the first semester and have done well. Here 'well' is very subjective so if you are not sure then you need to talk to me!.

<u>TextBooks:</u>

Brey, The Intel Microprocessors, Prentice Hall, 5thEdition.

Gaonkar, Microprocessor Architecture Programming and Apps /Prentice Hall. Besides the other aspects of the 8085 programming we will talk about the programmable 8085 peripherals and data transfer.

<u>Useful Books:</u>

M. A. Mazidi &. G. Mazidi,"The 80x86 IBM PC and Compatible Computers", Prentice Hall,2000.

Antonakos, An Introduction to the Intel Family of Microprocessors, Prentice Hall, 1999

K.R. Irvine, Assembly Language for Intel Based Computers, Prentice Hall,1999.

W. A. Triebel and A. Singh, The 8088and 8086 Microprocessors: Programming, Interfacing, Software, Hardware and Applications” Prentice Hall, 2000

Flynn, Computer Architecture Pipelined and Parallel Processor Design

Computer Architecture and Logic Design, Thomas Bartee, McGraw Hill

and in combination with other computer architecture books available.

Syllabus

LAB for the course

Essential Programs for the course: The DEBUG command on DOS. MASM Assembler, CODEVIEW and emu8086v103.zip.

See lab page for more information

Grading: Midterm %30, Final %35,Homework %5, Lab-Works %30

Attempts of cheating in Homeworks and Lab-Works will NOT be tolerated. No exceptions.

Attendance: Required in ALL course hours and ALL LAB hours

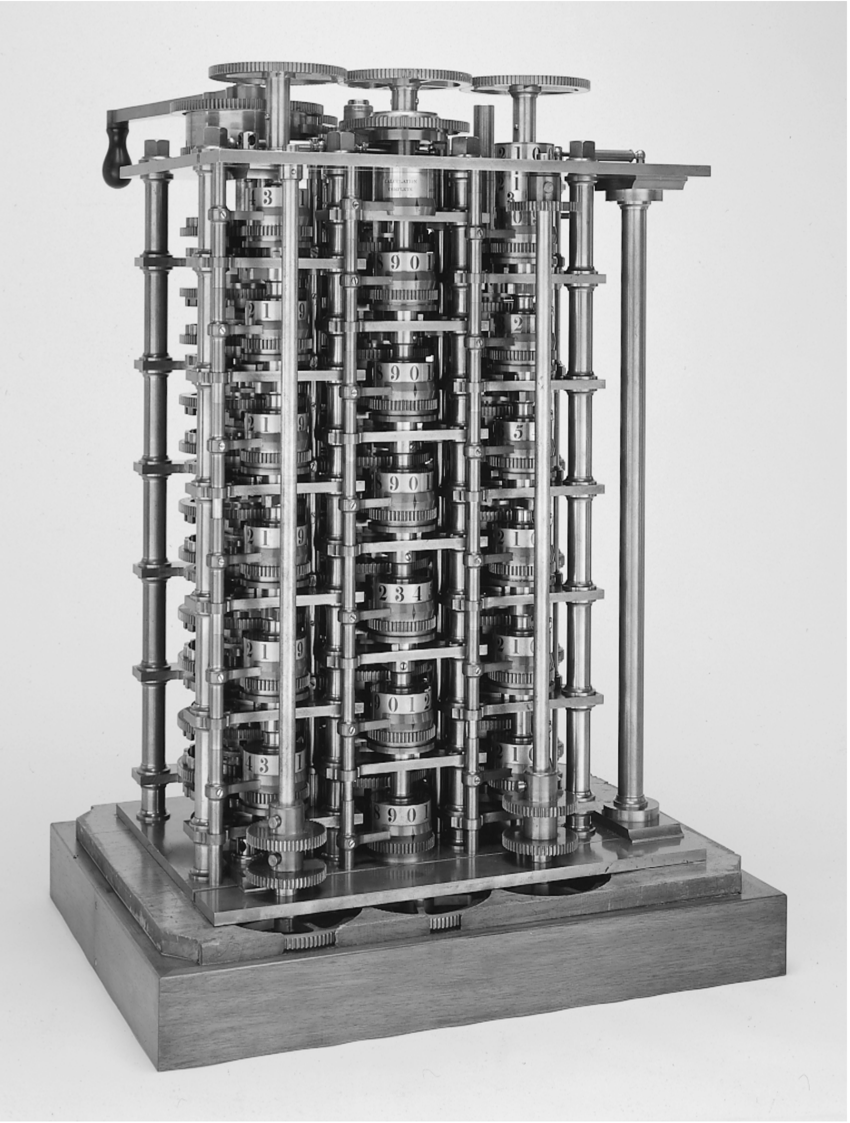
WEEKS
1. Introduction to Microcomputers and Microprocessors, 80x86 Processor Architecture
2. 80x86 Processor Architecture
3. 8088/8086 Instruction Set, Machine Codes, Addressing Modes, Debug
4. 8088/8086 Microprocessor Programming
5. 8088/8086 Microprocessor Programming
6. The 8088 and 8086 Microprocessors and Their Memory and Input/Output Interfaces, ISA Bus
7. Memory and Memory Interfacing
8. Input/Output Interface Circuits and Peripheral Devices 8255 MIDTERM WEEK

9. Input/Output Interface Circuits and Peripheral Devices 8255
10. 8254 + Interrupt Interface of the 8088 and 8086 Microprocessors
11. Programmable Interrupt Controller (8259)
12. An Introduction to PIC microcontrollers
13. Serial Data Communication and 16450/8250/8251 chips
14. Co-processors and programming

Week 1

Introduction to Microcomputers and Microprocessors, Computer Codes, Programming, and Operating Systems

First Computer



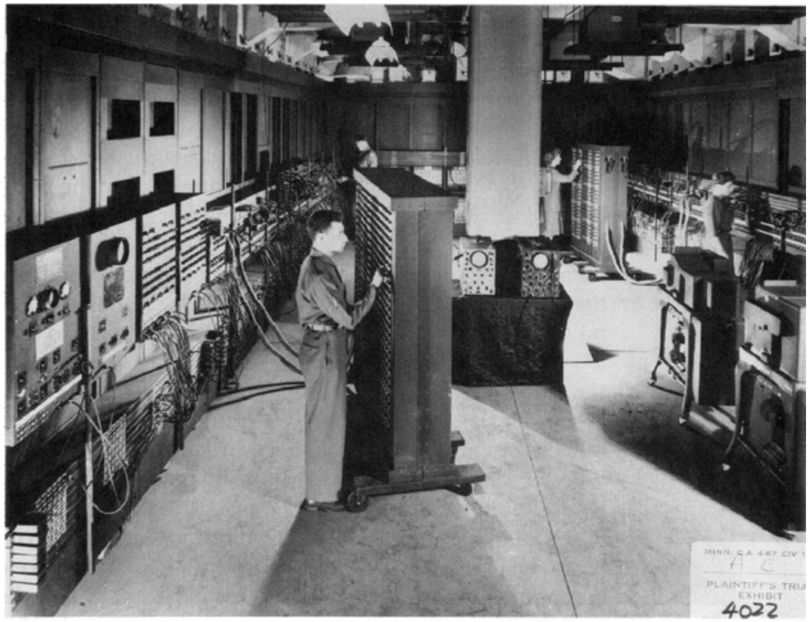
- It all started with the 1832 Babbage mechanical machine to calculate the navigation tables for the Royal Army, U.K.

The Babbage Difference Engine (1832)

25,000 parts

cost: £17,470

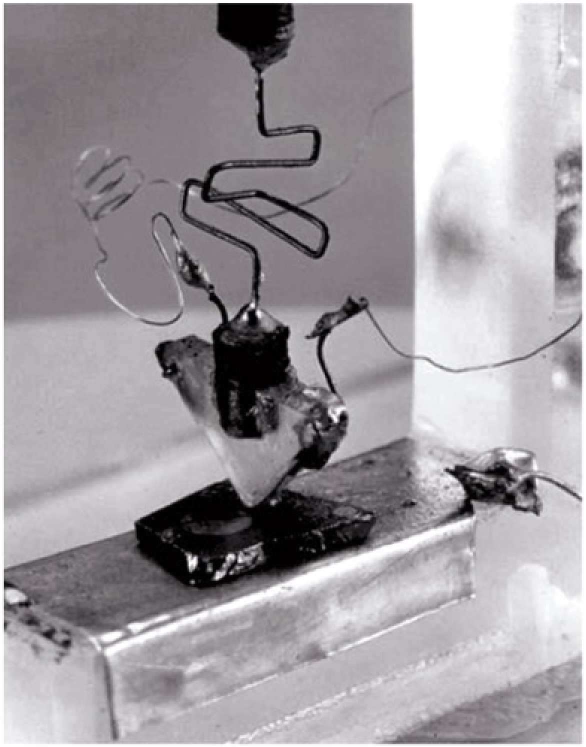
ENIAC



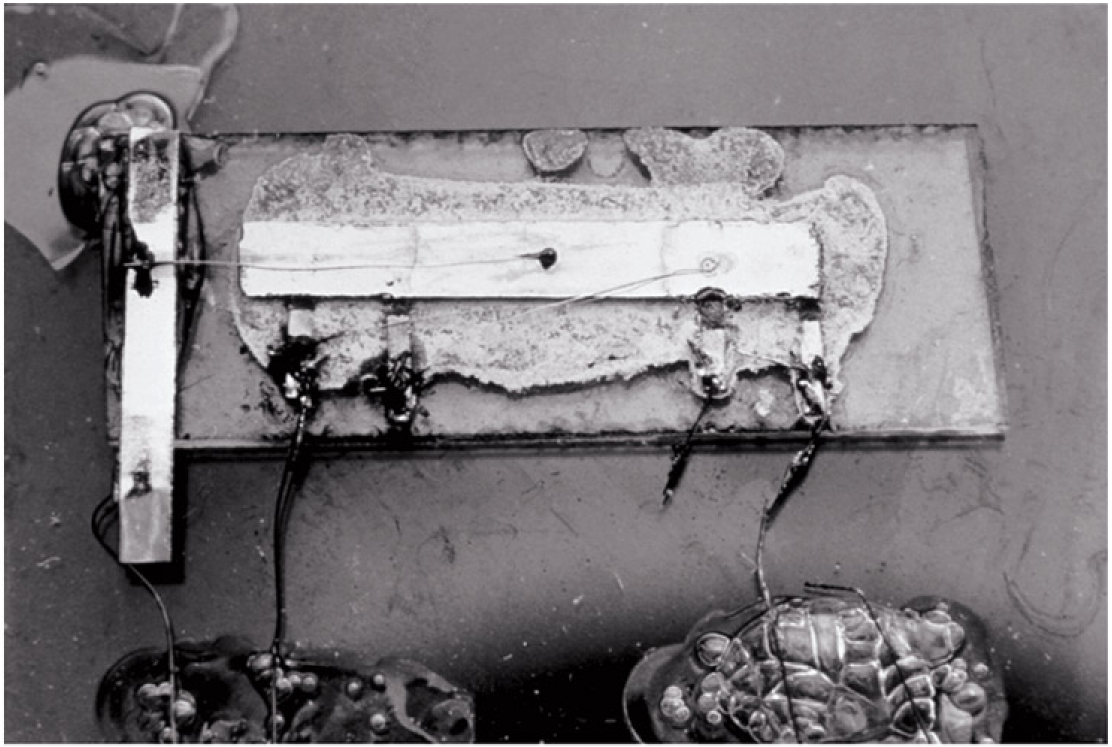
- Vacuum tube based
- “BIG BRAIN”
- ENIAC
  - 1,800 sq. Feet area
  - 30 ton
  - 18000 vacuum tubes
- Application: IInd WW

1943 First electronic computer is used to decode the German Army secret codes, coded by the Enigma machine: Colossus,
1946 First General Purpose computer: ENIAC 17000 vacuum tubes, 500 miles of wire 30 tons, 100 000 ops per sec.@ U.of Penn

First Transistor



(a)

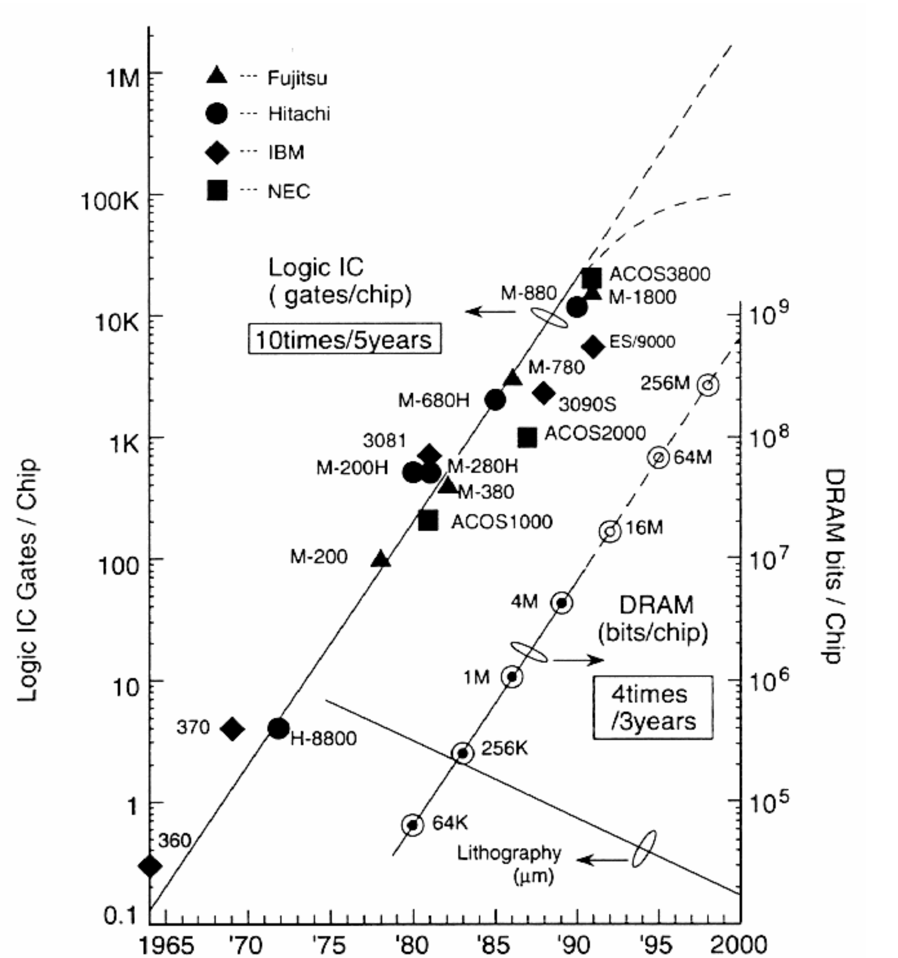


(b)

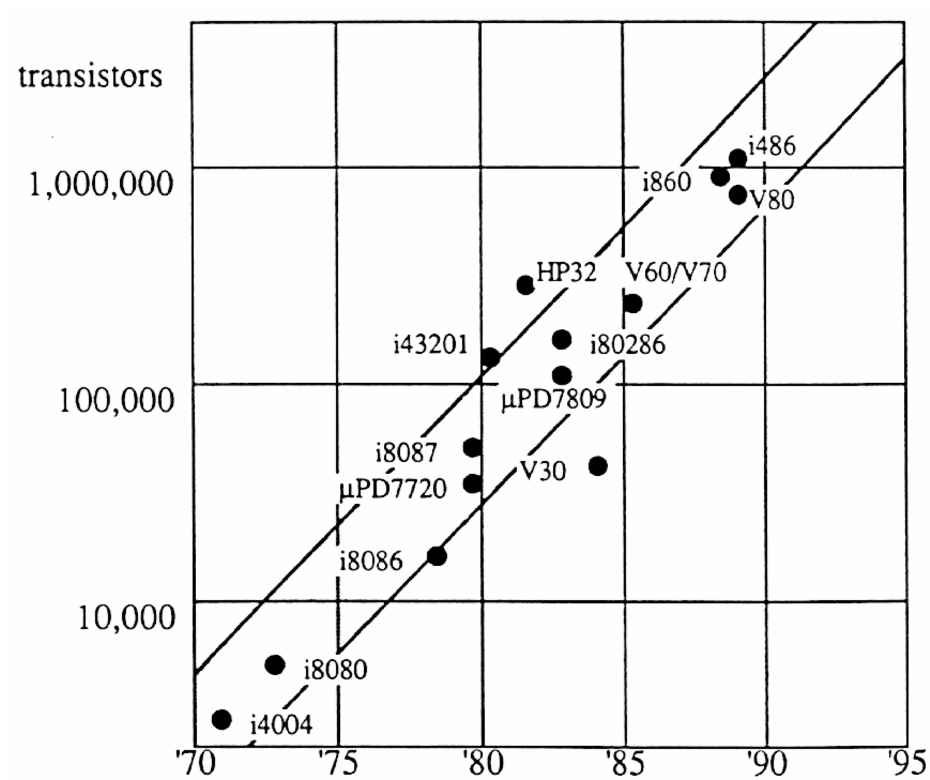
FIG 1.2 (a) First transistor (Courtesy of Texas Instruments.) and (b) first integrated circuit. (Property of AT&T Archives. Reprinted with permission of AT&T.)

Bell Labs 1946

Change over the years

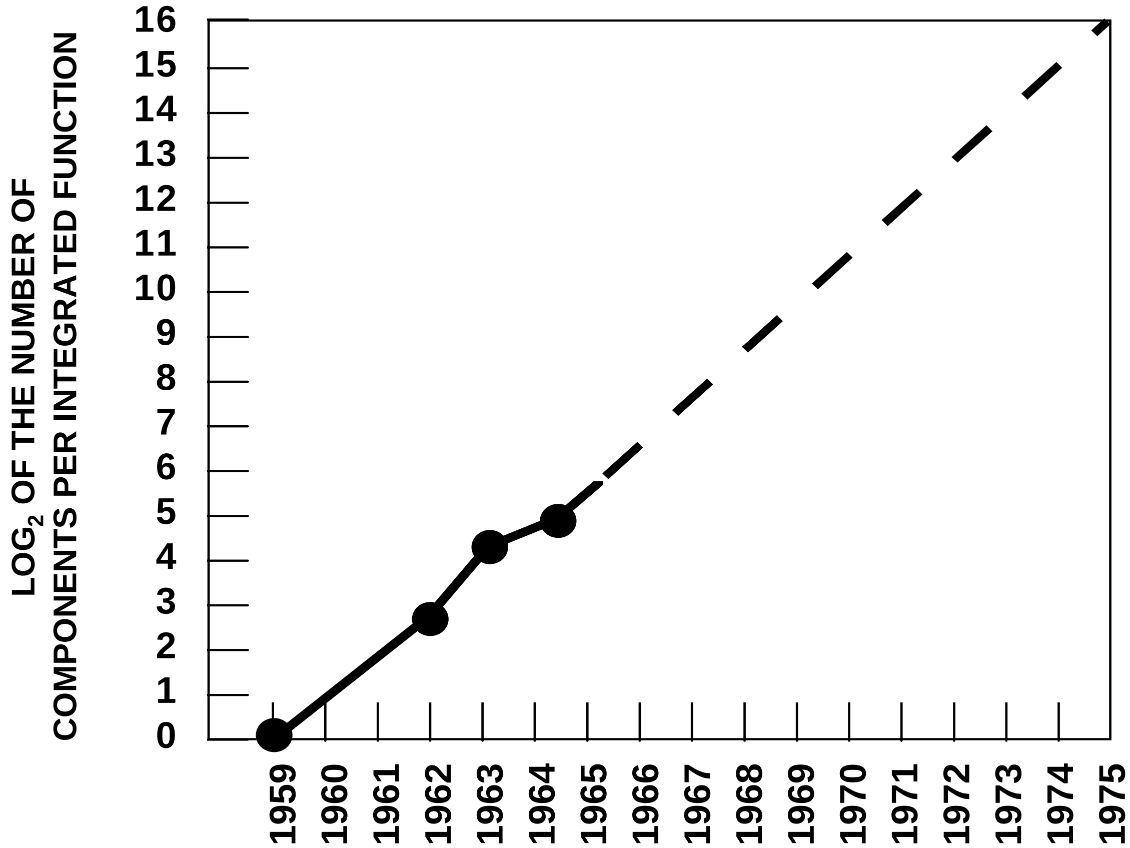


Change in Complexity



Change in Transistors

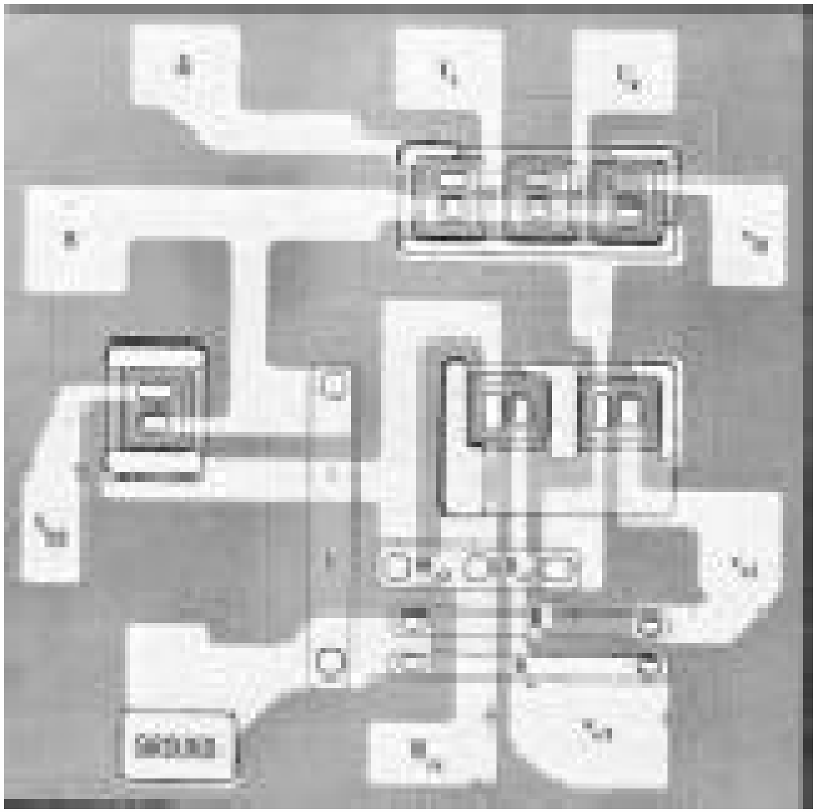
Moore's Law



Intel's Founder Gordon Moore 19 April 1965, Electronics

First IC

- 1958 Invention of the IC by Jack Kilby at Texas Instruments



Bipolar logic
1960's

ECL 3-input Gate
Motorola 1966

A brief history

- First microprocessor at Intel in 1971--- 4004
- Intel 4004 was a 4 bit up. Only 45 instructions P Channel Mosfet technology. 50 K instructions per second (< ENIAC!).
- Later 8008 as an 8 bit µ processor then 8080 and Motorolla 6800.
- 8080 was 10x faster than 8008 and TTL compatible (easy interfacing)
- MITS Altair 8800 1974. The BASIC Interpreter was written by Bill Gates. Assembler program was written by Digital Research Corporation (Author comp. Of Dr-DOS)
- 1977 8085 microprocessor. Internal clock generator, higher frequency at reduced cost and integration. There are 200 million 8085's around the world!
- 1978 8086+8088 microprocessors 16 bit. Addressed 1 Mbyte of memory. Small instruction cache (4-6 bytes) enabled prefetch of instructions.
- IBM decided to use 8088 in PC.

A brief history

- In 1983 80286 released, identical to 8086 except the addressing and higher clock speed.
- 32 bit microprocessor era. In 1986 major overhaul on 80286 architecture → 80386 DX with 32bit data + 32 bit address (4 G bytes)
- 1989 80486 = 80386 +80387co processor + 8KB cache
- 1993 Pentium (80586). Includes 2 execution engines.
- Pentium Pro included 256K Level 2 cache mechanism as well as Level 1 cache. Also 3 execution engines which can execute at the same time and can conflict and still execute in parallel. The address bus was expended to 36.
- Pentium 2 included L2 cache on its circuit board (called slot)
- Later Pentium 3 and 4 released with several architectural and technological innovations.

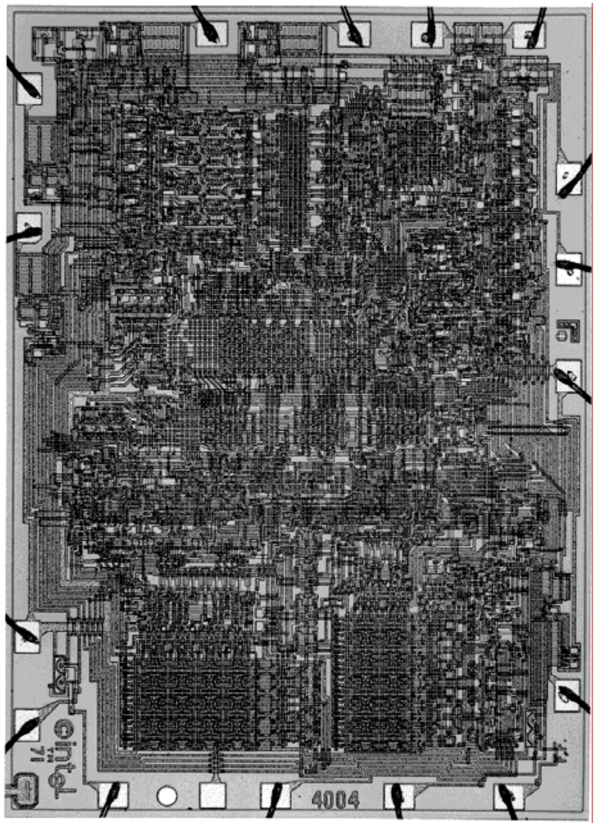
Evolution of Intel Microprocessors

Processor	Codename	Year Introduced	Transistors	Minimum Feature Size (microns)	Package	Socket or Slot	Core/Bus Frequency (Max)[1]	External Data Bus Width	Internal Register Widths	Address Bus Width	NDP[2]	L1 Cache	L2 Cac
4004		1971	2,250	10.0	16 pin DIP		.108 MHz	4	8	12	none	none	noı
8008		1972	3,500	10.0	18 pin DIP		.200 MHz	8	8	14	none	none	noı
8080		1974	6,000	6.0	40 pin DIP		3 MHz	8	8	16	none	none	noı
8085[3]		1976	6,000	6.0	40 pin DIP		6 MHz	8	8	16	none	none	noı
8086		1978	29,000	3.0	40 pin DIP		10 MHz	16	16	20	external	none	noı
8088		1979	29,000	3.0	40 pin DIP		10 MHz	8	16	20	external	none	noı
80286		1982	134,000	1.5	68 pin PLCC or PGA[4]		12.5 MHz	16	16	24	external	none	noı
80386DX		1985	275,000	1.0	132 pin PGA or QFP[5]		33 MHz	32	32	32	external	none	exter
80386SX		1988	275,000	1.0	100 pin PQFP[7]		33 MHz	16	32	24	external	none	exteı
80486DX		1989	1.2 million	0.8	168 pin PGA	Socket 3	50 MHz	32	32	32	on-chip	8 KB	exte
80486SX		1991	1.185 million	1.0	196 lead PQFP or 168 pin PGA	Socket 3	33 MHz	32	32	32	none	8 KB	exte
80486DX2		1992	1.2 million	0.6	168 pin PGA	Socket 3	66/33 MHz	32	32	32	on-chip	8 KB	exte
80486DX4		1994	1.2 million	0.6	168 pin PGA	Socket 3	100/ 33 MHz	32	32	32	on-chip	8 KB	exte
Pentium Classic	P5	1993	3.1 million	0.8	273 pin PGA	Socket 4, 5	66 MHz	64	32	32	on-chip	8/8 KB C/D[8]	exte
Pentium Classic	P54	1994	3.3 million	0.35, 0.5	296 pin PGA	Socket 7	200/66 MHz	64	32	32	on-chip	8/8 KB C/D	exte
Pentium MMX	P55	1997	4.5 million	0.25, 0.28	296 pin PGA	Socket 7	300/66 MHz	64	32	32	on-chip	16/16 KB C/D	exte
Pentium Pro	P6	1995	5.5 million[9]	0.35, 0.5	387 pin dual cavity PGA or PPGA[10]	Socket 8	200/66 MHz	64	32	36	on-chip	8/8 KB C/D	256/ 1M

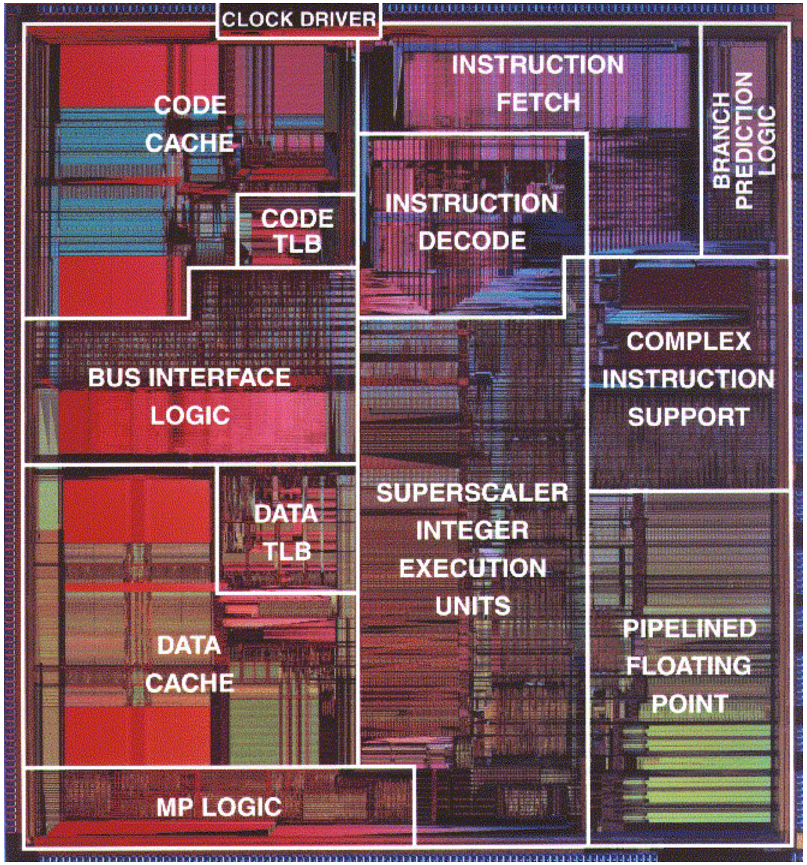
Pentium II	(Klamath) Deschutes[12]	(1997) 1998	7.5 million	(0.28), (0.25)	242 contact SEC cartridge	Slot 1	(233/66 MHz) 450/100 MHz	64	32	36	on-chip	16/16 KB C/D	512 KB[13]
Celeron	(Covington) Mendocino[14]	1998	(7.5 million) 19 million[15]	0.25	(242 contact SEP cartridge)	Slot 1	(300/66 MHz)						
					370 pin PPGA	Socket 370	466/66 MHz	64	32	36	on-chip	16/16 KB C/D	(external) 128 KB[16]
Pentium III	Katmai	1999	9.5 million	0.25	242 contact SEC cartridge	Slot 1	550/100 MHz	64	32	36	on-chip	16/16 KB C/D	512 KB[17]
					330 contact SEC cartridge	Slot 2							
	Coppermine	1999		0.18	370 pin PGA	Socket 370	733/133 MHz						256 KB[18]
Itanium[19]	Merced	2000		0.18			6XX/133 MHz	128	64	64	on-chip		256 KB[20]

[1]It is likely that higher frequency versions of the newer processors will be offered in the future.
[2]Numeric data processor (also called coprocessor or floating point unit).
[3]Improved 8080 with three new instructions to enable/disable three added interrupt pins. Simplified hardware with single +5 V power supply and on-board clock generator.
[4]Plastic leaded chip carrier or pin grid array.
[5]Quad flat package (QFP).
[6]Some 386 computers (and nearly all later processors) incorporated external L2 caches.
[7]Plastic quad flat package.
[8]Separate code and data caches are supplied
[9]On-board 256 KB L2 cache (separate silicon die) has 15.5 million transistors (31 million for 512 KB cache). 1 MB cache has two separate 512 KB die.
[10]Plastic pin grid array
[11]Separate die in package. Cache operates at core speed.
[12]Specifications for Klamath processor are shown in parentheses.
[13]Separate die in SEC package. Cache operates at one-half core speed.
[14]Specifications for the Covington processor are shown in parentheses. The Mendocino processor is also called Celeron A.
[15]Includes integrated 128 KB L2 cache.
[16]128 KB cache is on the same die with the processor and operates at the core frequency of the processor.
[17]Separate die operating at 0.5 times core speed (slot 1) or integrated with the processor operating at core speed (slot 2).
[18]Integrated with the processor and operating at core speed. Includes 256-bit (vs. 64 bit on previous chips) processor–cache data bus.
[19]Specifications for this processor have not yet been finalized by Intel.
[20]Integrated with the processor die and operating at full core speed.

Old and New



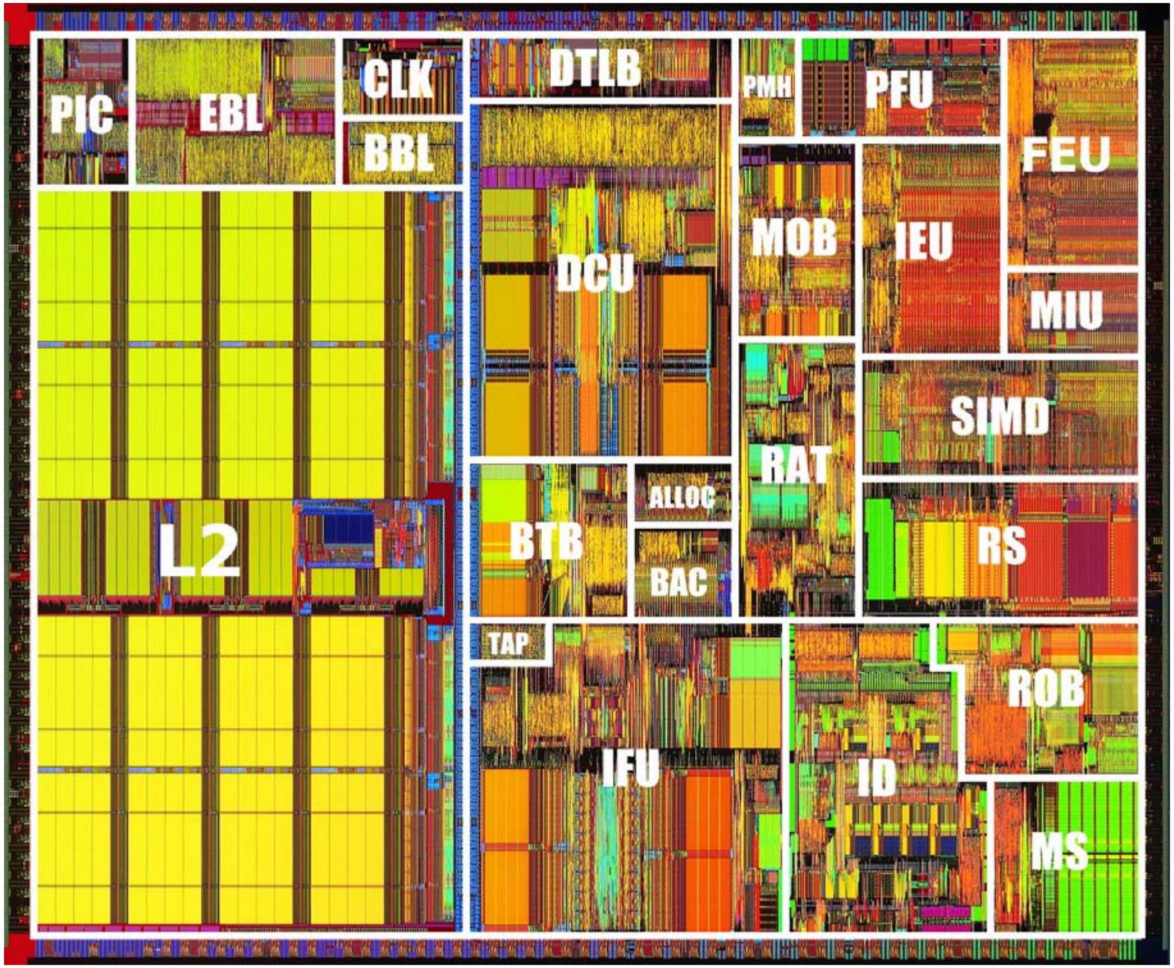
Intel 4004 Microprocessor



Intel Pentium Microprocessor

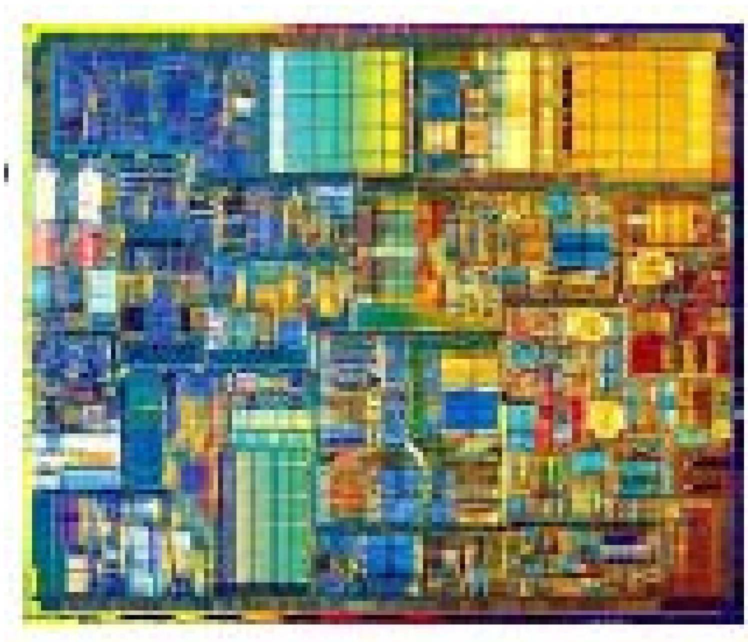
[Adapted from *http://infopad.eecs.berkeley.edu/~icdesign/. Copyright 1996 UCB]*

Pentium III



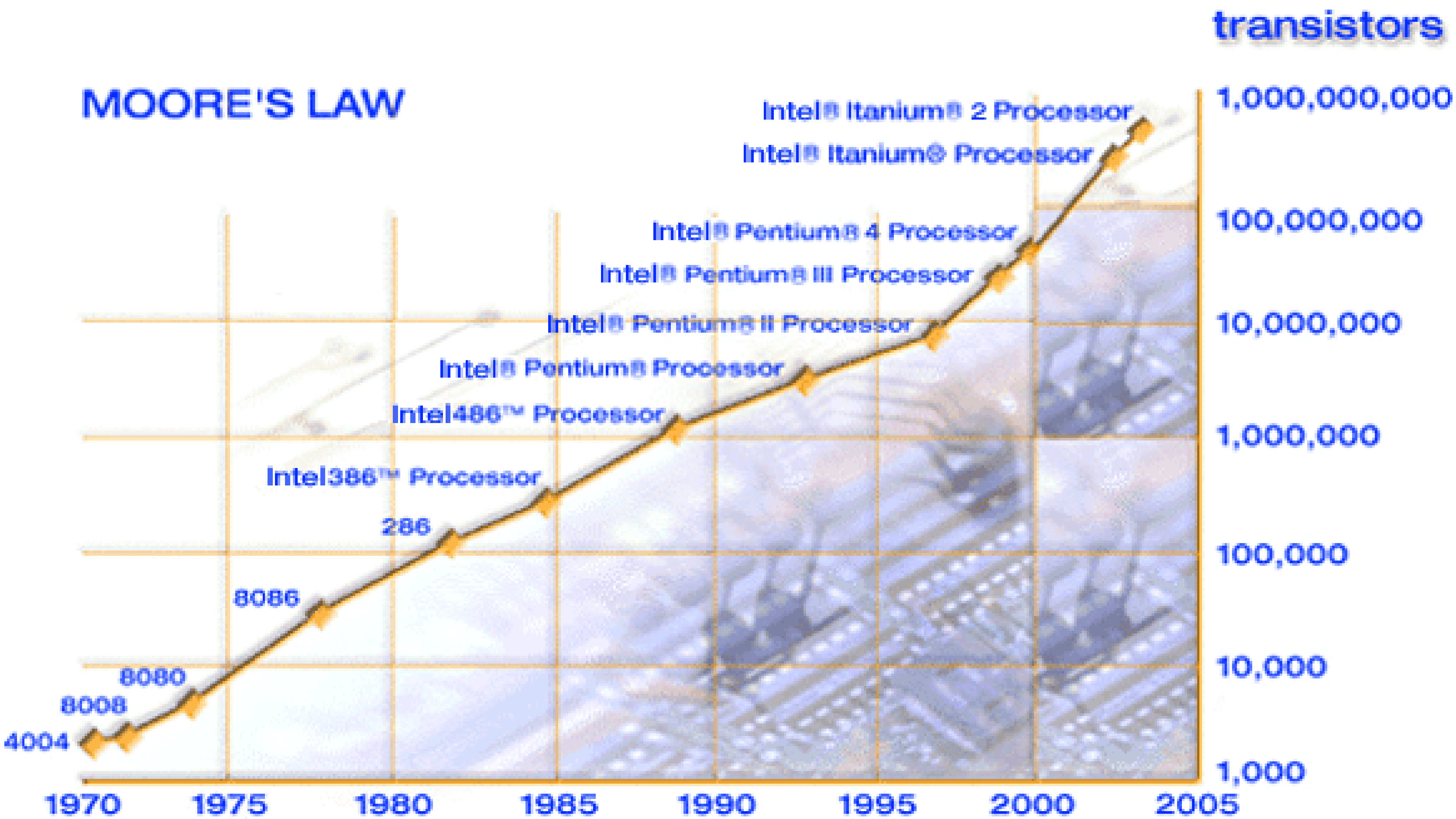
- Info
  - 28.1M transistors
  - 0.18 micron, 6-layer metal CMOS
  - 106 mm^2 die area
  - 3-way superscalar, 256K L2 cache, 133 MHz I/O bus

Pentium IV

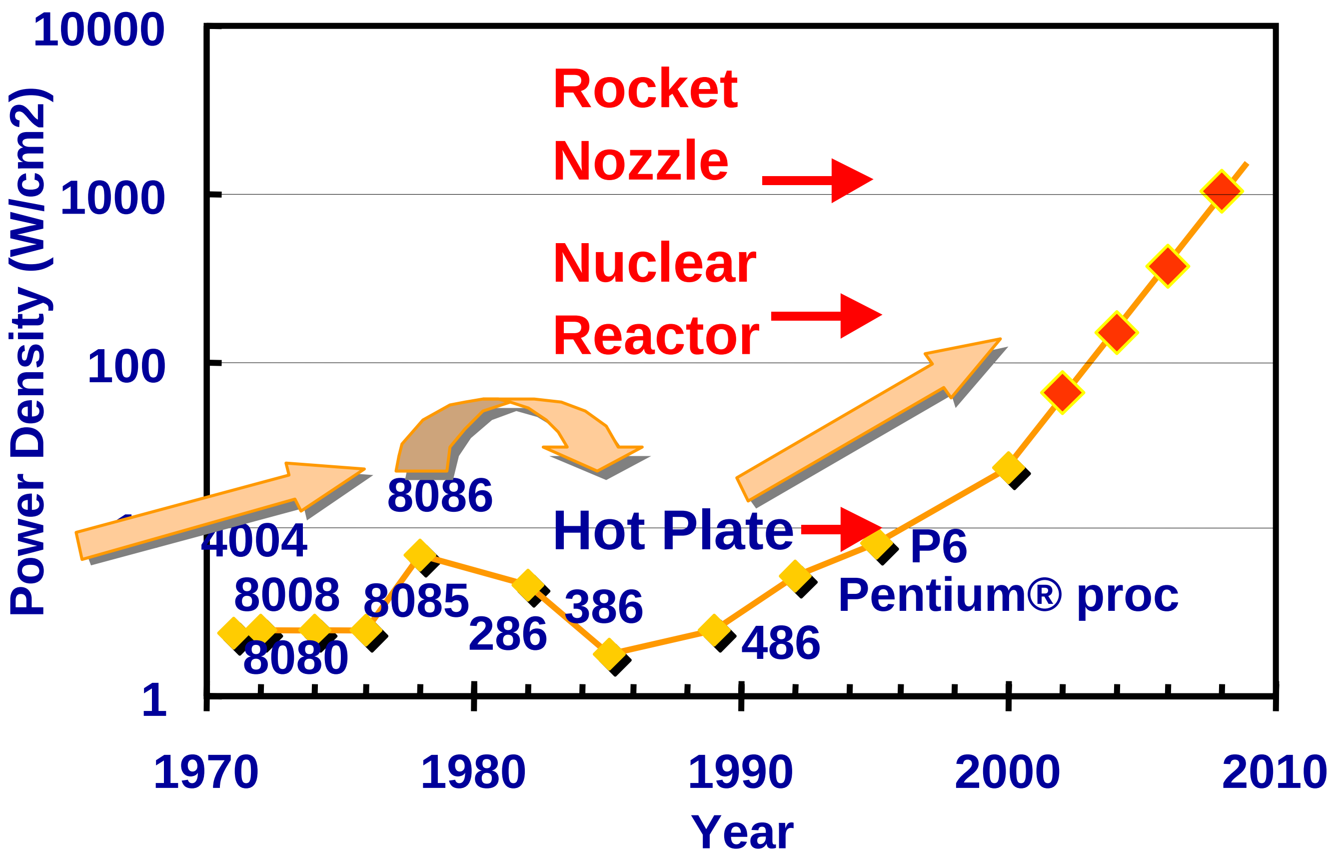


- **0.18-micron process technology (2, 1.9, 1.8, 1.7, 1.6, 1.5, and 1.4 GHz)**
  – Introduction date: August 27, 2001 (2, 1.9 GHz); ...; November 20, 2000 (1.5, 1.4 GHz)
  – Level Two cache: 256 KB Advanced Transfer Cache (Integrated)
  – System Bus Speed: 400 MHz
  – SSE2 SIMD Extensions
  – Transistors: 42 Million
  – Typical Use: Desktops and entrylevel workstations
- **0.13-micron process technology (2.53, 2.2, 2 GHz)**
  – Introduction date: January 7, 2002
  – Level Two cache: 512 KB Advanced
  – Transistors: 55 Million

Change in Microprocessors



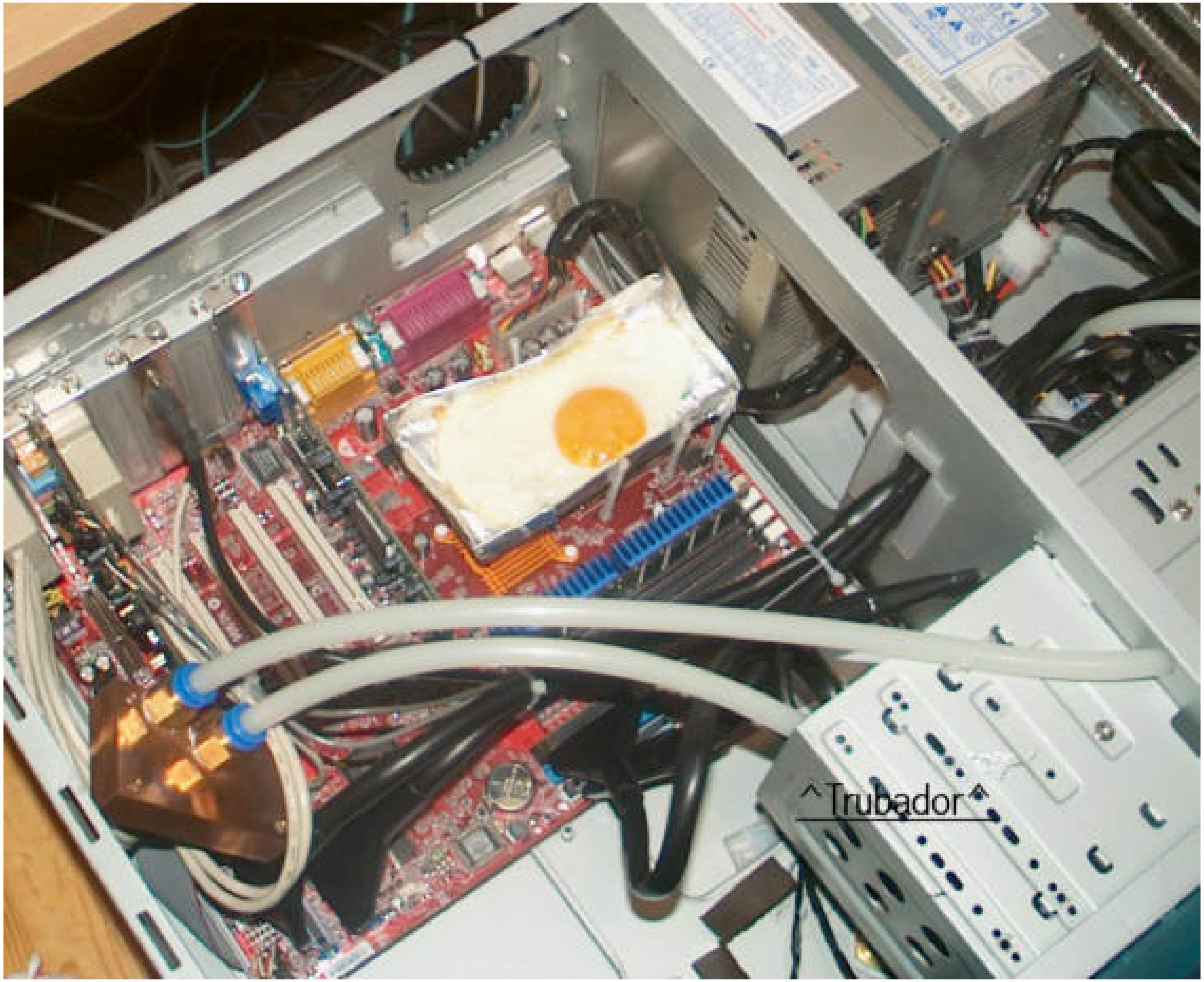
Power Density



Courtesy, Intel

Power Density increase

Power Density



Evolution in terms of Technology

Year	1947	1950	1961	1966	1971	1980	1990	2000
Technology	*Invention of the transistor*	*Discrete components*	*SSI*	*MSI*	*LSI*	*VLSI*	*ULSI**	*GSI†*
Approximate numbers of transistors per chip in commercial products	1	1	10	100–1000	1000–20,000	20,000–1,000,000	1,000,000–10,000,000	>10,000,000
Typical products	—	Junction Transistor and diode	Planar devices Logic gates Flip-flops	Counters Multiplexers Adders	8 bit micro-processors ROM RAM	16 and 32 bit micro-processors Sophisticated peripherals GHM Dram	Special processors, Virtual reality machines, smart sensors	

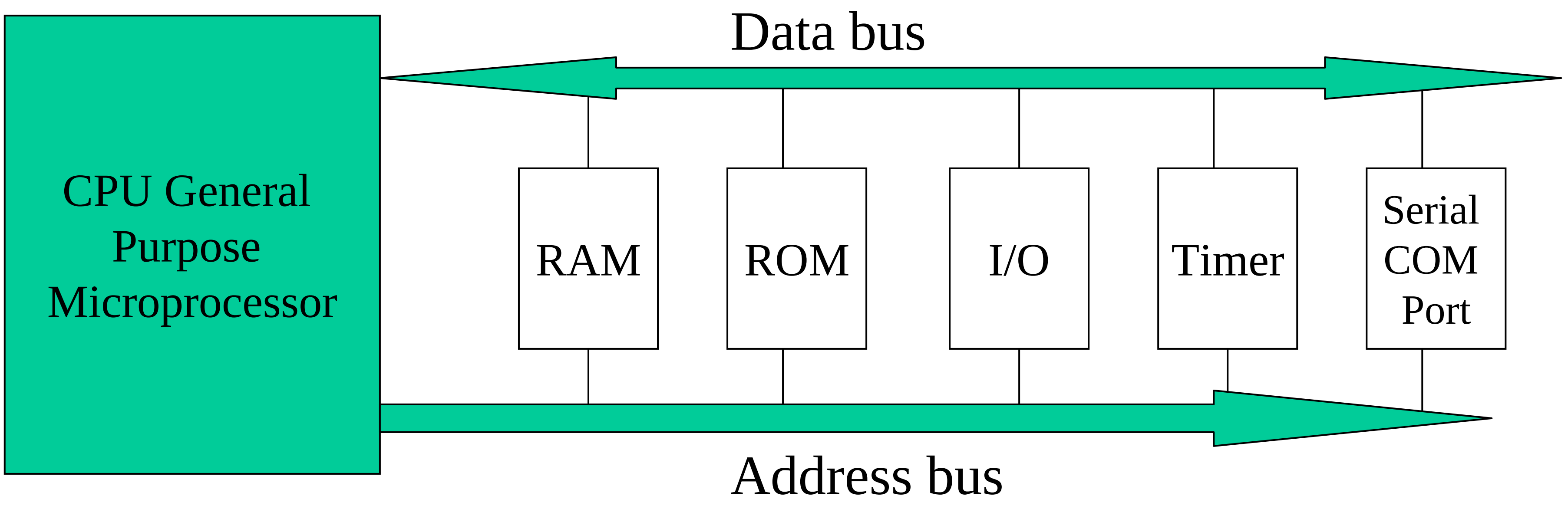
* Ultra large-scale integration
† Giant-scale integration

Types of Microcomputers

- *Microprocessor:* Processor on a chip
- In 1982, IBM began selling the idea of a *personal computer*. It featured a system board designed around the Intel 8088 8-bit microprocessor, 16 K memory and 5 expansion slots.
  - This last feature was the most significant one as it opened the door for 3rd party vendors to supply video, printer, modem, disk drive, and RS 232 serial adapter cards.
  - Generic PC: A computer with interchangable components manufactured by a variety of companies
- *Microcontroller* is an entire computer on a chip, a microprocessor with on-chip memory and I/O.
  - These parts are designed into (embedded within) a product and run a program which never changes
  - Home appliances, modern automobiles, heat, air-conditioning control, navigation systems
  - Intel's MCS-51 family, for example, is based on an 8-bit microprocessor, but features up to 32K bytes of on-board ROM, 32 individually programmable digital input/output lines, a serial communications channel.

General Purpose Microprocessors

Microprocessors lead to versatile products



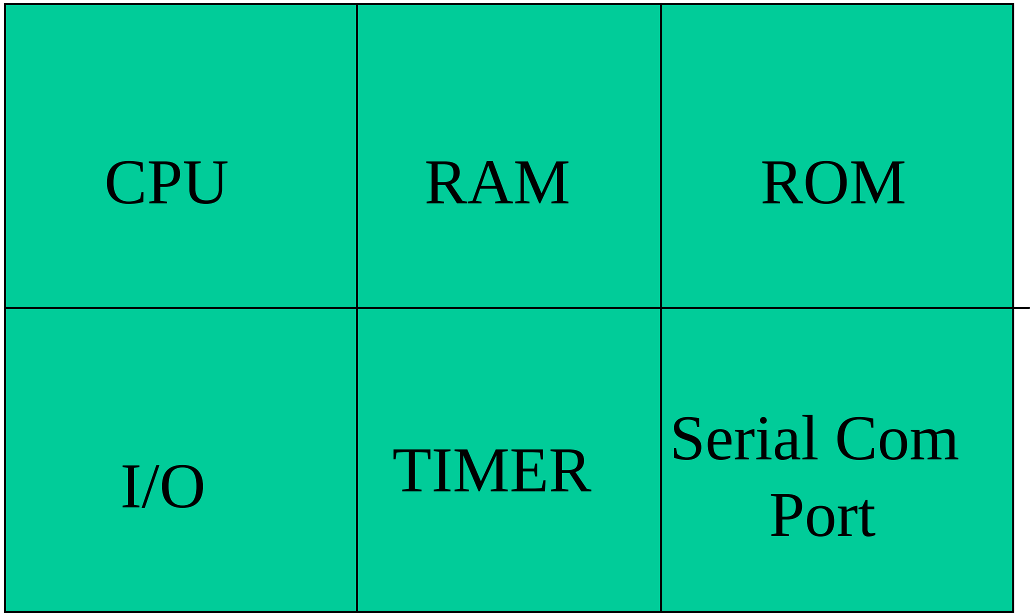
These general microprocessors contain no RAM, ROM, or I/O ports on the chip itself

Ex. Intel’s x86 family (8088, 8086, 80386, 80386, 80486, Pentium)

Motorola’s 680x0 family (68000, 68010, 68020, etc)

Microcontrollers

Microcontroller



A microcontroller has a CPU in addition to a fixed amount of RAM, ROM, I/O ports on one single chip; this makes them ideal for applications in which cost and space are critical

Example: a TV remote control does not do computing power of a 486

Embedded Systems

- An embedded system uses a microcontroller or a microprocessor to do one task and one task only
  - Example: toys, garage door openers, answering machines, ABS, keyless entry, etc.
  - Inside every mouse, there is a microcontroller that performs the task of finding the mouse position and sends it to the PC
- Although microcontrollers are the preferred choice for embedded systems, there are times that the microcontroller is inadequate for the task
- Intel, Motorola, AMD, Cyrix have also targeted the embedded market with their general purpose microprocessors
- For example, Power PC microprocessors (IBM Motorola joint venture) are used in PCs and routers/switches today
- Microcontrollers differ in terms of their RAM,ROM, I/O sizes and type.
  - ROM: One time-programmable, UV-ROM, flash memory

Instruction Set

- The list of all recognizable instructions by the instruction decoder is called the instruction set
  - CISC (Complex Instruction Set Computers), e.g., 80x86 family has more than 3000 instructions
  - RISC (Reduced Instruction Set Computers) - A small number of very fast executing instructions
- Most microprocessor chips today are allowed to fetch and execute cycles to overlap
  - This is done by dividing the CPU into
    - EU (Execution Unit)
    - BIU (Bus Interface Unit)
  - BIU fetches instructions from the memory as quickly as possible and stores them in a queue, EU then fetches the instructions from the queue not from the memory
    - The total processing time is reduced
  - Modern microprocessors also use a *pipelined* execution unit which allows the decoding and execution of instructions to be overlapped.

RISC versus CISC

- **Advantages of complex instruction set machines (CISC)**
  - Less expensive due to the use of microcode; no need to hardwire a control unit
  - Upwardly compatible because a new computer would contain a superset of the instructions of the earlier computers
  - Fewer instructions could be used to implement a given task, allowing for more efficient use of memory
  - Simplified compiler, because the microprogram instruction sets could be written to match the constructs of high-level languages
  - More instructions can fit into the cache, since the instructions are not a fixed size
- **Disadvantages of CISC**

Although the CISC philosophy did much to improve computer performance, it still had its drawbacks:

  - Instruction sets and chip hardware became more complex with each generation of computers, since earlier generations of a processor family were contained as a subset in every new version
  - Different instructions take different amount of time to execute due to their variable-length
  - Many instructions are not used frequently; Approximately 20% of the available instructions are used in a typical program

RISC versus CISC

Advantages of RISC

Advantages of a reduced instruction set machine:

- Faster
- Simple hardware
- Shorter design cycle due to simpler hardware

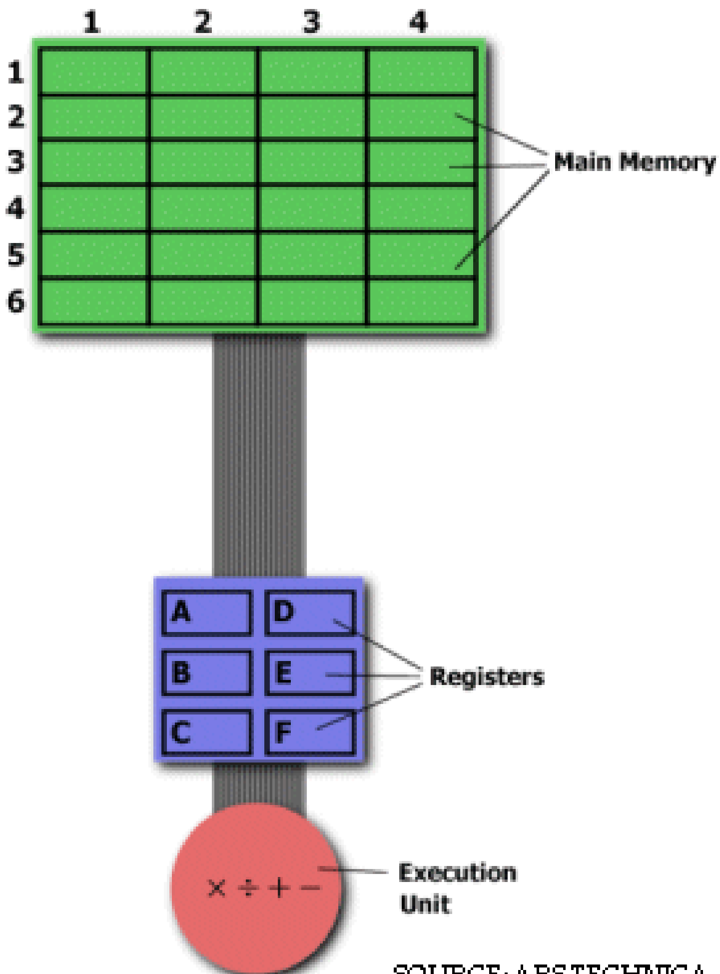
Disadvantages of RISC

Drawbacks of a reduced instruction set computer include

- Programmer must pay close attention to instruction scheduling so that the processor does not spend a large amount of time waiting for an instruction to execute
- Debugging can be difficult due to the instruction scheduling Require very fast memory systems to feed them instructions

- Nearly all modern microprocessors, including the Pentium (hybrid RISC/CISC) Power PC, Alpha and SPARC microprocessors are superscalar

More on RISC and CISC



SOURCE: ARSTECHNICA

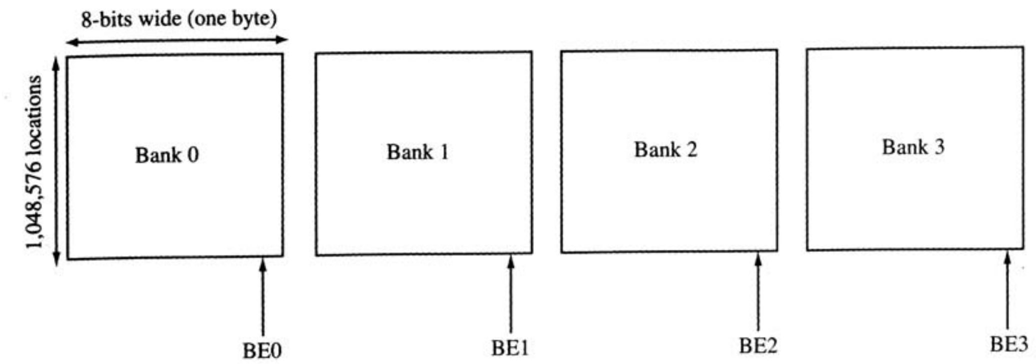
MULT 2:3, 5:2

LOAD A, 2:3
LOAD B, 5:2
PROD A, B
STORE 2:3, A

Three Bus System Architecture

- A collection of electronic signals all dedicated to particular task is called a *bus*
  - *data bus*
  - *address bus*
  - *control bus*
- **Data Bus**
  - The width of the data bus determines how much data the processor can read or write in one memory or I/O cycle (**Machine Cycle)**
  - 8-bit microprocessor has an 8-bit data bus
  - 80386SX 32-bit internal data bus, 16-bit external data bus
  - 80386 32-bit internal and external data busses
  - Data Buses are bidirectional.
  - More data means more expensive computer however faster processing speed.

Address Bus



Here the Total amount of memory is 4Mbytes

- **Address Bus** - Unidirectional
  - The address bus is used to identify the memory location or I/O device (also called port) the processor intends to communicate with
  - 20 bits for the 8086 and 8088
  - 32 bits for the 80386/80486 and the Pentium
  - 36 bits for the Pentium Pro
- 8086 has a 20-bit address bus and therefore addresses all combinations of addresses from all 0s to all 1s. This corresponds to 2^{20} addresses or 1M (1 Meg) addresses or memory locations.
- Pentium: 4Gbyte main memory

Control Bus

- Control bus is Uni-directional
- How can we tell the address is a memory address or an I/O port address
  - Memory Read
  - Memory Write
  - I/O Read
  - I/O Write
- When Memory Read or I/O Read are active, data is *input* to the processor.
- When Memory Write or I/O Write are active, data is *output* from the processor.
- The control bus signals are defined from the processor's point of view.

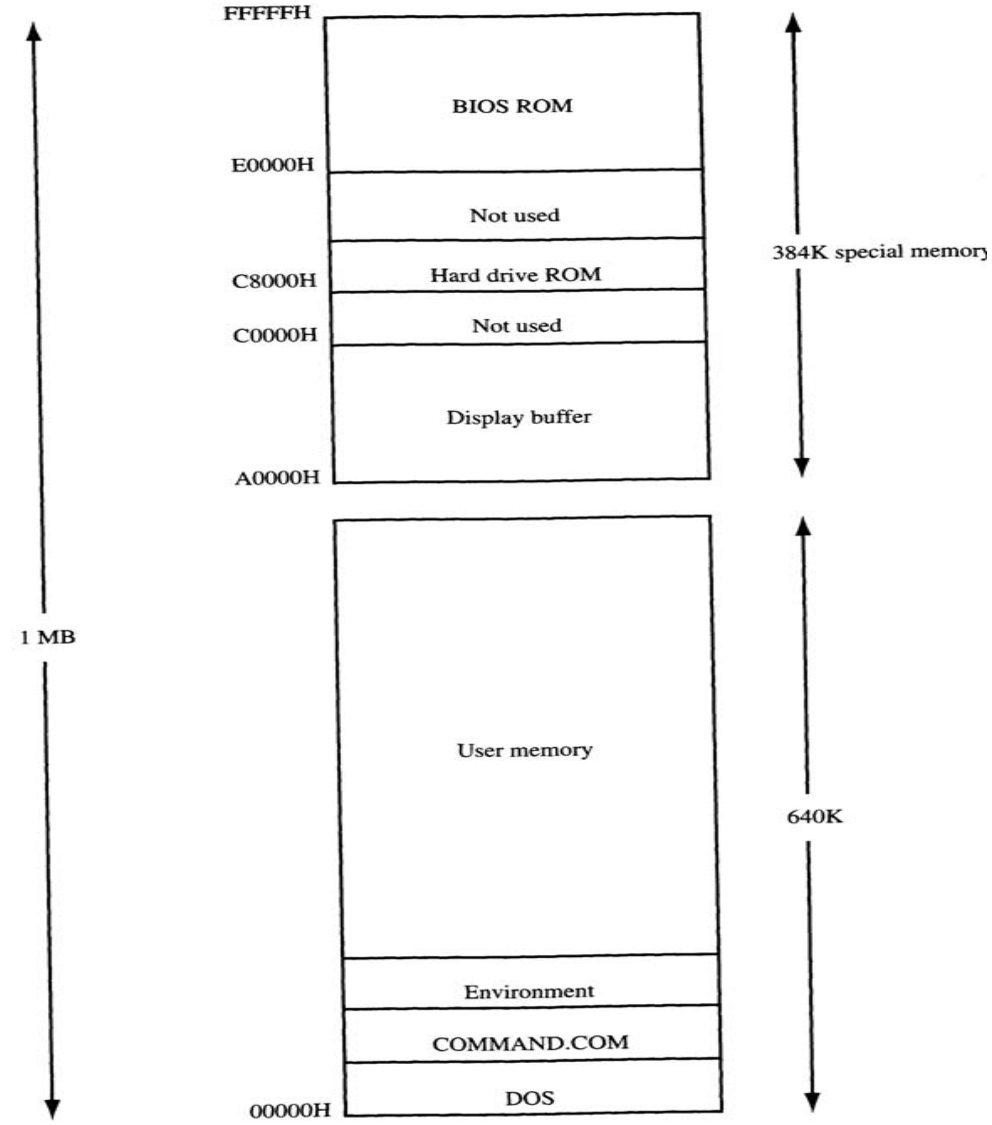
Some Important Terminology

- Bit is a binary digit that can have the value 0 or 1
- A byte is defines as 8 bits
- A nibble is half a byte
- A word is two bytes
- A double word is four bytes
- A kilobyte is 2^10 bytes (1024 bytes), The abbreviation K is most often used
  - Example: A floppy disk holding 356Kbytes of data
- A megabyte or meg is 2^20 bytes, it is exactly 1,048,576 bytes
- A gigabyte is 2^30 bytes

Computer Operating Systems

- What happens when the computer is first turned on?
- MS-DOS
  - A startup program in the BIOS is executed
  - This program in turn accesses the master boot record on the floppy or hard disk drive
  - A loader then transfers the system files IO.SYS and MSDOS.SYS from the disk drive to the main memory
  - Finally, the command interpreter COMMAND.COM is loaded into memory which puts the DOS prompt on the screen that gives the user access to DOS's built-in commands like DIR, COPY, VER.
- The 640 K Barrier
  - DOS was designed to run on the original IBM PC
  - 8088 microprocessor, 1Mbytes of main memory
  - IBM divided this 1Mb address space into specific blocks
    - 640 K of RAM (user RAM)
    - 384 K reserved for ROM functions (control programs for the video system, hard drive controller, and the basic input/output system)

Memory Map


FFFFFH
BIOS ROM
E0000H
Not used
Hard drive ROM
C8000H
Not used
C0000H
Display buffer
A0000H
384K special memory
1 MB
User memory
Environment
COMMAND.COM
DOS
00000H
640K

MS-DOS Functions and BIOS Services

- Program Support
- *<u>BIOS:</u>* usually stored in ROM these routines provide access to the hardware of the PC
- Access to the BIOS is done through the software interrupt instruction Int *n*
- For example, the BIOS keyboard services are accessed using the instruction INT 16h
- In addition to BIOS services DOS also provides higher level functions
  - INT 21h
  - More details later