Intro to Microprocessors and Microcomputers

Content

- Microprocessor, microcontrollers and microcomputers
  - Communication within microcomputers
  - Registers
  - Process architecture
- CPU
- Data and program storage
  - Negative number representation
- Memory
  - Types

Microprocessor

- A CPU built into a single chip is called microprocessor.
- It contains arithmetic and logic unit (ALU), Instruction decode and control unit, Instruction register, Program counter (PC), clock circuit (internal or external), reset circuit (internal or external) and registers.
- For example, Intel 8085 is 8-bit microprocessor and Intel 8086/8088 is 16-bit microprocessor.

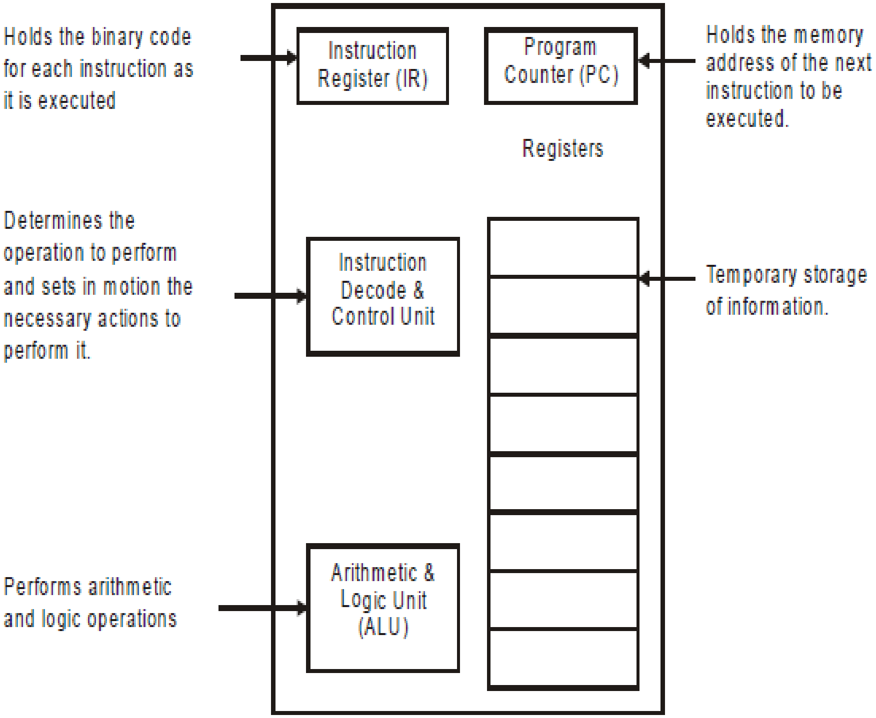
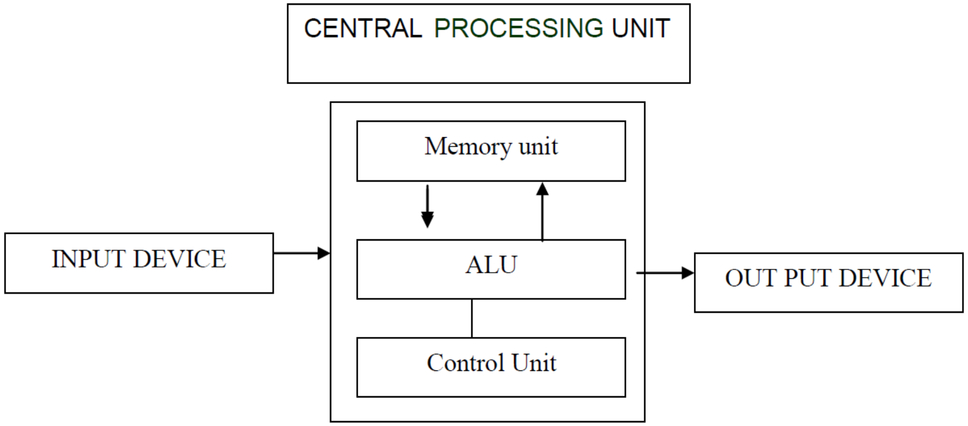


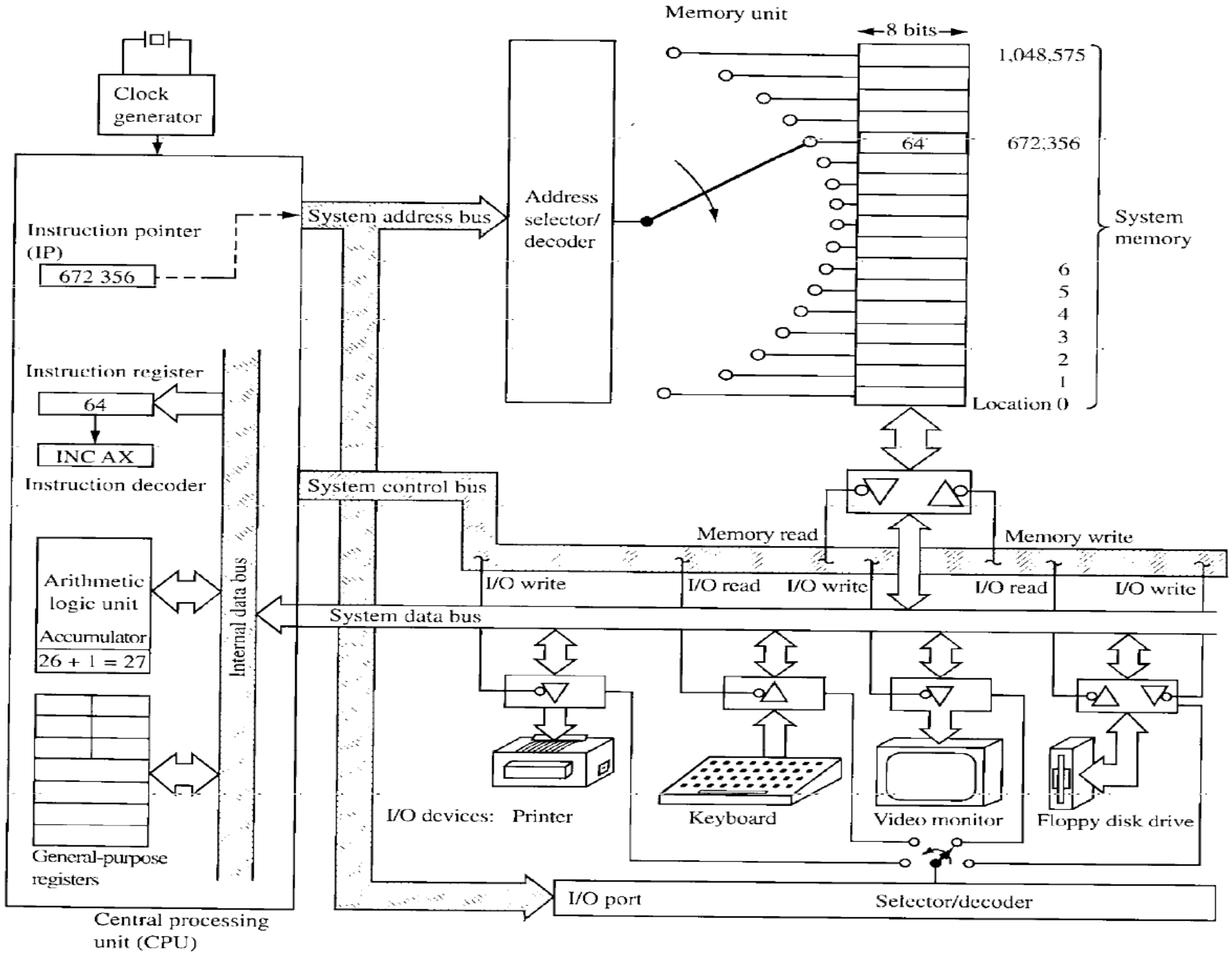
Figure 1.1 General block diagram of CPU (Microprocessor)

S.No.	Microprocessor	Date	Transistors	Clock speed	Data width
1	8080	1974	6000	2MHZ	8 bits
2	8088	1979	29,000	5 MHZ	16 bits 8-bit bus
3	80286	1982	134,000	6 MHZ	16 bits
4	80386	1985	275,000	16 MHZ	32 bits
5	80486	1989	1,200,000	25 MHZ	32 bits
6	Pentium I	1993	3,100,000	60 MHZ	32 bits 64-bit bus
7	Pentium II	1997	7,500,000	233 MHZ	32 bits 64-bit bus
8	Pentium III	1999	9,500,000	450 MHZ	32 bits 64-bit bus
9	Pentium 4	2000	42,000,000	1.5 GHZ	32 bits 64-bit bus
10	Pentium 4 “Prescott”	2004	125,000,000	3.6 GHZ	32 bits 64-bit bus

Microcomputer

- Input device : Reads information from input media and enters to the computer in a coded form
- CPU
  - Memory unit : Stores program and data
  - Arithmetic Logic unit : Performs arithmetic and logical functions
  - Control Unit : Interprets program instructions and controls the input and output devices
- Output device : decodes information and presents it to the user





Clock generator
Instruction pointer (IP)
672 356
System address bus
Address selector/ decoder
Memory unit
8 bits
1,048,575
64
672,356
System memory
6
5
4
3
2
1
Location 0
Instruction register
64
INC AX
Instruction decoder
Internal data bus
System control bus
Memory read
Memory write
I/O write
I/O read
I/O write
I/O read
I/O write
Arithmetic logic unit
Accumulator
26 + 1 = 27
System data bus
General-purpose registers
I/O devices: Printer
Keyboard
Video monitor
Floppy disk drive
I/O port
Selector/decoder
Central processing unit (CPU)

Microcontrollers

- A microcontroller is a highly integrated chip, which includes on single chip, all or most of the parts needed for a controller.
- The microcontroller typically includes: CPU (Central Processing Unit), RAM (Random Access Memory), EPROM/PROM/ROM (Erasable Programmable Read Only Memory), I/O (input/output) – serial and parallel, timers, interrupt controller. For example, Intel 8051 is 8-bit microcontroller and Intel 8096 is 16-bit microcontroller.

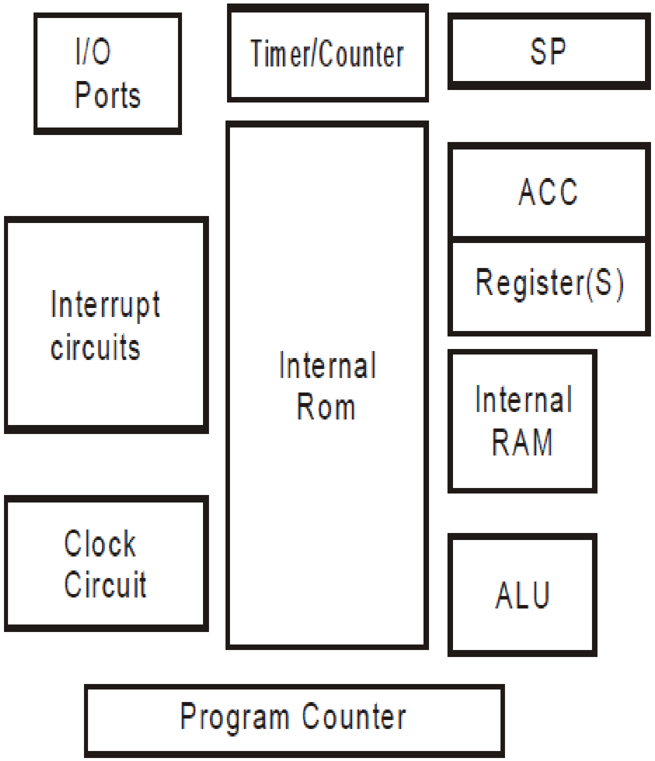


Figure 1.3 A block diagram of a microcontroller

Differences μprocessor and μcontroller

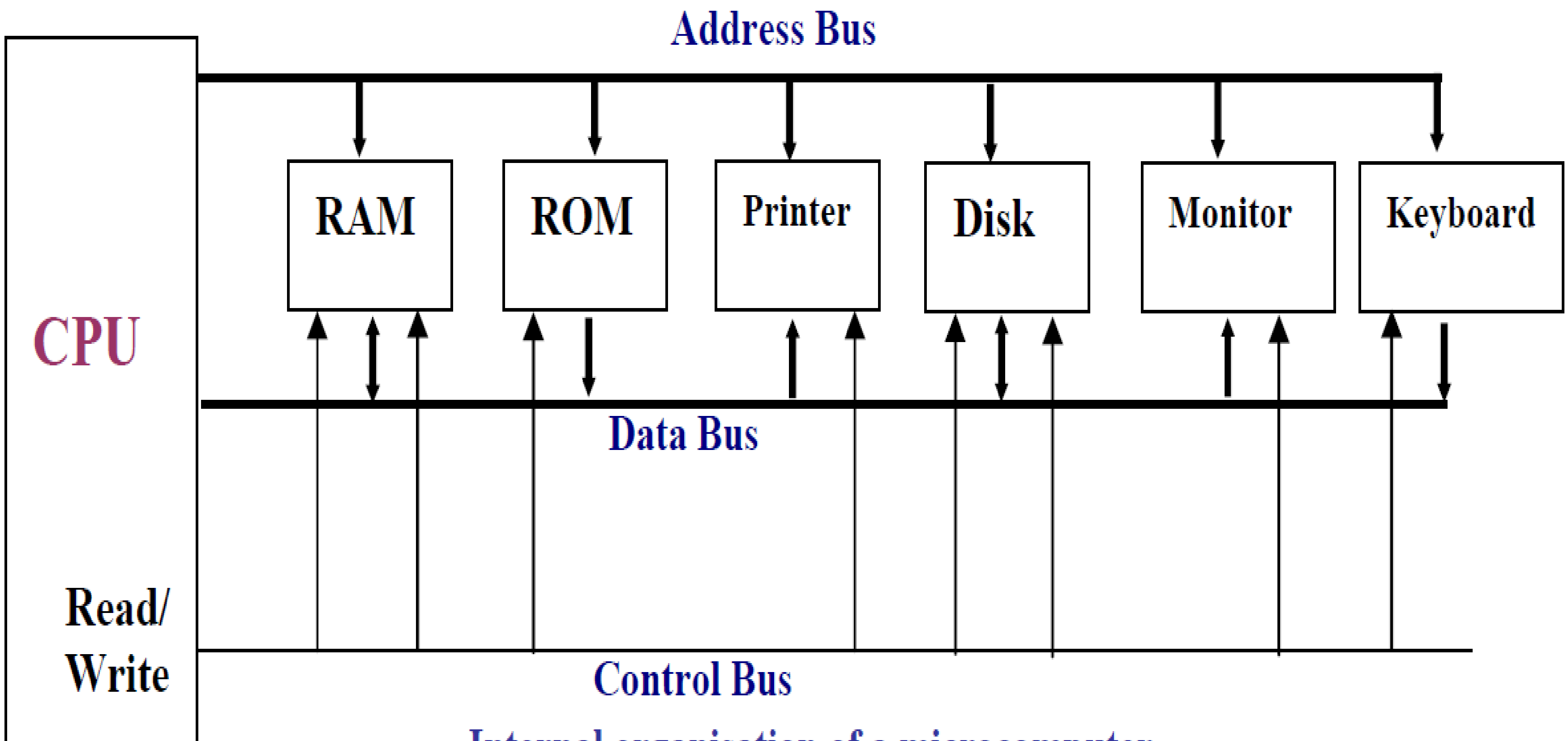
- Microprocessor is a single chip CPU, microcontroller contains, a CPU and much of the remaining circuitry of a complete microcomputer system in a single chip.
- Microcontroller includes RAM, ROM, serial and parallel interface, timer, interrupt schedule circuitry (in addition to CPU) in a single chip.
  - Interrupt system is an important feature, as microcontrollers have to respond to control oriented devices in real time. E.g., opening of microwave oven's door cause an interrupt to stop the operation.
- Microprocessors are most commonly used as the CPU in microcomputer systems. Microcontrollers are used in small, minimum component designs performing control-oriented activities.
- Microprocessor instruction sets are processing intensive, implying powerful addressing modes with instructions catering to large volumes of data. Their instructions operate on nibbles, bytes, etc. Microcontrollers have instruction sets catering to the control of inputs and outputs. Their instructions operate also on a single bit. E.g., a motor may be turned ON and OFF by a 1-bit output port.

CPU

- CPU is the brain of the computer system, administers all activity in the system and performs all operations on data. It continuously performs two operations: fetching and executing instructions. It understand and execute instructions based on a set of binary codes called the instruction set.
- To execute an instruction–the processor must:
  - Fetch the instruction from memory
  - Decode the instruction
  - Execute the instruction
  - Store the result back in the memory.

Memory cycle

Communication



Internal organisation of a microcomputer

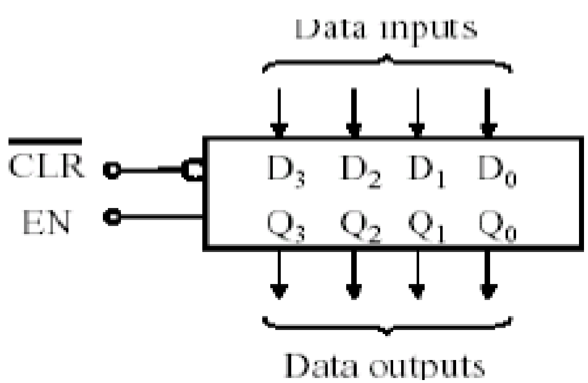
- Addressing range: An 8-bit address bus would be able to specify only 256 addresses

Processor

- Series of registers (index registers, instruction registers, process status registers)
- Some electronic circuitry to perform arithmetic and logical operations on the contents of registers
- Some circuitry to decode and execute sequence of instructions
- Buffers to interface the signal within the processor of the real world (address and data bus)
- A series of buses that join the various components together

Registers

- The register is a fundamental building block within a computer system for e.g.: the memory section of the computer consists of a large number of registers that can be used to store both data and programs.
- D-flip flop :when EN is high, the outputs follow the inputs, when EN goes low the outputs latch and hold the last D value

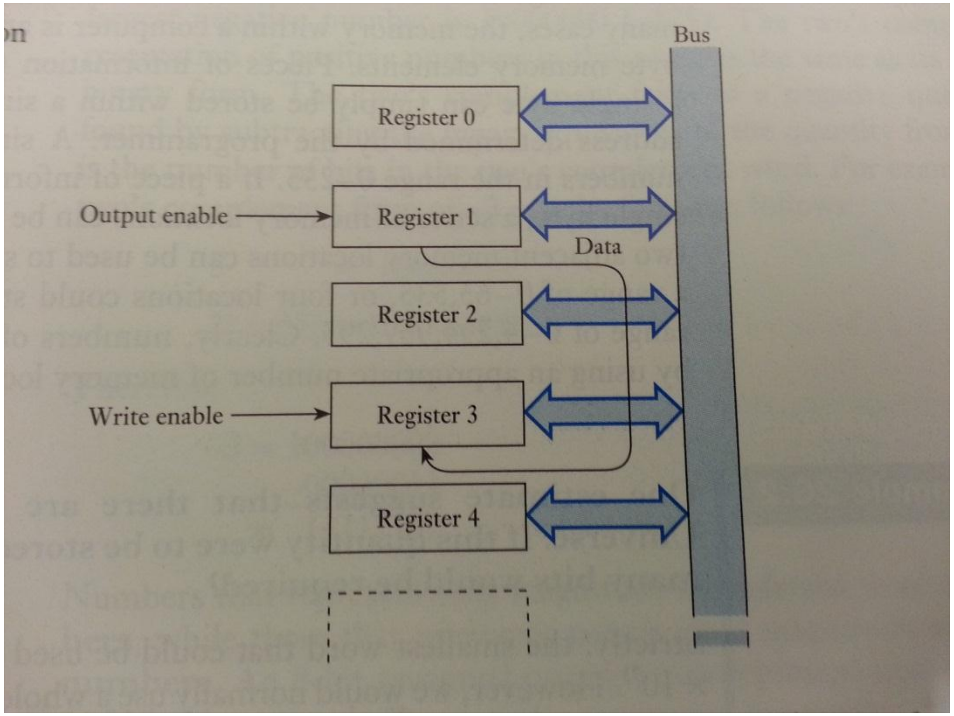


THE BUSES: ADDRESS, DATA, AND CONTROL

- ADDRESS BUS carries the address of a specified location. For n address lines, 2^n locations can be accessed. E.g., A 16-bit address bus can access $2^{16} = 65{,}536$ locations or 64K locations ($2^{10} = 1024 = 1K$, $2^6 = 64$).
- DATA BUS carries information between the CPU and memory or between the CPU and I/O devices.
- CONTROL BUS carries control signals supplied by the CPU to synchronize the movement of information on the address and data bus.

Data Busing

- Reading: The process of taking information from register and placing it on the bus.
- Writing: The process of storing information in a register



- The contents of any register can be parallel-transferred over the bus to any of the others

- E.g. to transfer [A]→ [C]:
- Only register A should have enabled outputs so,

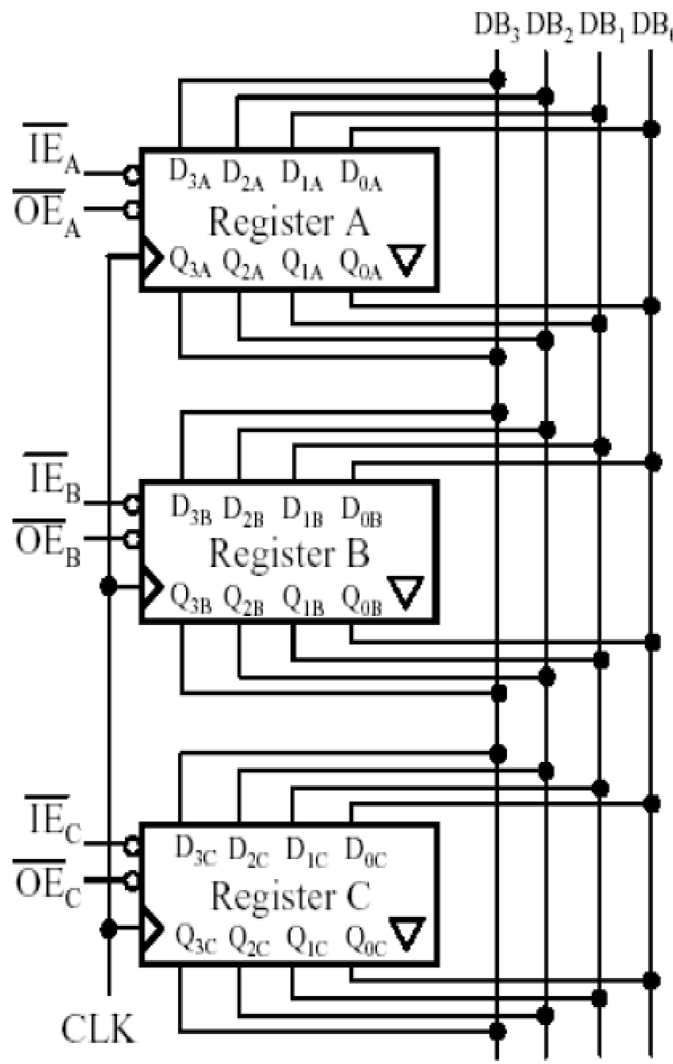
$$\overline{OE}_A=0 \ \& \ \overline{OE}_B=\overline{OE}_C=1$$

- This will cause the contents of A to appear on the data bus lines

- Next only C should have its inputs enabled so

$$\overline{IE}_C=0, \ \overline{IE}_A=\overline{IE}_B=1$$

- On the next rising clock edge C will latch the data from the bus



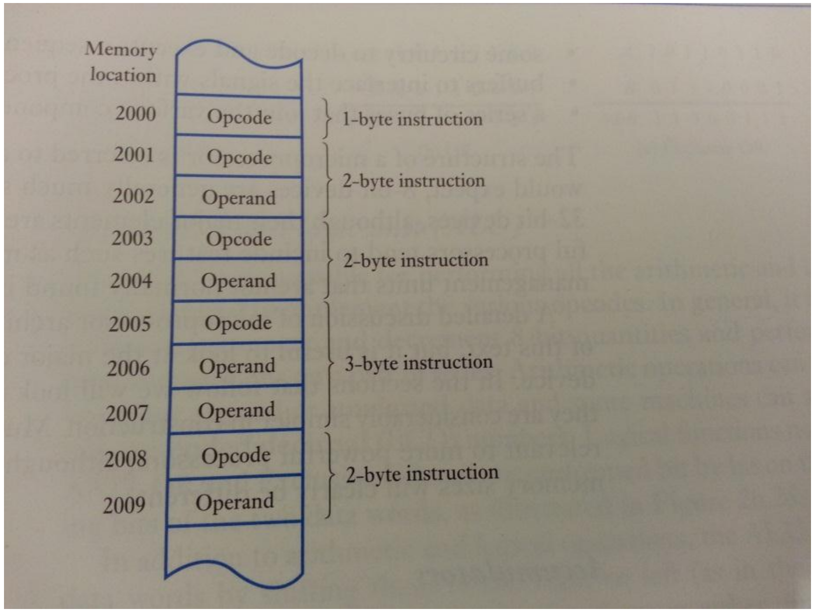
Data and program storage

- Number system: Decimal, binary, hexadecimal

- Negative number representation
- $101_2 = 5_{10}$ (positive) . .
- $0101_2 = 5_{10}$ (positive)
  - . | . Extra bit, representing sign (0=positive, 1=negative). .
- $1011_2 = -5_{10}$(negative)
  - . | . Extra bit, representing sign (0=positive, 1=negative)
- 8-bit representation: 00000011 = 3 and -3 is ?
- What is the range of 16 bit signed quantity?

Program

- A computer program is a list of instructions to the processor
- Instructions for transferring data between registers, transferring data between registers and memory, performing various arithmetic and logical operations, comparisons and test on register contents and controlling the sequence of program execution



- FETCHING AND EXECUTING AN INSTRUCTION
- Fetching involves the following steps:
  - Contents of PC are placed on address bus.
  - READ signal is activated.
  - Data (instruction opcode) are read from RAM and placed on data bus.
  - Opcode is latched into the CPU's internal instruction register.
  - PC is incremented to prepare for the next fetch from memory.
- While execution involves decoding the opcode and generating control to gate internal registers in and out of the ALU and to signal the ALU to perform the specified operation.

Architecture

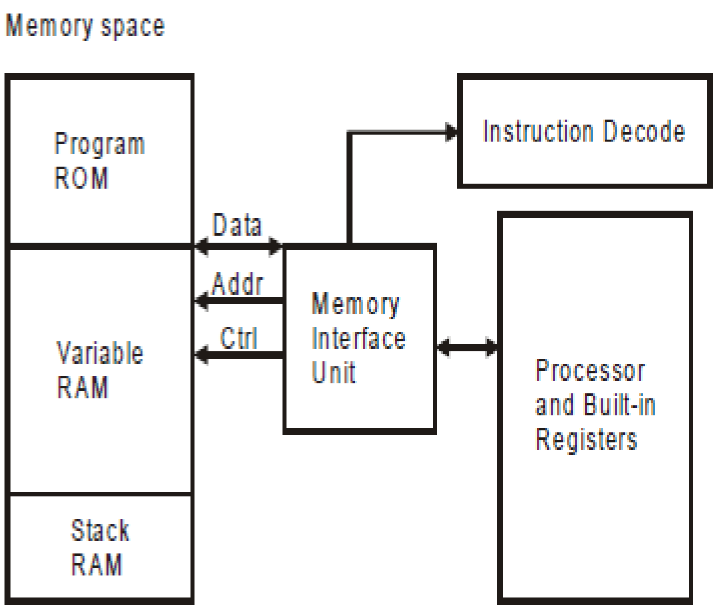


Figure 1.5 Von-neuman architecture block diagram

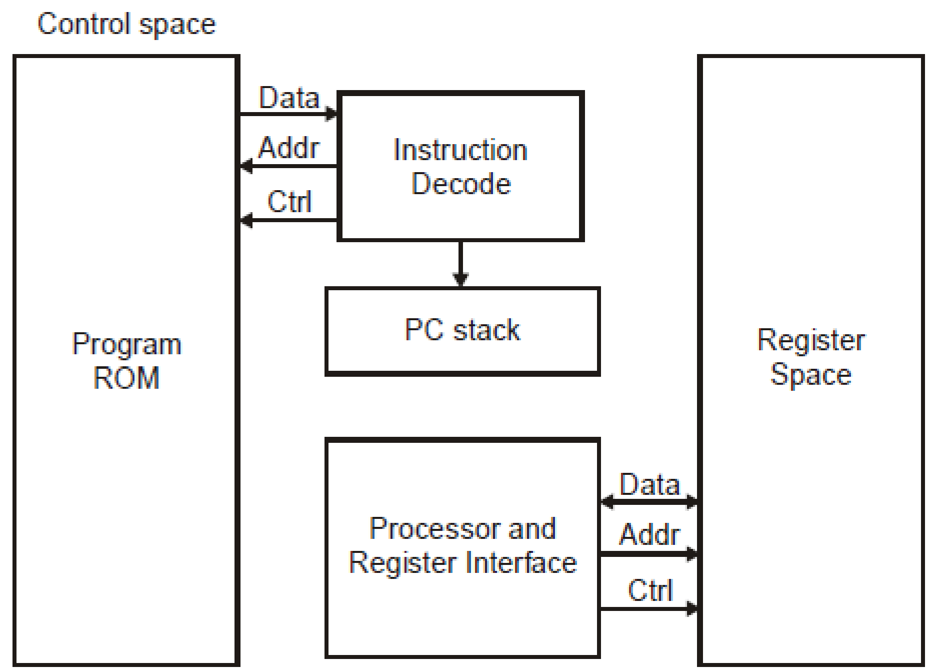


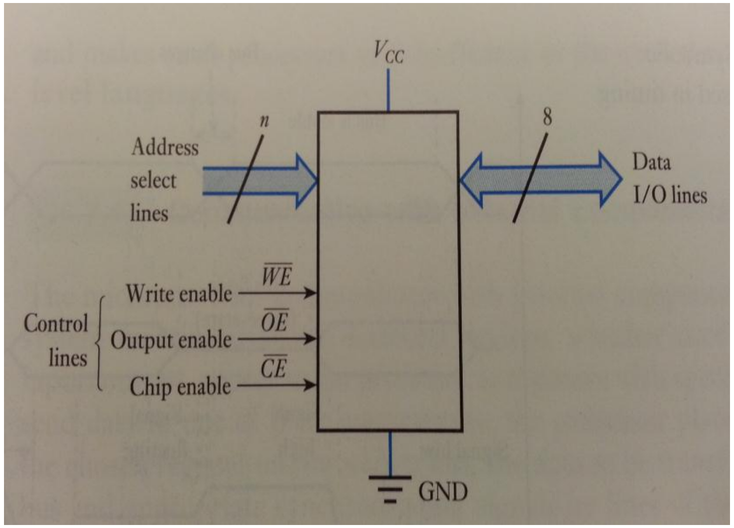
Figure 1.6 Harvard architecture block diagram

- Example : An Instruction "Read a byte from memory and store it in the accumulator" as follows:
- Cycle 1 :- Read instruction
- Cycle 2 - Read data out of RAM and put into Accumulator

- The same instruction would be executed as follows:
- Cycle 1: - Complete previous instruction - Read the "Move Data to Accumulator" instruction
- Cycle 2: - Execute "Move Data to Accumulator" instruction - Read next instruction

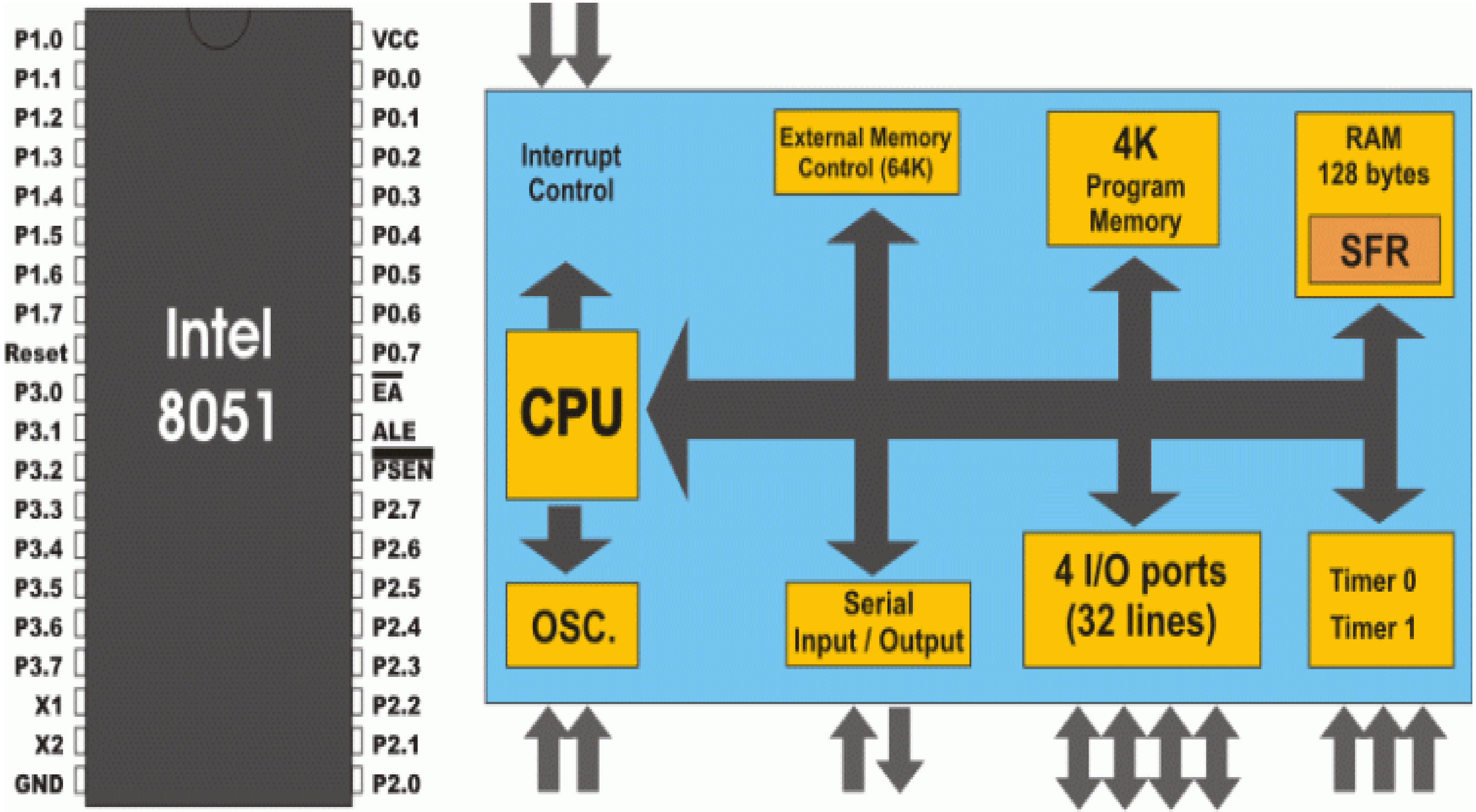
Memory

- Modern IC's may consists of millions of memory registers
- A device with 1024 8-bit memory would be called a 1kbyte memory and would have 10 address lines while a device with 4096 memory would be 4kbyte with 12 address lines



- Two of the controls are output enable and write enable which are invariably low hence $\overline{\text{OE}}$ and $\overline{\text{WE}}$
- Types:
  - Random Access Memory
  - Read Only Memory

Intel 8051



- 4 Kb of ROM is not much at all.
- 128b of RAM (including SFRs) satisfies the user's basic needs.
- 4 ports having in total of 32 input/output lines are in most cases sufficient to make all necessary connections to peripheral environment.

- Pins 1-8 and Pins10-17: Each of these pins can be configured as an input or an output. each of these pins can serve as general input or output. Besides, all of them have alternative functions. Pin 9: RS A logic one on this pin disables the microcontroller and clears the contents of most registers. In other words, the positive voltage on this pin resets the microcontroller.
- Pin 10-11: RXD and TXD Serial asynchronous communication input or Serial synchronous communication/clock output.
- Pin 12: INT0 Interrupt 0 input. Pin 13: INT1 Interrupt 1 input. Pin 14: T0 Counter 0 clock input. Pin 15: T1 Counter 1 clock input.
- Pin 16: WR Write to external (additional) RAM. Pin 17: RD Read from external RAM.
- Pin 18, 19: X2, X1 Internal oscillator input and output. A quartz crystal which specifies operating frequency is usually connected to these pins. Instead of it, miniature ceramics resonators can also be used for frequency stability. Later versions of microcontrollers operate at a frequency of 0 Hz up to over 50 Hz.
- Pin 20: GND Ground. Pin 40: VCC +5V power supply.
- Pin 21-28: Port 2 If there is no intention to use external memory then these port pins are configured as general inputs/outputs. In case external memory is used, the higher address byte, i.e. addresses A8-A15 will appear on this port. Pin 29: PSEN If external ROM is used for storing program then a logic zero (0) appears on it every time the microcontroller reads a byte from memory. Pin 30: ALE Prior to reading from external memory, the microcontroller puts the lower address byte (A0-A7) on P0 and activates the ALE output. Immediately after that, the ALU pin is returned its previous logic state and P0 is now used as a Data Bus. As seen, port data multiplexing is performed by means of only one additional (and cheap) integrated circuit. In other words, this port is used for both data and address transmission.
- Pin 31: EA By applying logic one to the EA pin, the microcontroller will use both memories, first internal then external (if exists).
- Pin 32-39: if external memory is not used, these pins can be used as general inputs/outputs. Otherwise, P0 is configured as address output (A0-A7)