CSE213

Microcontroller Programming

Introduction to the Microprocessor and Computer

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Introduction

- Overview of Intel microprocessors.
- Discussion of history of computers.
- Function of the microprocessor.
- Terms and jargon (**computerese).**

Chapter Objectives

Upon completion of this chapter, you will be able to:

- Converse by using appropriate computer terminology such as bit, byte, data, real memory system, protected mode memory system, Windows, DOS, I/O.
- Detail history of the computer and list applications performed by computer systems.
- Provide an overview of the various 80X86 and Pentium family members.

Chapter Objectives (*cont.*)

Upon completion of this chapter, you will be able to:

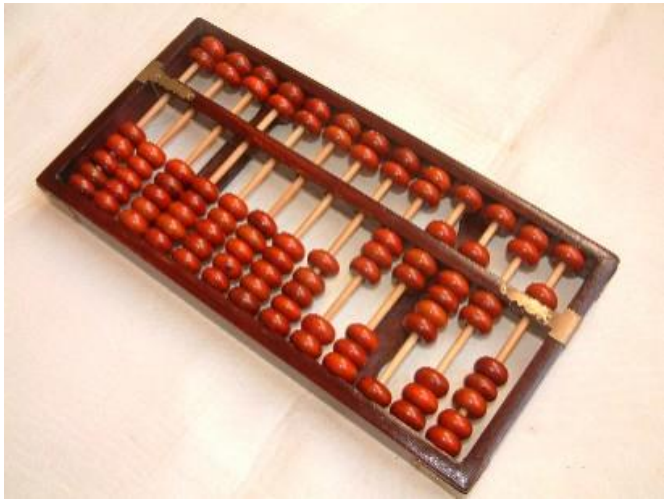
- Draw the block diagram of a computer system and explain the purpose of each block.
- Describe the function of the microprocessor and detail its basic operation.
- Define the contents of the memory system in the personal computer.

1–1 A HISTORICAL BACKGROUND

- Events leading to development of the microprocessor.
- 80X86, Pentium, Pentium Pro, Pentium III, Pentium 4, and Core2 microprocessors.
- While not essential to understand the microprocessor, furnishes:
  - interesting reading
  - historical perspective of fast-paced evolution

The Mechanical Age

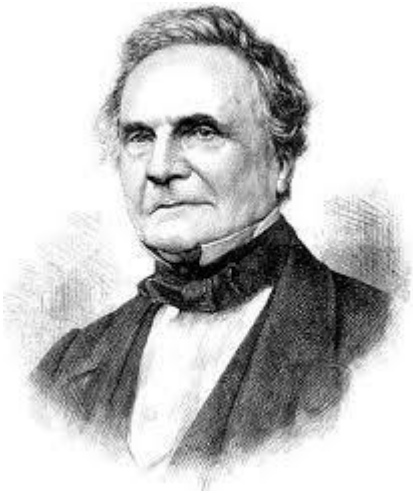
- Idea of computing system is not new.
- Calculating with a machine dates to 500 BC.
- Babylonians invented the **abacus.**
  - first mechanical calculator
  - strings of beads perform calculations

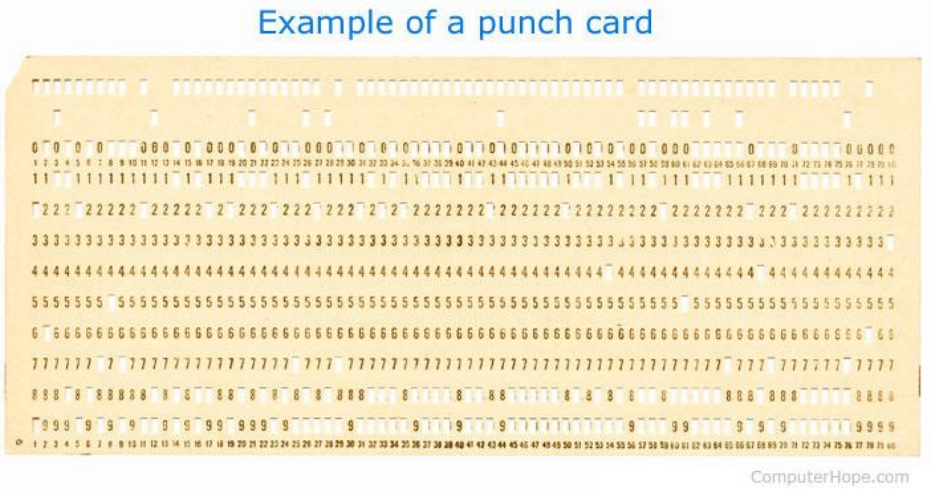


http://en.wikipedia.org/wiki/Abacus

- In 1642, mathematician **Blaise Pascal** invented a calculator constructed of gears and wheels.
- When moved one complete revolution, a second gear advances one place.
  - same principle used in automobile odometer
- Basis of all mechanical calculators.
- PASCAL programming language is named in honor of Blaise Pascal.

- In 1823, Charles Babbage (aided by Augusta Ada Byron) began to create his **Analytical Engine** (programmable calculating machine)
  - Steam-powered mechanical computer
  - Generated navigational tables
  - Used punched cards
  - Stored 1000 20-digit decimal numbers





The Electrical Age

- 1800s, The advent of electric motor
- 1889, Herman Hollerith developed a machine that counted, sorted, and collated data stored on punched cards
- 1941, Z3 calculating computer by Konrad Zuse
  - used in aircraft and missile design
- 1943, Alan Turing, Colossus
  - broke secret German military codes generated by ENIGMA
  - used vacuum tubes
  - not programmable
  - could not solve other problems (special-purpose computer)

- 1946, ENIAC, University of Pennsylvania
  - 17,000 vacuum tubes, 500 miles of wires
  - weighted over 30 tons
  - 100,000 operations per second
  - The first programmable machine
  - programmed by rewiring its circuits
- 1948, Development of the transistor
- 1958, Invention of the integrated circuit (IC)
- 1960s, Digital integrated circuits
- 1971, The first microprocessor by Intel (4004)

Programming Advancements

- Once programmable machines developed, programs and programming languages began to appear.
- As early practice of rewiring circuits proved too cumbersome, computer languages began to appear in order to control the computer.
- The first, **machine language**, was constructed of ones and zeros using binary codes.
  - stored in the computer memory system as groups of instructions called a program

- More efficient than rewiring a machine to program it.
  - still time-consuming to develop a program due to sheer number of program codes required
- Mathematician John von Neumann, first modern person to develop a system to accept instructions and store them in memory.
- Computers are often called **von Neumann machines** in his honor.
  - Recall that Babbage also had developed the concept long before von Neumann.

- **Assembly language** was then used to simplify entering binary code.
- Assembler allows programmer to use mnemonic codes…
  - such as ADD for addition
- In place of a binary number.
  - such as 0100 0111
- Assembly language an aid to programming.

- Since early days of programming, additional languages have appeared.
  - FLOWMATIC-FORTRAN-ALGOL-**COBOL**-RPG
- Some common modern programming languages are BASIC, PASCAL, C/C++, C#, Java, and ADA.
  - BASIC and PASCAL languages both designed as teaching languages, but escaped the classroom.

- Scientific community uses primarily C/C++.
- Recent survey of embedded system developers showed C was used by 60%.
  - 30% used assembly language
  - remainder used BASIC and JAVA
- These languages allow programmer almost complete control over the programming environment and computer system.
  - especially C/C++

- Assembly language still plays important role.
  - many video games written almost exclusively in assembly language
- Assembly also interspersed with C/C++ to perform machine control functions efficiently.
  - some newer parallel instructions found on Pentium and Core2 microprocessors only programmable in assembly language

Reminder

- A **bit** is a binary digit with a value of one or zero
- 4-bit-wide memory location is often called a **nibble**
- 8-bit-wide memory location is called a **byte**
- A **word** is a collection of 2 bytes (or 16 bits)
- 1 **KB** = 1024 Bytes = 2^{10} Bytes(1 KB = 1024 bytes)
- 1 **MB** = 1024 KB = 2^{20} Bytes
- 1 **GB** = 2^{30} Bytes, 1 TB = 2^{40} Bytes
- **B** is used for *byte* and **b** is used for *bit*
  - 8 Mbps = 8 Megabits per second (ADSL speed)

The Microprocessor Age

- World's first microprocessor the Intel 4004.
- A 4-bit microprocessor-programmable controller on a chip.
- Addressed 4096, 4-bit-wide memory locations.
- The 4004 instruction set contained 45 instructions.

The Microprocessor Age

- 1971, Intel 4004 and 4040
  - 4-bit microprocessors
  - addressed 4096 (4-bit) memory locations
  - 45 instructions
  - most calculators and low-end applications such as microwave ovens still use 4-bit microprocessors
- 1972, Intel 8008
  - 8-bit microprocessor
  - addressed 16K memory locations
  - 48 instructions
  - 50,000 instructions per second

The Microprocessor Age

- 1973, Intel 8080 (compatible with TTL)
  - addressed 64K memory locations
  - 500,000 instructions per second (2 μs per instr.)
- 1974, Motorola 6800
- 1974, The first personal computer
    - (MITS Altair 8800) -> BASIC interpreter by Gates&Allen
- 1977, Intel 8085 (last 8-bit μp by Intel)
  - 769,230 instructions per second (1.3 μs per instr.)
  - internal clock generator and system controller

The Modern Microprocessors

- 1978, Intel 8086 and 8088
  - 16-bit microprocessors
  - 400 ns per instruction
  - 2,5 million instructions per second
  - addressed 1M memory locations
  - multiply and divide instructions are added
  - over 20,000 instruction variations
    - such microprocessors are called **CISC** (complex instruction set computers)
    - Alternative is **RISC** (reduced instruction set computers)

The Modern Microprocessors

- 1983, Intel 80286
  - addressed 16M memory locations
  - increased clock speed (8 MHz)
  - some instructions took 250 ns. to be executed
- 1986, Intel 80386
  - 32-bit microprocessor
  - addressed 4GB memory
- 1989, Intel 80486
  - same as 80386 but half of its instructions are executed in one clock cycle instead of two
  - 8 KB cache

The Pentium Microprocessor

- 1993, Intel Pentium (P5 or 80586)
  - Introductory versions operated with a clocking frequency 60 & 66 MHz, and a speed of 110 MIPs
  - Over-clocked versions operated on 120, 133, and 233 MHz clocking frequencies
  - 16 KB cache
  - Full-frame video displays at scan rates of 30 Hz or higher (which is comparable to commercial television)

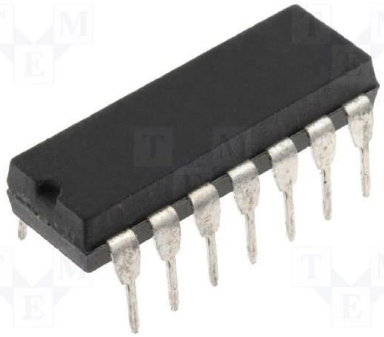
Next Microprocessors

- Pentium Pro
- Pentium II
- Pentium III
- Pentium IV
- Core2
- Quad Core
- 64-bit microprocessors
- …

Some Definitions

Integrated Circuit

- a.k.a. IC, microcircuit, microchip, silicon chip, or chip
- Integrated Circuit is a miniaturized electronic circuit (consisting mainly of semiconductor devices, as well as passive components) that has been manufactured in the surface of a thin substrate of semiconductor material.



Microprocessor

- A microprocessor is a programmable digital electronic component that incorporates the functions of a central processing unit (CPU) on a single semiconducting integrated circuit (IC).
- 8-bit, 16-bit, 32-bit, and 64-bit microprocessor: refers to number of bits manipulated in one operation. It requires external memory to execute programs. It cannot directly interface to I/O devices, peripheral chips are needed.

Microcomputer and Microcontroller

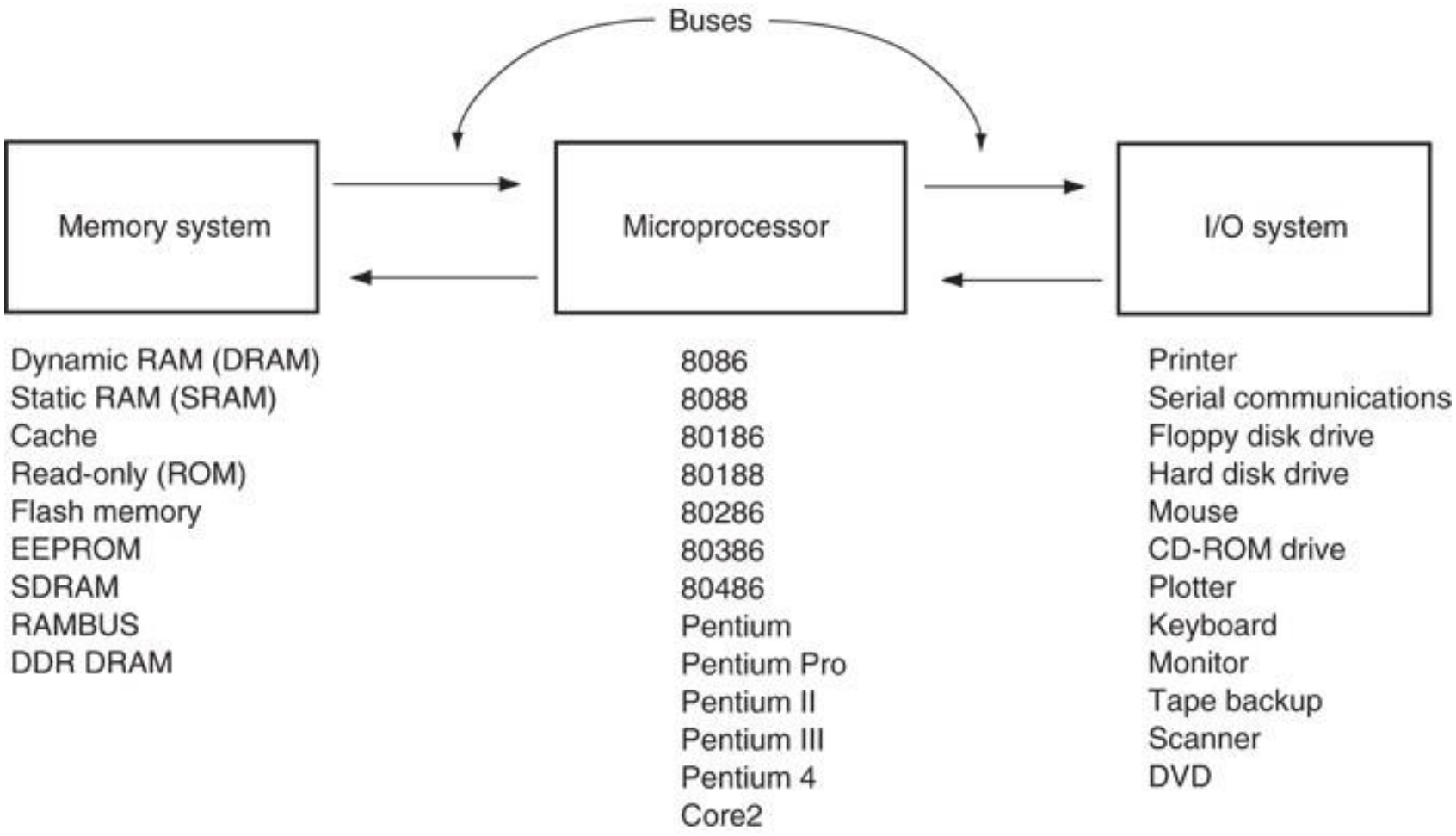
- A **microcomputer** is a computer that uses a microprocessor as its CPU.
- A **microcontroller** (or MCU) is a computer-on-a-chip. It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor (the kind used in a PC).
- The only difference between a **microcontroller** and a **microprocessor** is that a microprocessor has three parts - ALU, Control Unit and registers, while the microcontroller has additional elements like ROM, RAM, peripherals (timer, I/O ports, etc).

THE MICROPROCESSOR-BASED PERSONAL COMPUTER SYSTEM

- Computers have undergone many changes recently.
- Machines that once filled large areas reduced to small desktop computer systems because of the microprocessor.

- Figure 1–6 shows block diagram of the personal computer.
- Applies to any computer system, from early mainframe computers to the latest systems.
- Diagram composed of three blocks interconnected by buses.
  - a **bus** is the set of common connections that carry the same type of information

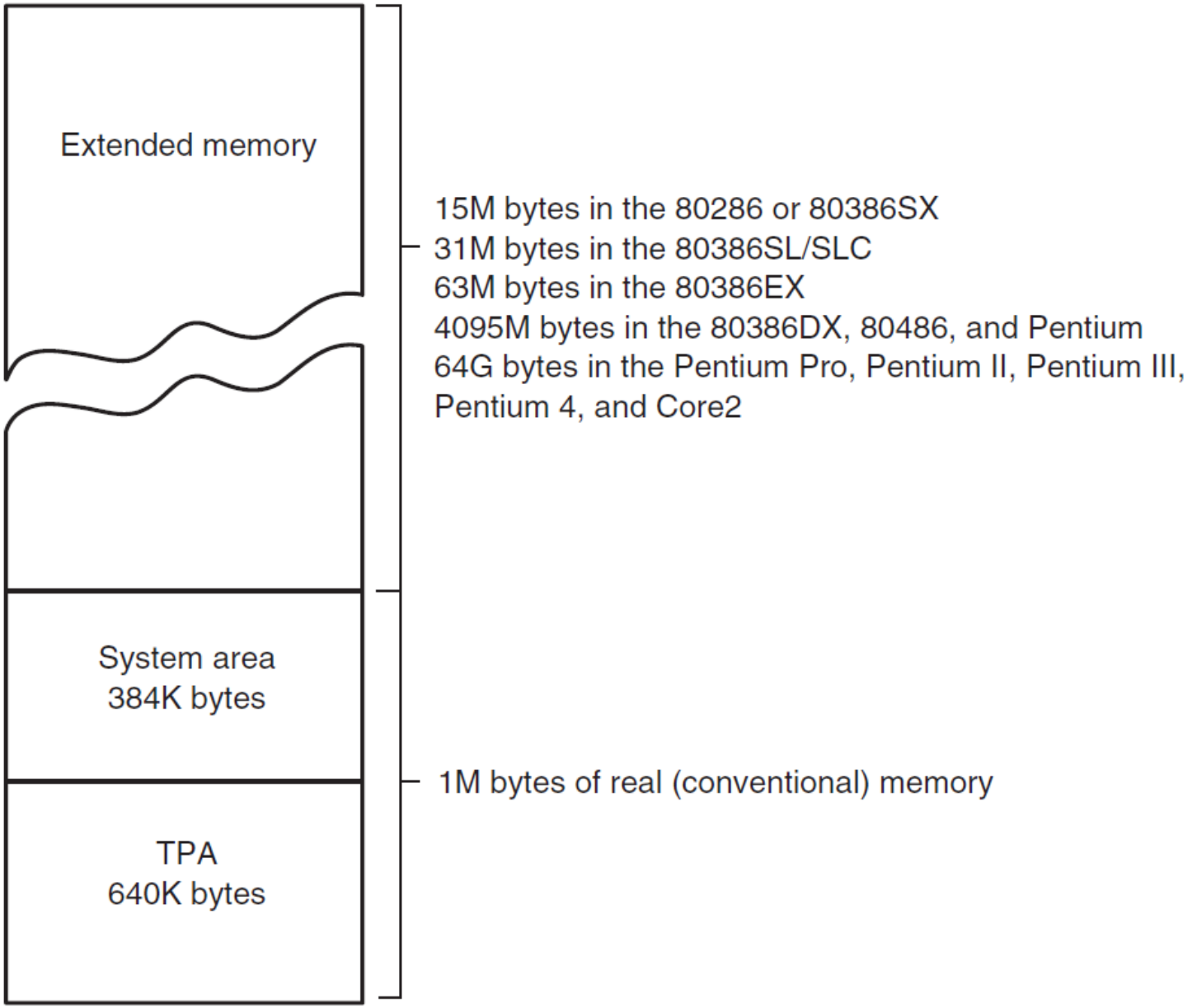
Figure 1–6 The block diagram of a microprocessor-based computer system.



The Memory and I/O System

- Memory structure of all Intel-based personal computers similar.
- Figure 1–7 illustrates memory map of a personal computer system.
- This map applies to any IBM personal computer.
  - also any IBM-compatible clones in existence

Figure 1–7 The memory map of a personal computer.

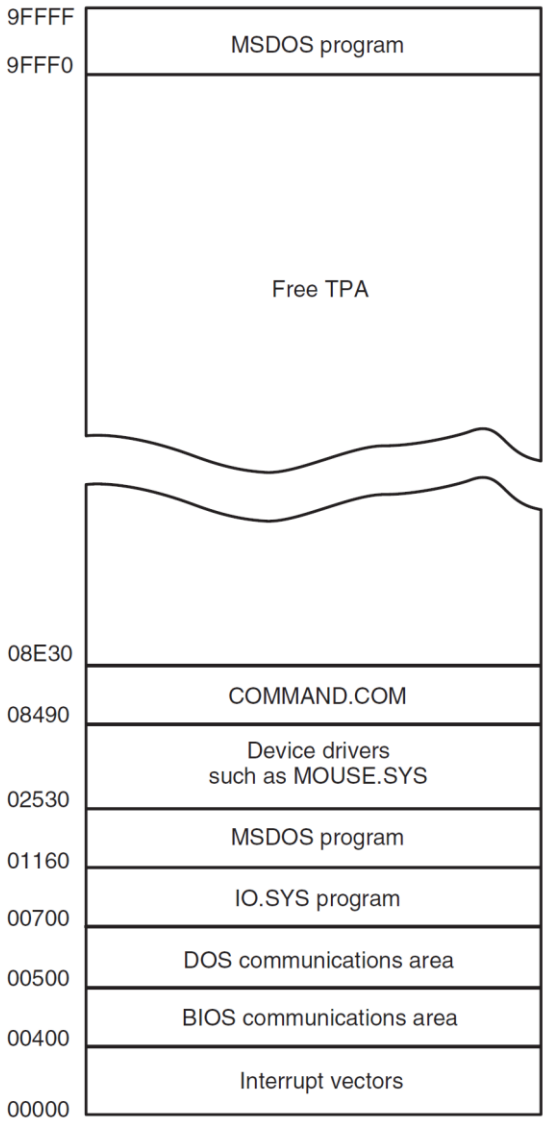


- Main memory system divided into three parts:
  - TPA (transient program area)
  - system area
  - XMS (extended memory system)
- Type of microprocessor present determines whether an extended memory system exists.
- First 1M byte of memory often called the real or conventional memory system.
  - Intel microprocessors designed to function in this area using real mode operation

The TPA

- The transient program area (TPA) holds the DOS (**disk operating system**) operating system; other programs that control the computer system.
  - the TPA is a DOS concept and not really applicable in Windows
  - also stores any currently active or inactive DOS application programs
  - length of the TPA is 640K bytes

Figure 1–8 The memory map of the TPA in a personal computer. (Note that this map will vary between systems.)

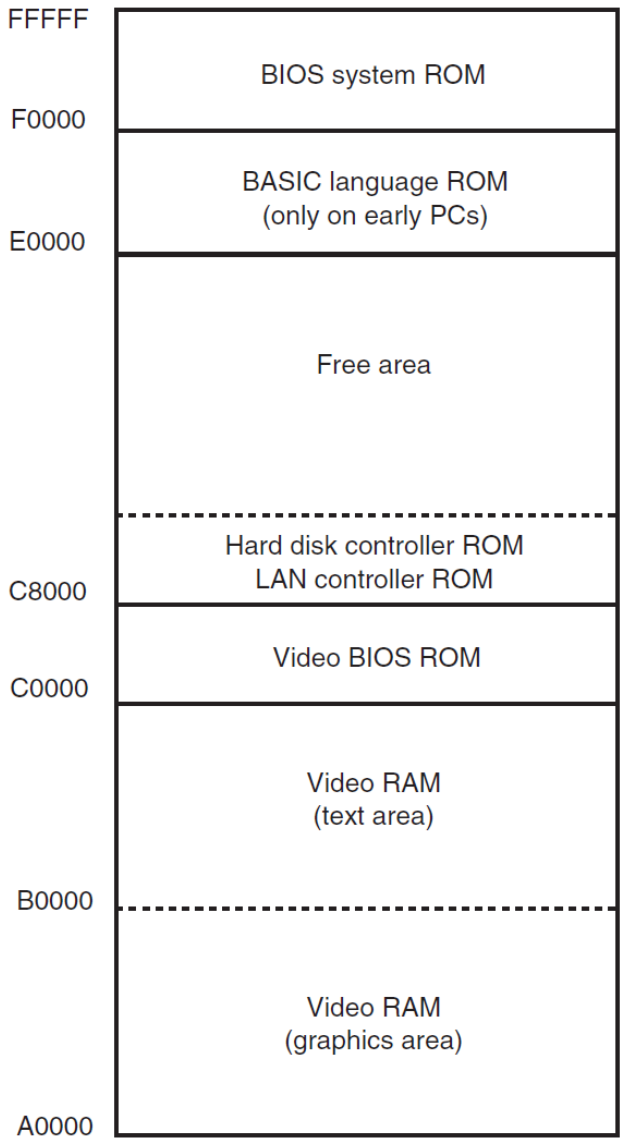


- DOS memory map shows how areas of TPA are used for system programs, data and drivers.
  - also shows a large area of memory available for application programs
  - hexadecimal number to left of each area represents the memory addresses that begin and end each data area

The System Area

- Smaller than the TPA; just as important.
- The **system area** contains programs on read-only (ROM) or flash memory, and areas of read/write (RAM) memory for data storage.
- Figure 1–9 shows the system area of a typical personal computer system.
- As with the map of the TPA, this map also includes the hexadecimal memory addresses of the various areas.

Figure 1–9 The system area of a typical personal computer.

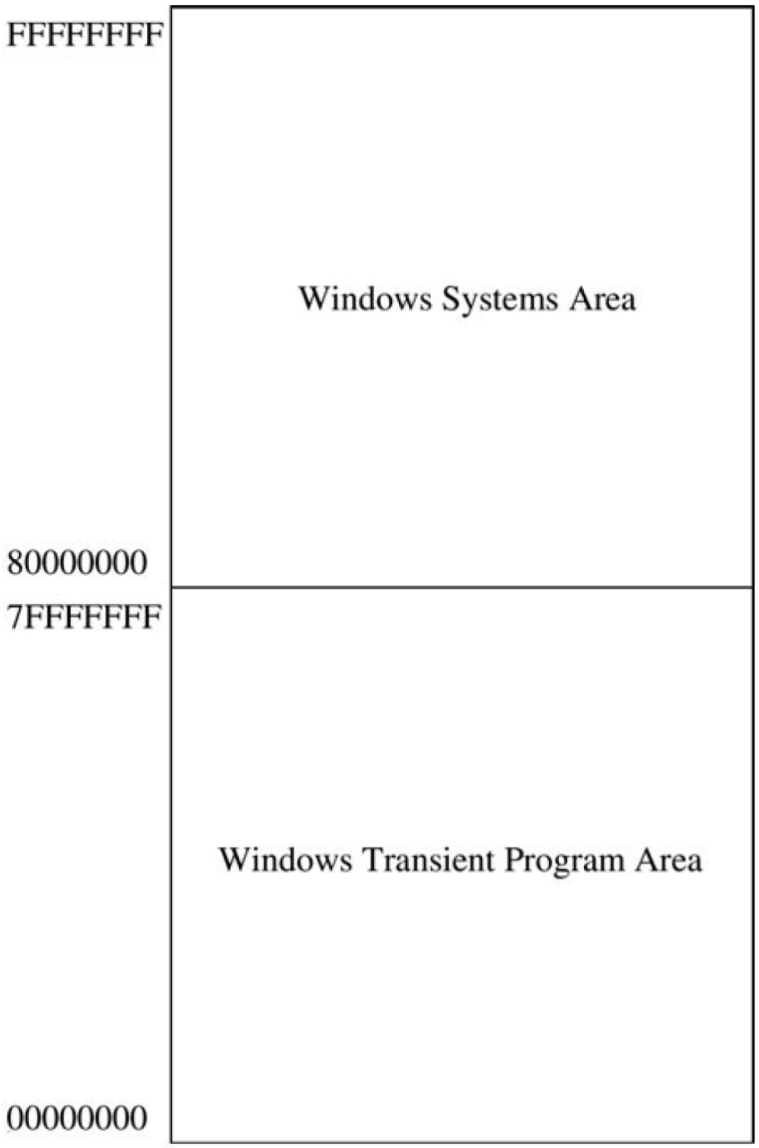


- First area of system space contains video display RAM and video control programs on ROM or flash memory.
  - area starts at location A0000H and extends to C7FFFH
  - size/amount of memory depends on type of video display adapter attached

Windows Systems

- Modern computers use a different memory map with Windows than DOS memory maps.
- The Windows memory map in Figure 1–10 has two main areas; a TPA and system area.
- The difference between it and the DOS memory map are sizes and locations of these areas.

Figure 1–10 The memory map used by Windows XP.

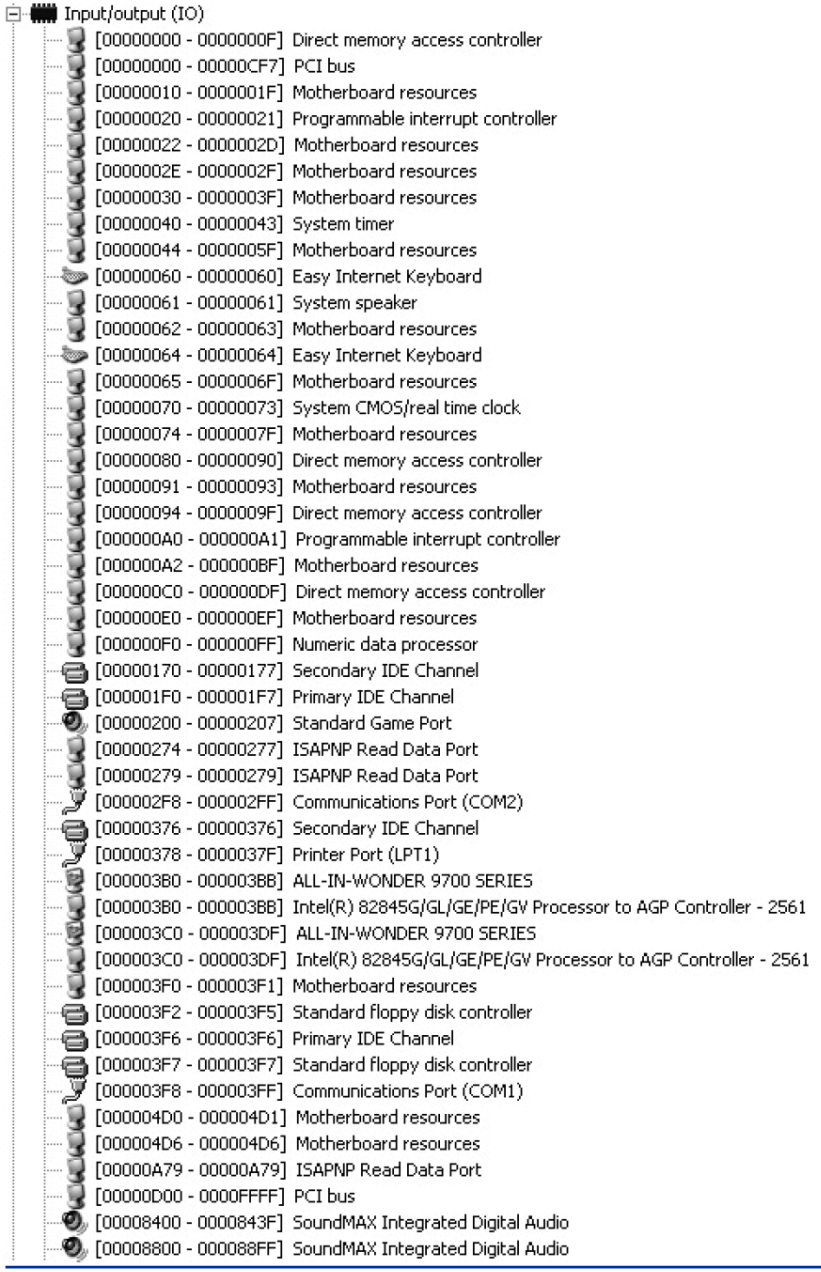


- TPA is first 2G bytes from locations 00000000H to 7FFFFFFFH.
- Every Windows program can use up to 2G bytes of memory located at linear addresses 00000000H through 7FFFFFFFH.
- System area is last 2G bytes from 80000000H to FFFFFFFFH.

I/O Space

- I/O devices allow the microprocessor to communicate with the outside world.
- I/O (input/output) space in a computer system extends from I/O port 0000H to port FFFFH.
  - **I/O port address** is similar to a memory address
  - instead of memory, it addresses an I/O device
- Figure 1–11 shows the I/O map found in many personal computer systems.

Figure 1–11 Some I/O locations in a typical personal computer.



- Access to most I/O devices should always be made through Windows, DOS, or BIOS function calls.
- The map shown is provided as a guide to illustrate the I/O space in the system.

- The area below I/O location 0400H is considered reserved for system devices
- Area available for expansion extends from I/O port 0400H through FFFFH.
- Generally, 0000H - 00FFH addresses main board components; 0100H - 03FFH handles devices located on plug-in cards or also on the main board.
- The limitation of I/O addresses between 0000 and 03FFH comes from original standards specified by IBM for the PC standard.

The Intel Microprocessors: 8086/8088, 80186/80188, 80286, 80386, 80486 Pentium, Pentium Pro Processor, Pentium II, Pentium, 4, and Core2 with 64-bit Extensions Architecture, Programming, and Interfacing, Eighth Edition
Barry B. Brey