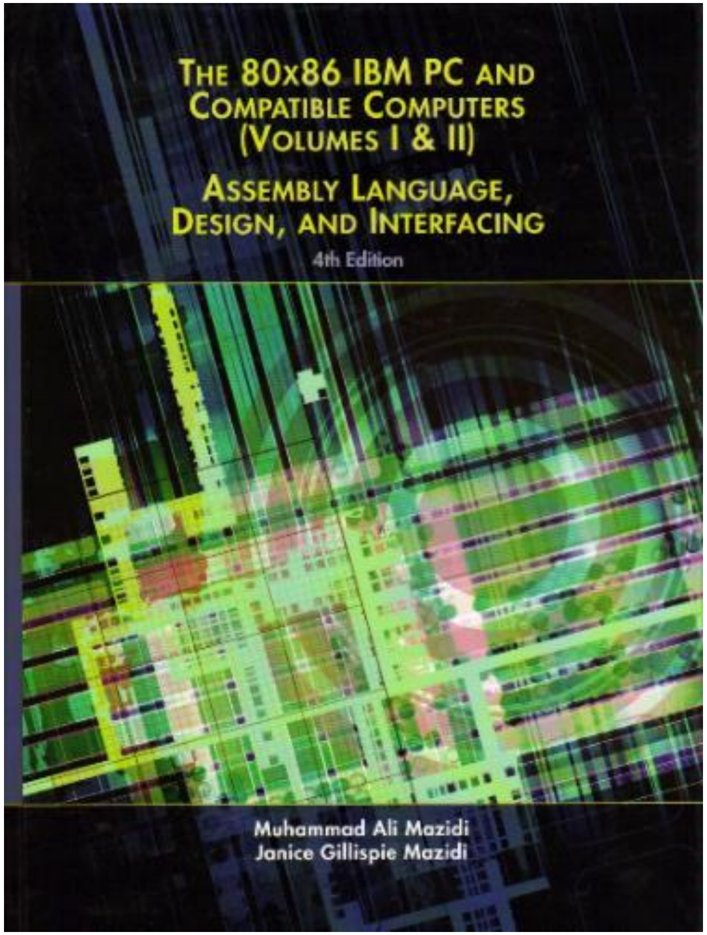

The 80x86 IBM PC and Compatible Computers:
Assembly Language, Design, and Interfacing

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Fall 2019/20 – Lecture Notes # 1

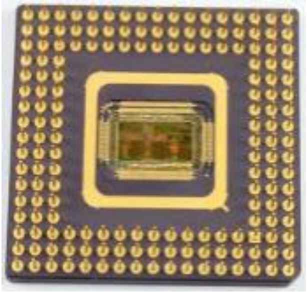
- Microcomputers and Microprocessors
- Evolution of Intel 80x86 Family Microprocessors
- Binary and Hexadecimal Number Systems

8086

Microcomputers and Microprocessors

There are **three** main components of a **Computer System**.

- ***Central Processing Unit (CPU):*** Also simply called as the microprocessor acts as the brain coordinating all activities within a computer.
- ***Memory:*** The program instructions and data are primarily stored.
- ***Input/output (I/O) Devices:*** Allow the computer to input information for processing and then output the results. I/O Devices are also known as computer peripherals.



- The integrated Circuit (IC) chip containing the CPU is called the ***microprocessor***.
- A microcomputer is a relatively smaller computer with a central processing unit (***CPU***) as a ***microprocessor***. A microcomputer is typically used as a personal computer (PC) which is smaller than a mainframe computer.

Microcomputers and Microprocessors

The CPU is connected to memory and I/O devices through a strip of wires called a ***bus***. The bus inside a computer carries information from place to place. There are three types of busses:

1. ***Address Bus:*** The address bus is used to identify the memory location or I/O device the processor intends to communicate with. The width of the Address Bus rages from **20 bits (8086)** to **36 bits for (Pentium II).**
2. ***Data Bus:*** Data bus is used by the CPU to get data from / to send data to the memory or the I/O devices. The width of a microprocessor is used to classify the microprocessor. The size of data bus of Intel microprocessors vary between **8-bit (8085)** to **64-bit (Pentium).**
3. ***Control Bus:*** How can we tell if the address on the bus is memory address or an I/O device address? This is where the control bus comes in. Each time the processor outputs an address it also activates one of the four control bus signals: **Memory Read**, **Memory Write**, **I/O Read** and **I/O Write**.

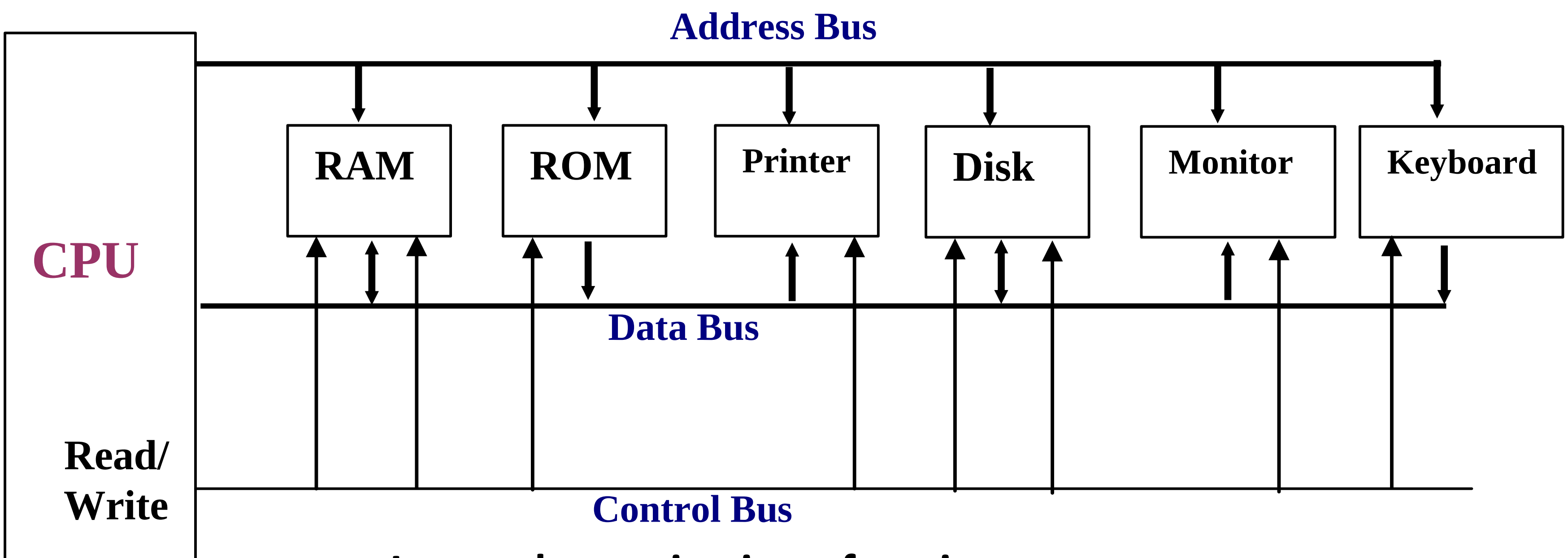
The ***address and control bus*** contains output lines only, therefore it is ***unidirectional***, but the ***data bus*** is ***bidirectional***.

Microcomputers and Microprocessors

There two types of memory used in microcomputers:

- ***RAM*** **(Random Access Memory/ Read-Write memory)** is used by the computer for the temporary storage of the programs that is running. Data is lost when the computer is turned off. So known as ***volatile*** memory.
- ***ROM*** **(Read Only Memory)** the information in ROM is permanent and not lost when the power is turned off. Therefore, it is called ***nonvolatile*** memory.

Note that RAM is sometimes referred as ***primary storage***, where magnetic /optical disks are called ***secondary storage***.



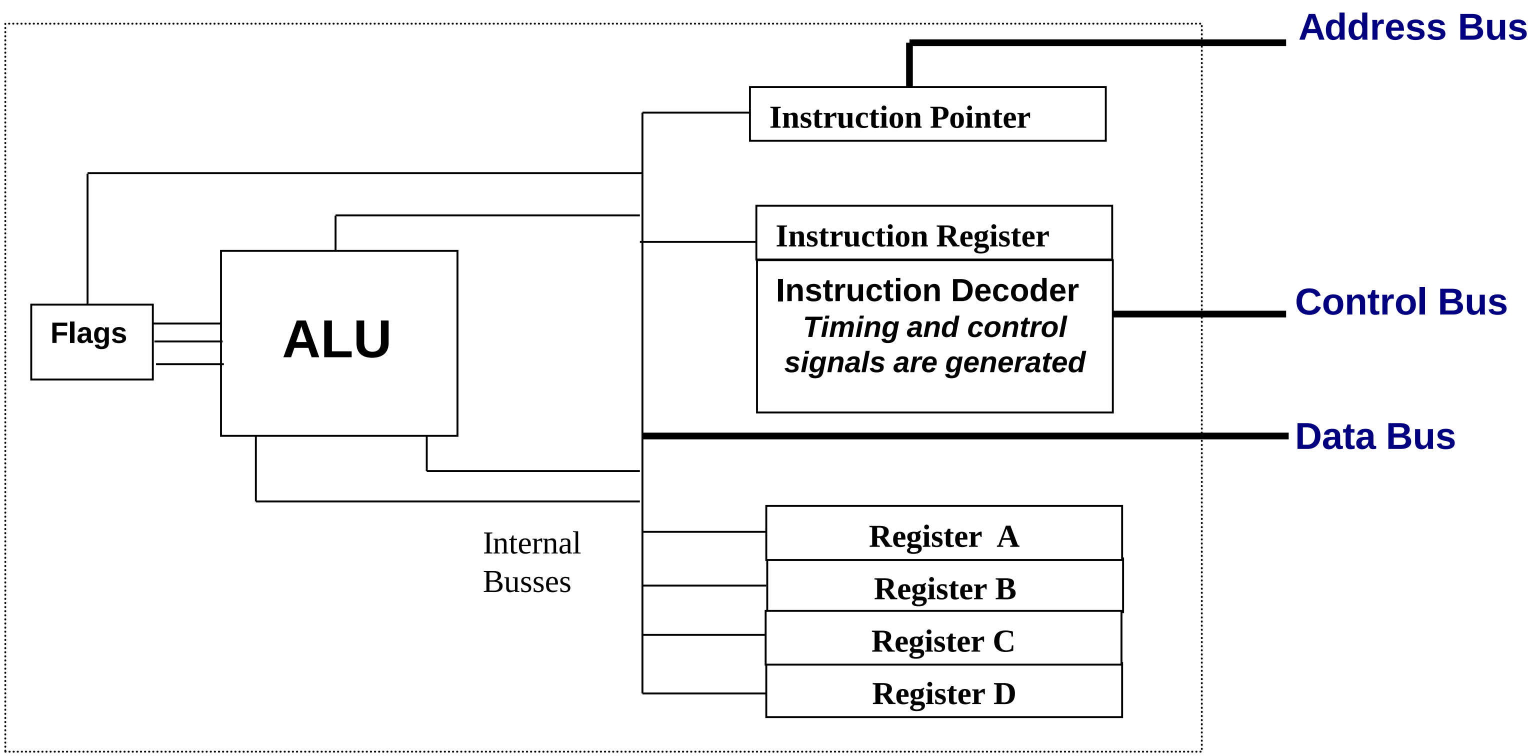
Internal organisation of a microcomputer

Inside the CPU:

A program stored in the memory provides instructions to the CPU to perform a specific action. This action can be a simple addition. It is function of the CPU to ***fetch*** the program instructions from the memory and ***execute*** them.

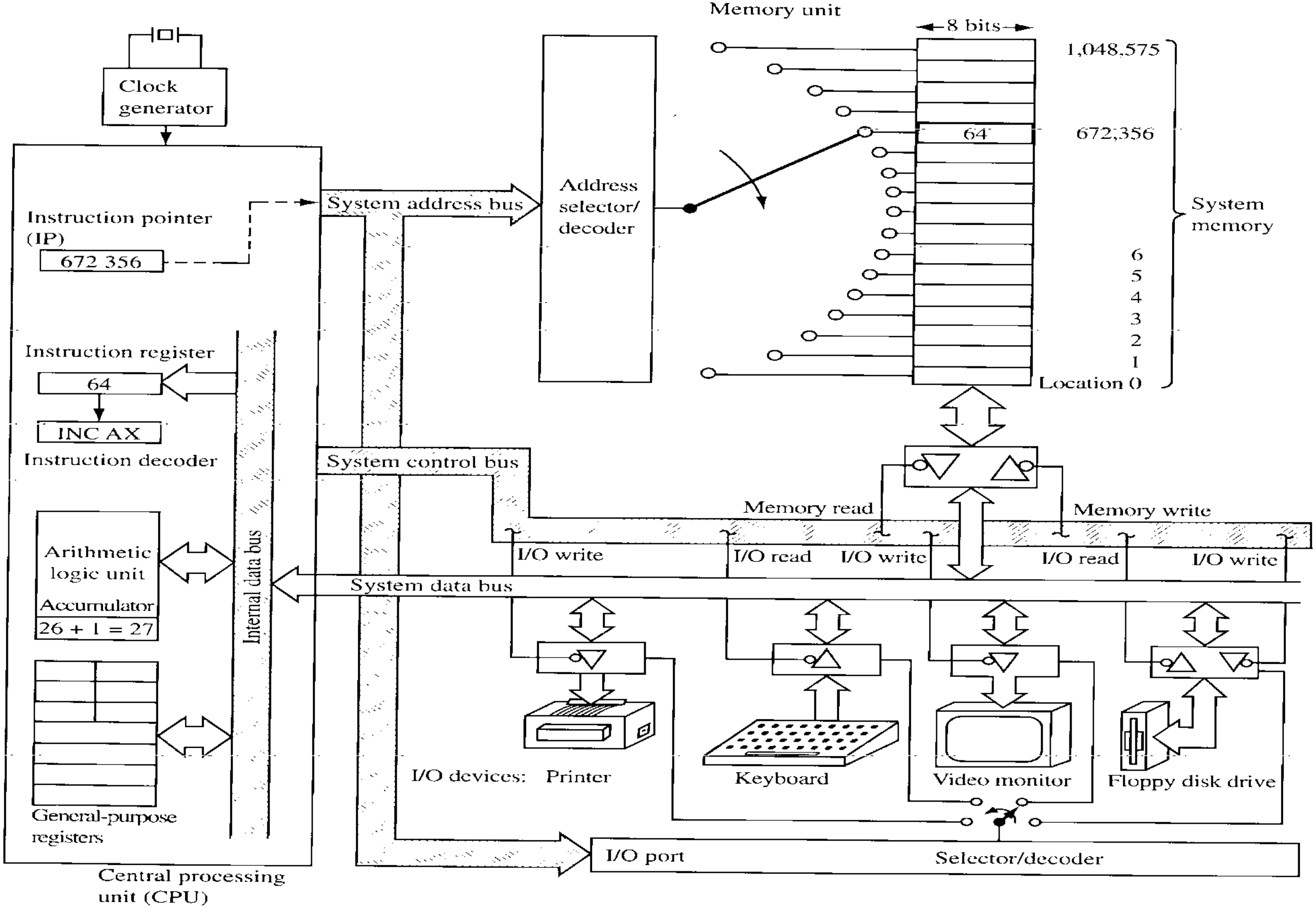
- The CPU contains a number of ***registers*** to store information inside the CPU temporarily. Registers inside the CPU can be 8-bit, 16-bit, 32-bit or even 64-bit depending on the CPU.
- The CPU also contains ***Arithmetic and Logic Unit (ALU).*** The ALU performs arithmetic (add, subtract, multiply, divide) and logic (AND, OR, NOT) functions.
- The CPU contains a program counter also known as the ***Instruction Pointer*** to point the address of the next instruction to be executed.
- ***Instruction Decoder*** is a kind of dictionary which is used to interpret the meaning of the instruction fetched into the CPU. Appropriate control signals are generated according to the meaning of the instruction.

Inside the CPU:



Internal block diagram of a CPU

The interaction between the CPU, memory and I/O Devices.



Brief History of the Computers

- **1946:** The first generation of Computer **ENIAC** was started to be used based on the vacuum tube technology.
- **1958:** The first transistorized computer **TRADIC** was announced by IBM.
- **1959:** The first **IC (integrated circuit)** was invented.
- **1960s:** ICs were started to be used in **CPU boards**.
- **1970s:** Entire CPU was put in a single chip. (**1971** the first microprocessor of **Intel 4004** (4-bit data bus and 2300 transistors).
- **1974:** Motorolla **6800** is introduced with **8-bit data** bus and **16-bit address bus**.
- **Late 1970s:** Intel **8080/85** appeared with **8-bit data** bus and **16-bit address bus** and used from traffic light controllers to homemade computers.
- **1978:** Intel **8086** is produced with **16-bit data** bus and **20-bit address bus**.
- **1981:** First **PC** was introduced by IBM with Intel **8088** microprocessor.
- Apple Macintosh computers started to use 68000 series of microprocessors.

Evolution of Intel 80x86 Family Microprocessors

Processor	Year Intro.	Transistors	Clock Rate (MHz.)	External Data Bus	Internal Data Bus	Add. Bus
4004	1971	2,250	0.108	4	8	12
8008	1972	3,500	0.200	8	8	14
8080	1974	6,000	3	8	8	16
8085	1976	6,000	6	8	8	16
8086	1978	29,000	10	16	16	20
8088	1979	29,000	10	8	16	20
80286	1982	134,000	12.5	16	16	25
80386DX	1985	275,000	33	32	32	32
80386SX	1988	275,000	33	16	32	24
Pentium C	1993	3,100,000	66 -200	64	32	32
Pentium MMX	1997	4,500,000	300	64	32	32
Pentium Pro	1995	5,500,000	200	64	32	36
Pentium II	1997	7,500,000	233-450	64	32	36
Pentium III	1999	9,500,000	550-733	64	32	36
Itanium	2001	30,000,000	800-…	128	64	64

Binary and Hexadecimal Number Systems

- As human being we use ***base 10* (decimal)** arithmetic
- Computers use ***base 2* (binary)** system.
- ***Base 16* (Hexadecimal)** number system is a convenient way of represented binary numbers.
- ***ASCII*** (binary format of the alphanumeric code) is used to represent alpha-numerical characters.

Decimal and Binary number systems:

- There is a speculation of the fact that Humans use base 10 system is because they have 10 fingers. But there is no speculation behind the fact that the computers use binary system. The binary system is used in computers, because 1 and zero represent the two voltage levels of ON and OFF.
- There are **10 digits** in Decimal system: **0,1,2,3,4,5,6,7,8,9**
- There are only **2 digits** in Binary system: **0,1** (**Bi**nary digi**t** is referred as **bit**)

Converting from Decimal to Binary

Example: Convert **25_{10}** to binary:

			Remainder	
25/2	=	12	**1**	LSB (least significant bit)
12/2	=	6	**0**	
6/2	=	3	**0**	
3/2	=	1	**1**	
1/2	=	0	**1**	MSB (most significant bit)

Therefore, **$25_{10} = 11001_2$**

Converting from Binary to Decimal

Example: Convert 110101_2 to decimal:

110101_2 =

			Decimal
$1x2^0$	=1x1	=	1
$0x2^1$	=0x2	=	0
$1x2^2$	=1x4	=	4
$0x2^3$	=0x8	=	0
$1x2^4$	=1x16	=	16
$1x2^5$	=1x32	=	+ 32
			53

110101_2 = **53_{10}**

Hexadecimal Number system:

Hexadecimal system is defined to be the **base 16** number system and is used as a convenient representation of binary numbers.

Hexadecimal	Binary	Decimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
A	1010	10
B	1011	11
C	1100	12
D	1101	13
E	1110	14
F	1111	15

- **Converting from binary to hex (hexadecimal):**

Example: Convert 100111110101_2 to hex:

1001 1111 0101

= 9 F 5

Therefore, 100111110101_2 = **9F5 Hex**

- **Converting from hex to binary:**

Example: Convert hex 29B to binary:

2 9 B

= 0010 1001 1011 Dropping zeros, 29B = **1010011011**

Converting from Decimal to Hex (Hexadecimal)

Example: Convert 45_{10} to hex:

		Quotient	Remainder	
45/16	=	2	13 (hex D)	LSD (least significant bit)
2/16	=	0	2	MSD (most significant bit)

Therefore, $\mathbf{45_{10}} = 2D_{16}$ **= 2DH** **(Abbreviation H is used to indicate Hexadecimal)**

Converting from Hex to Decimal

Example: Convert $6B2_{16}$ to decimal:

$6B2_{16}$ =

			Decimal
2×16^0	$= 2 \times 1$	=	2
11×16^1	$= 11 \times 16$	=	176
6×16^2	$= 6 \times 256$	=	+ 1536
			1714

Therefore, $\mathbf{6B2_{16}} = \mathbf{1714_{10}}$

Addition in binary numbers

Example:

```
   1101
   1001
+ 10110
 101100
```

A + B	Carry	Sum
0 + 0	0	0
0 + 1	0	1
1 + 0	0	1
1 + 1	1	0

Binary Addition

Subtraction of Binary Numbers

Given binary numbers x and y. x–y is performed by taking 2's complement of y and adding to x.

Example: 11001001 – 10011101 => 2's comp. of 10011101= 01100010 (1's comp.)

```
+        1
  01100011  (2's comp.)
```

```
    11001001
+   01100011
  1 00101100   (ignore the carry)
```

11001001 – 10011101 = **00101100**

Addition and Subtraction of Hex numbers

Addition Example :

23D9	LSD : 9 + 14= 23	23-16= **7** with a carry to next digit
+ 94BE	1+13+11= 25	25-16= **9** with a carry to next digit
B897	1+3+4=	**8**
	MSD 2 + 9=	**B**

Subtraction Example :

59F	LSD : 15 - 8	=	**7**
– 2B8	25 (9+16) – 11 (B)	= 14, which is	**E**
2E7	MSD 4 (5–1) –2	=	**2**

ASCII Code : (American Standard Code for Information Interchange)

Hex	Symbol	Hex	Symbol
41	A	61	a
42	B	62	b
43	C	63	c
44	D	64	d
45	E	65	e
46	F	66	f
47	G	67	g
48	H	68	h
49	I	69	i
4A	J	6A	j
4B	K	6B	k
4C	L	6C	l
4D	M	6D	m
4E	N	6E	n
4F	O	6F	o
50	P	70	p
51	Q	71	q
52	R	72	r
53	S	73	s
54	T	74	t
55	U	75	u
56	V	76	v
57	W	77	w
58	X	78	x
59	Y	79	y
5A	Z	7A	z

Some important terminology

Bit	**0**
Nibble (4 bits)	**0000**
Byte (8 bits)	**0000 0000**
Word (16 bits)	**0000 0000 0000 0000**
double-word (32 bits)	**0000 0000 0000 0000 0000 0000 0000 0000**
quad-word (64 bits)	**0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000**

1 kilobyte (KB) is **2^{10}** bytes - **1,024 bytes**

1 megabyte (MB) is **2^{20}** bytes - **1,048,576 bytes** (a little over 1 million)

1 gigabyte (GB) is **2^{30}** bytes - **1,073,741,824 bytes** (over 1 billion)

1 terabyte (TB) is **2^{40}** bytes - **1,099,511,627,776 bytes** (over trillion)

1 petabyte (PB) is **2^{50}** bytes – **1,125,899,906,842,624** bytes (over quadrillion)