UMP OPEN COURSEWARE

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

Chapter 1

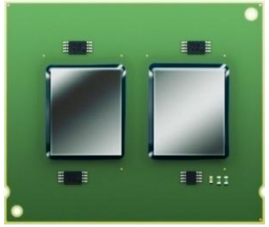
Introduction to Microprocessors

Expected Outcomes

- Explain the role of the CPU, memory and I/O device in a computer
- Distinguish between the microprocessor and microcontroller
- Differentiate various form of programming languages
- Compare between CISC vs RISC and Von Neumann vs Harvard architecture

Introduction

- A microprocessor is an integrated circuit built on a tiny piece of silicon
- It contains thousands or even millions of transistors which are interconnected via superfine traces of aluminum
- The transistors work together to store and manipulate data so that the microprocessor can perform a wide variety of useful functions
- The particular functions a microprocessor perform are dictated by software
- The first microprocessor was the Intel 4004 (16-pin) introduced in 1971 containing 2300 transistors with 46 instruction sets
- Power8 processor, by contrast, contains 4.2 billion transistors



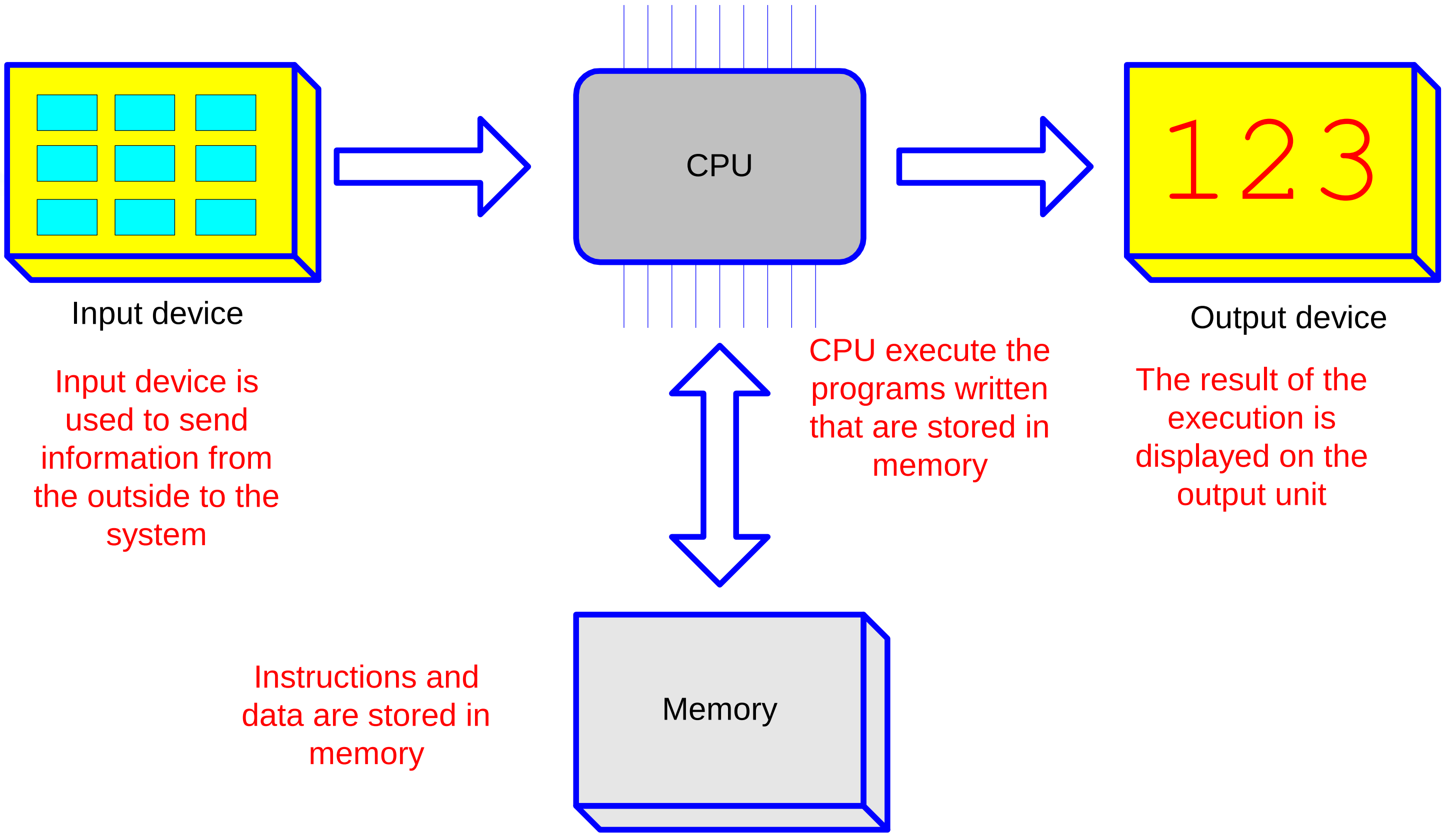
Introduction

- Computer is an electronic machine that perform arithmetic operation and logic in response to instructions written
- Computer requires hardware and software to function
- **Hardware** is electronic circuit boards that provide functionality of the system such as power supply, cable, etc
  - **CPU** – Central Processing Unit/Microprocessor
  - **Memory** – store all programming and data
  - **Input/Output device** – the flow of information
- **Software** is a programming that control the system operation and facilitate the computer usage
  - **Programming** is a group of instructions that inform the computer to perform certain task

Introduction

- Computer hardware consists of four main modules
  - **CPU (central processing unit)**
    The heart of computer as it contain all circuitry for fetching and interpreting instructions and for controlling and performing various operations
  - **Input unit**
    A complete instructions and data is fed into the computer system and memory unit
  - **Output Unit**
    The unit takes data from the memory units and printout, display, or presents the information to the user
  - **Memory**
    The memory stores the instructions and data received from the input

Introduction



CPU

- CPU consists of 3 components
  - **Register** : memory that store temporary data during CPU operation
  - **Arithmetic Logic Units (ALU)** : perform operation
  - **Control Unit** : control the flow of information in CPU, memory and I/O device

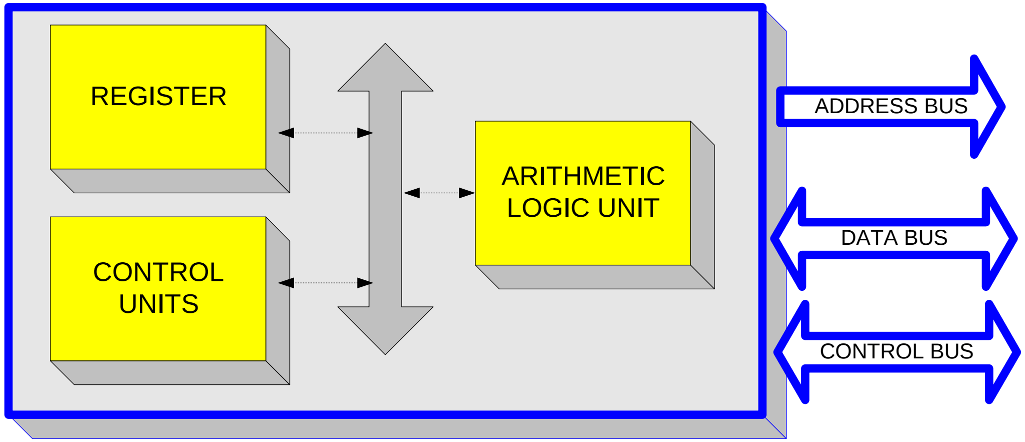
- Basic CPU operation
  - **Fetch** data from input device
  - **Decode** & **execute** (process) instructions stored in memory
  - **Display** result of operation through output device

Central Processing Unit

- CPU consists of 3 components
  - **Registers**
    Fast memory to store information temporary during CPU operation
  - **Arithmetic Logic Unit (ALU)**
    Perform operation such as addition, logics etc
    Size of ALU is important to determine the computer efficiency (8-bits, 16-bits, 32-bits etc)
  - **Control Units**
    Control the operation in CPU or between CPU, memory and I/O

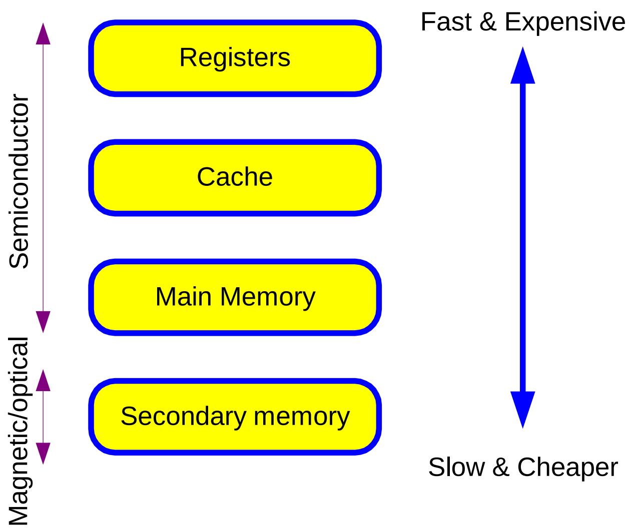
Address, Data & Control Buses

- CPU, memories and I/O devices are connected using buses
  - **Address bus**
    unidirectional buses that carry the location in memory or I/O device
  - **Data bus**
    bidirectional buses that carry the data in or out from CPU
  - **Control bus**
    carry timing signal & other control signal to synchronize the CPU with I/O



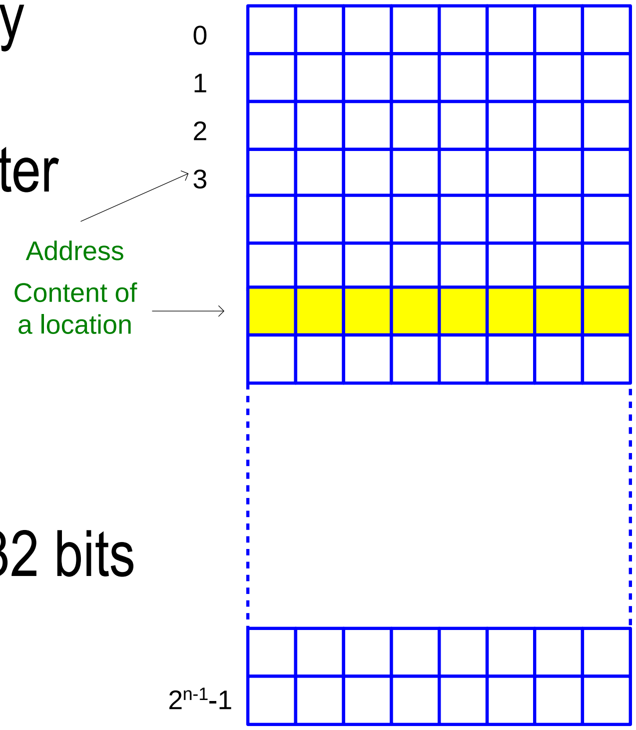
Types of Memories

- Classification by access
  - Register : Internal to the CPU
  - Cache : closely linked to the CPU
  - Main Memory : Connected through system buses
  - Secondary memory : On-line
- Classification by technology
  - Semiconductor : RAM, ROM
  - Magnetic memory : Disk, tape
  - Optical : CDROM
  - Flash



Semiconductor Memory

- Storage device in microcomputer where instructions and data are stored in binary format
- To retrieve information, the microcomputer assigns addresses to the location
- Each address stores one byte
  - **1 byte** = 8 bits
  - **1 word** = 2 bytes = 16 bits
  - **1 longword** = 2 words = 4 bytes = 32 bits
  - **1 nibble** = 4 bits
- Total location is 2^N (N is address bus)

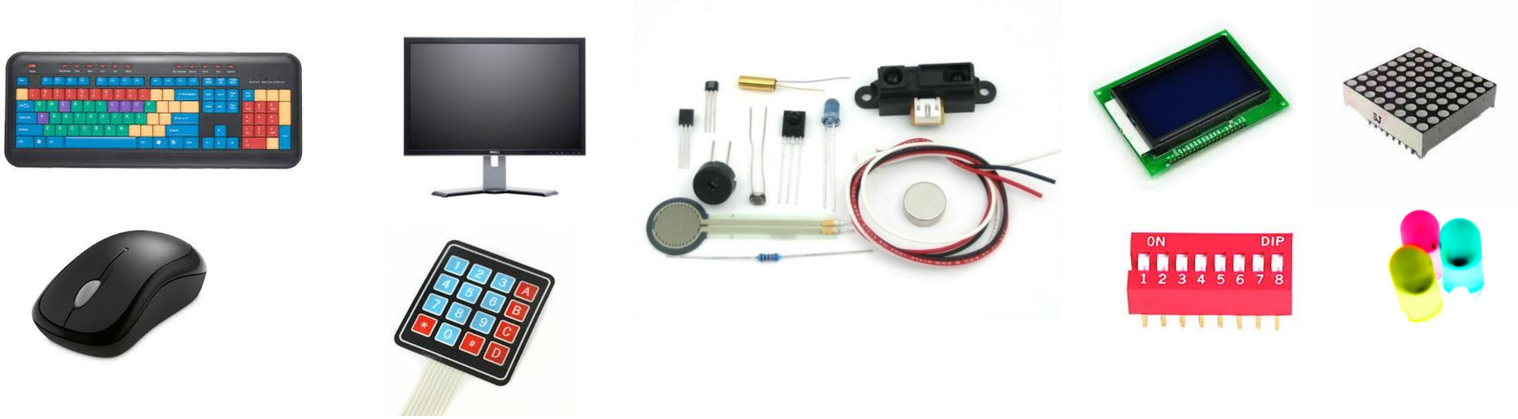


Semiconductor Memory

- Some typical semiconductor memory
  - ROM (read only memory)
    - Nonvolatile storage
    - Masked ROM, PROM, EPROM, OTPROM, EEPROM, flash memory
  - RAM (random access memory)
    - Volatile, read and write
    - Static and dynamic RAM

I/O Devices

- I/O device allows the computer to communicate with the outside world
  - **Mass storage devices** to hold large quantities of information such as disks, tapes and CD-ROM
  - **Human interface devices** such as monitor, keyboard, mouse and printer
  - **Control/monitor devices** such as actuator and sensor



Types of Computers

- Computers can be generally classified by size and power
- **Microcomputer/Personal computer**
  - A small, single-user computer based on a microprocessor
  - Use personal computers for word processing, accounting, desktop publishing, running spreadsheet and database management applications, for playing games and recently for surfing the Internet
  - Examples are desktop computer, laptops, netbook, handheld computer/ palmtop/pocket computer, personal digital assistant (PDA), tablets and smart-phones





Types of Computers

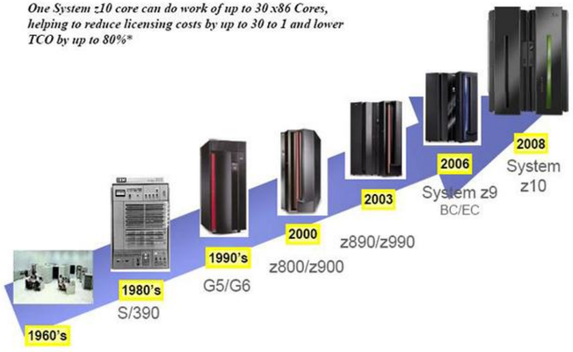
- **Minicomputer**
  - A multi-user computer capable of supporting up to hundreds of users simultaneously
  - It is a midsize computer and in general, a minicomputer is a multiprocessing system capable of supporting from up to 200 users simultaneously.
  - Minicomputers are used by small businesses & firms.
  - These are small machines and can be accommodated on a disk with not as processing and data storage capabilities as super-computers & Mainframes.
  - Use for specific purposes such as for monitoring certain production process.
  - Examples are K-202 Texas Instrument TI-990, SDS-92,IBM Midrange computers

Types of Computers

- Workstation
  - Use for engineering applications (CAD/CAM), desktop publishing, software development, and other types of applications that require a moderate amount of computing power and relatively high quality 3-D graphics capabilities.
  - Large, high-resolution graphics screen, at large amount of RAM, built-in network support, and a graphical user interface.
  - The most common operating systems for workstations are UNIX and Windows NT
  - single-user computers and normally are typically linked together to form a LAN
  - Excellent OS with high speed RISC-processor
  - SPARC-10, DEC, Silicon Graphic

Types of Computers

- **Mainframe**
  - Large computer normally used for business by many large firms & government organizations
  - Not as powerful as supercomputers but must be accommodated in large air-conditioned rooms because of its size
  - Like supercomputer, mainframes can also process & store large amount of data
  - Banks educational institutions & insurance companies use mainframe computers to store data about their customers, students & insurance policy holders.
  - Popular Mainframe computers are Fujitsu's ICL VME and Hitachi's Z800

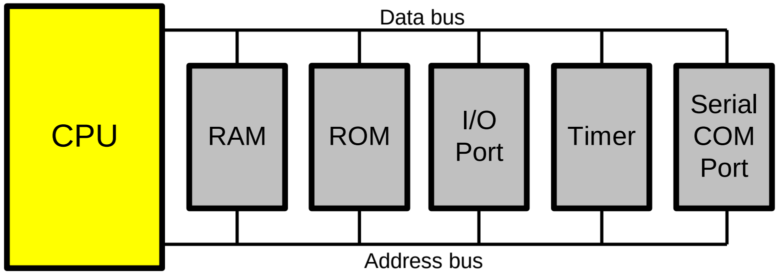


Types of Computers

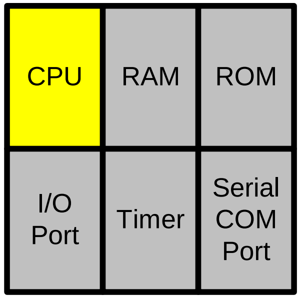
- **Supercomputer**
  - High speed for high precision calculation with combination of thousand of processors using parallel processing technique
  - The fastest and the most expensive computers with typical supercomputer can do up to ten trillion individual calculations every second.
  - Use to solve very complex science and engineering problems
  - Use in many fields such as space exploration, earthquake studies, natural resources exploration, weather forecasting, nuclear weapons testing, weapon simulation etc
  - The chief difference between a supercomputer and a mainframe is that a supercomputer channels all its power into executing a few programs as fast as possible, whereas a mainframe uses its power to execute many programs concurrently
  - Examples are
    - Tianhe – 2
    - Titan - Cray XK7, Cray Inc.
    - Sequoia - BlueGene/Q, IBM, K Computer
    - Tofu Interconnect Fujitsu
    - Mira - BlueGene/Q, Custom IBM

μP vs μC

- General purpose microprocessor such as Intel's x86 family (8086, 80286, 80386, 80486 and Pentium) or Motorola's 680x0 family (68000, 68010, etc) contain no RAM, ROM or I/O on the chip itself
- They require these devices externally to make them function
- A microcontroller consists of CPU, ROM, RAM, I/O port and timer embedded together in a single chip
- It is an ideal for applications in which cost and space are critical



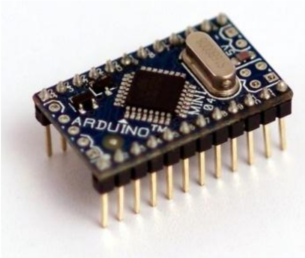
General-purpose Microprocessor system

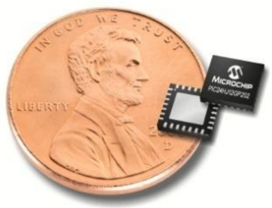


Microcontroller

µP vs µC

Advantages of Microcontroller	Advantages of Microprocessor
High integration with small space for PCB	Offer high performance
Cost is much cheaper	Very flexible and can easily be upgraded
Special architecture and features	Large size of memory
Low power consumption	Unlimited number of I/O
More reliable due to less connection	
The system design is simple and flexible	
Reduce the design time due to less connection (internal design)	
Faster in speed of execution as the microcontroller are fully integrated	





Hierarchy of Computer Design

- **Software level**
  - Application level language
  - High level language
  - Assembly level language
  - Machine language
- **Hardware level**
  - Register transfer level
  - Gate level
  - Transistor level

Simple and slow

Complex and faster

Programming Language

- There are three main languages
  - **Machine language**
    - The only language understand by the computer
    - Differ for each processor and normally is upward compatible
    - Fast execution and can control every component in a system
    - Complex programming and need to understand system configuration
    - Memorizing codes are out of question

Programming Language

- Assembly language
  - Much easier to write the programming
  - Require the assembler to convert to machine code
- High-level language
  - Solve all problem without much attention to CPU and configuration
  - Easy to write a program even involves floating point calculation
  - Difficult to control the hardware
  - C++, Pascal, BASIC to name a few

Programming Language

Machine language

```
10000011110001100101010000011111010101111111011111
```

Assembly language

```
CLR.L     D0
MOVE.W    #$234D, D4
MULU      D2, D6
```

High-level language

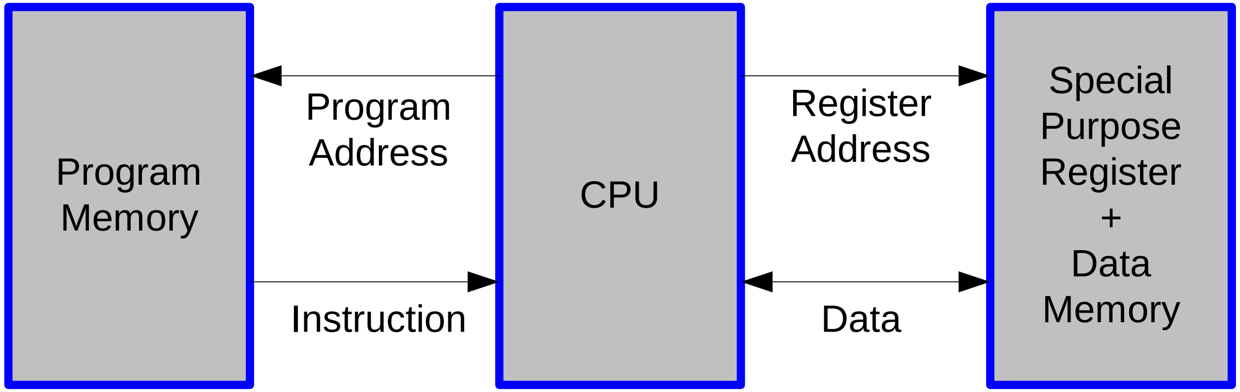
```
while (1) {
   for (i=0; i<=9; i++){
        printf "HELLO"}}
```

CISC vs RISC

- CISC (Complex Instruction Set Computer)
  - Numbers of instruction set (not all are used) with simple hardware
  - Various size instruction sets with different execution time
  - Thus transistor need to understand thousands of different instruction before execute – slowing down the processing time
- RISC (Reduced Instruction Set Computer)
  - Fixed microcode size with normally one clock cycle for each instruction
  - Easy to operate as less transistor is required and faster execution time
  - Prefer high level language operation

Von Neumann vs Harvard

- **Von Neumann (Princeton) vs Harvard Architecture**
  - Data and program in Von Neumann are placed in the same location
  - Harvard architecture has a split memory location thus allowing fast processing time as pre-fetch can be conducted



Instructions are fetched from program memory using buses that are distinct from the buses used for accessing data memory or I/O port

Computer Generation

- **First Generation (1940-1956) Vacuum Tubes**
  - The first computers used vacuum tubes for circuitry and magnetic drum for memory, and taking up entire rooms and relied on machine language
  - Input was based on punched cards and paper tape, and output was displayed on printouts.
  - The UNIVAC and ENIAC computers are examples of first-generation computing devices
- **Second Generation (1956-1963) Transistors**
  - Much better as it becomes smaller, faster, cheaper, energy-efficient and reliable.
  - Use symbolic, or assembly languages, which allowed programmers to specify instructions in words
  - High level languages were also developed such as COBOL and FORTRAN
  - The first computers that stored their instructions in their memory, which moved from a magnetic drum to magnetic core technology.

Computer Generation

- **Third Generation (1964-1971) Integrated Circuits**
  - Use IC to increase the speed and efficiency of computers
  - User interface features keyboard, monitor with OS
- **Fourth Generation (1971-Present) Microprocessors**
  - Thousands of integrated circuits were built onto a single silicon chip
  - The development of GUIs, mouse and handheld devices
- **Fifth Generation (Present and Beyond) Artificial Intelligence**
  - Voice recognition are widely being used
  - Parallel processing and superconductors make artificial intelligence a reality
  - Quantum computation, molecular, wireless and nanotechnology will radically change the face of computers in years to come
  - The goal of fifth-generation computing is to develop devices that respond to natural language input and are capable of learning and self-organization.

μP Chronology

Year	Name	Developer	Speed	Process	Transistor
1971	4004	Intel	740kHz	10μm	2250
1972	8008	Intel	500kHz	10μm	3500
1974	RCA 1802	RCA	3.2Mz	5μm	5000
1974	6800	Motorola	2MHz	n.a	4100
1974	8080	Intel	2MHz	6μm	6000
1974	TMS1000	T.I	400kHz	8μm	8000
1976	Z-80	Zilog	2MHz	4μm	8500
1976	8085	Intel	5MHz	3μm	6500
1977	6100	Intersil	4 MHz	n.a	20,000
1978	8086	Intel	5MHz	3μm	29,000
1978	6801	Motorola	n.a	5μm	35,000
1979	8088	Intel	5MHz	3μm	29,000
1979	6809	Motorola	1 MHz	5μm	40,000
1979	68000	Motorola	8MHz	4μm	68,000
1980	16032	National	n.a	n.a	60,000
1981	6120	Harris	10MHz	n.a	20,000
1982	80186	Intel	6MHz	n.a	55,000
1982	80286	Intel	6MHz	1.5μm	134,000
1984	68020	Motorola	16MHz	2μm	190,000
1985	80386	Intel	16MHz	1.5μm	275,000
1986	Z80000	Zilog	n.a	n.a	91,000
1986	SPARC	Sun	40MHz	0.8μm	800,000
1987	68030	Motorola	16MHz	1.3μm	273,000
1988	R3000	MIPS	12MHz	1.2μm	120,000
1989	80486	Intel	25MHz	1μm	1.18M
1990	68040	Motorola	40MHz	n.a	1.2M
1991	RSC	IBM	33MHz	0.8μm	1M
1992	SPARC I	Sun	40MHz	0.8μm	0.8M
1993	PowerPC 601	Motorola	50-80M	0.6μm	2.8M
1993	Pentium	Intel	60-66M	0.8μm	3.1M
1994	PowerPC 604	Motorola	100-180M	0.5μm	3.6M
1995	Pentium Pro	Intel	150-500M	0.35μm	5.5M
1996	K5	AMD	75-100M	0.5μm	4.3M
1997	Pentium II	Intel	233-300M	0.35μm	7.5M
1997	PowerPC 750	Motorola	233-366M	0.26μm	6.35M
1998	S/390 G5	IBM	500MHz	0.25μm	25M
1999	Pentium III	Intel	450-600M	0.25μm	9.5M
1999	PowerPC 7400	Motorola	350-500M	0.2μm	10.5M
1999	Athlon	AMD	500-1000	0.25μm	22M

μP Chronology

Date	Name	Developer	Speed(GH)	Process (nm)	Transistor
2000	Pentium 4	Intel	1.3-2G	180	42M
2000	Athlon XP	AMD	1.33-1.73	180	37.5M
2000	SPARC64 IV	Fujitsu	0.45-0.81	130	n.a
2000	Z900	IBM	0.918	180	47M
2001	Itanium	Intel	0.733-0.8	0.18μm	25M
2001	MIPS R14000	SGI	0.5-0.6	130	7.2M
2001	Power4	IBM	1.1-1.4	90	174
2001	UltraSPARC III	Sun	0.75-1.2	130	29M
2001	PowerPC 7450	Motorola	0.733-0.8	180	33M
2002	SPARC64 V	Fujitsu	1.1-1.35	0.13μm	190M
2002	Itanium 2	Intel	0.9-1.7	0.18μm	410M
2003	PowerPC 970	IBM	1.6-2	130	52M
2003	Pentium M	Intel	0.9-1.7	130	77M
2003	Opteron	AMD	1.4-2.4	130	106M
2004	POWER5	IBM	1.65-1.9	130	276M
2005	Opteron "Athens"	AMD	1.6-3	90	114M
2005	Athlon 64 X2	AMD	2-2.4	90	243M
2005	UltraSPARC IV	Sun	1.05-1.35	130	66M
2005	UltraSPARC T1	Sun	1-1.4	90	300M
2006	Core Duo	Intel	1.1-2.33	65	151M
2006	Core 2	Intel	1.06-2.67	65	291M
2006	Cell/B.E	IBM,Sony, etc	3.2-4.6	90	241M
2006	Itanium Montecito	Intel	1.4-1.6	90	1720M
2007	POWER6	IBM	3.5-4.7	65	790M
2007	UltraSPARC T2	Sun	1-1.4	65	503M
2007	Opteron Barcelona	AMD	1.8-3.2	65	463M
2008	Phenom	AMD	1.8-2.6	65	450M
2008	Z10	IBM	4.4	65	993M
2008	PowerXCell 8i	IBM	2.8-4	65	250M
2008	Atom	Intel	0.8-1.6	45	47M
2008	Core i7	Intel	2.66-3.2	45	730M
2008	Opteron Shanghai	AMD	2.3-2.9	45	751M
2009	Phenom II	AMD	2.5-3.2	45	758M
2009	Opteron Istanbul	AMD	2.2-2.8	45	904M
2010	POWER7	IBM	3-4.14	45	1200M
2010	Itanium Tukwila	Intel	2	65	2000M
2010	Opteron Magny-cours	AMD	1.7-2.4	45	1810M
2010	Xeon "Nehalem-EX"	Intel	1.73-2.66	45	2300M
2010	Z196	IBM	5.2	45	1400M
2010	SPARC T3	Sun	1.6	45	2000M
2010	SPARC64 VII+	Fujitsu	2.66-3	45	n.a

μP Chronology

Date	Name	Developer	Speed(GH)	Process (nm)	Transistor
2011	Intel “Sandy Bridge”	Intel	1.6-3.4	32	995M
2011	AMD Fusion	AMD	1-1.6	40	380M
2011	Xeon E7	Intel	1.73-2.67	32	2600M
2011	PowerPC BGQ	IBM	1.6 GHz	45 nm	1470M
2011	SPARC64 VIIIfx	Fujitsu	2.0 GHz	45 nm	760M
2011	FX "Bulldozer" Interlagos	AMD	3.1–3.6 GHz	32 nm	1200M
2011	SPARC T4	Oracle	2.8–3 GHz	40 nm	855M
2012	SPARC64 IXfx	Fujitsu	1.848 GHz	40 nm	1870M
2012	zEC12	IBM	5.5 GHz	32 nm	2750M
2012	POWER7+	IBM	3.1–5.3 GHz	32 nm	2100M
2012	Itanium "Poulson"	Intel	1.73–2.53 GHz	32 nm	3100M
2013	Intel "Haswell"	Intel	1.9–4.4 GHz	22 nm	1400M
2013	SPARC64 X	Fujitsu	2.8–3 GHz	28 nm	2950M
2013	SPARC T5	Oracle	3.6 GHz	28 nm	1500M
2014	POWER8	IBM	2.5–5 GHz	22 nm	4200M

μP Manufacturers

Manufacturer	Microprocessors
AMD	K5 series, K6 series, K7 series, K8 series and K9 series such as Athlon , Duron, Opteron, Sempron, Turion
ARM	ARM
DEC	V-11, MicroVAX
Elbrus	Elbrus-3
Fairchild	Clipper series
Freescale	6800 series such 6800, 6802, 6809, 68K series such 68000, 68020, 68030, PowerPC series, 88000 series
Fujitsu	SPARC64, SPARC IV, SPARC V, SPARC VI
HP	Capricorn
IBM	Cell Processor, POWERn series such as POWER1, POWER2, POWER3, POWER4, POWER6
Intel	8080, 8085, 8088, x86 series such 286, 386 and 486, Pentium series such as Pentium II and Pentium 4, Celeron, Itanium, Xeon
MIPS Technologies	R2000, R3000, R6000, R10000, R140000, CVAX, Alpha 21064, StrongARM
National	NS320xx
NEC	V20,V25,V40,V30,V33,V50
Sun	SPARC, UltraSPARC, UltraSPARC IIs
Western Electric	WE-32000
Zilog	Z80, Z8000

Self-Test

- **Exercise 1**
  What is bus in a computer system? Briefly describe type of buses
- **Exercise 2**
  Discuss the difference between microprocessor and microcontroller. Briefly, explain why microcontroller is chosen in home appliances design
- **Exercise 3**

Explain the importance of RISC technology in the computer architecture