Basics of Digital Electronics

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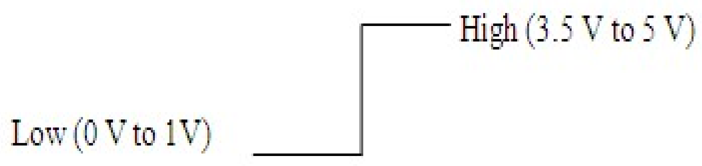
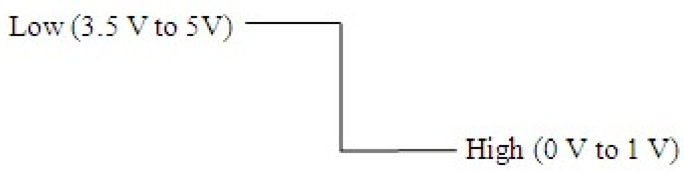
Digital Signals

- An electrical signal with two discrete levels (high and low)
- Two discrete levels are represented by binary digits 0 and 1 referred as Binary number system.
- Gorge Boole introduced binary number system with algebra developed "Boolean Algebra"
- Represented in two different ways
  - Positive logic system



  - Negative logic system



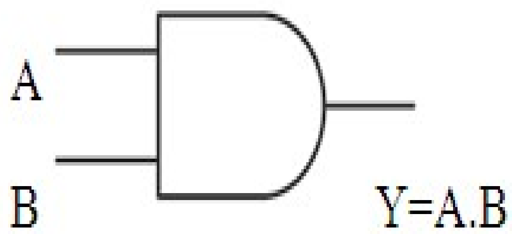
Digital system types

- Combinational logic system/circuits
  - An output at any instant depends only on inputs applied at that instant.
  - Example – Adder, subtractor, Comparator etc
  - Basic building block – logic gates

- Sequential logic system/circuits
  - An output at any instant depends only on inputs applied at that instant as well as on past inputs/outputs.
  - Example – counters, sequence generator/ detector etc
  - Requires memory
  - Basic building block – Flips and logic gates

Logic Gates

- Basic logic gates
  - **AND gate**
    - Logical Multiplication
    - Two input gate shown

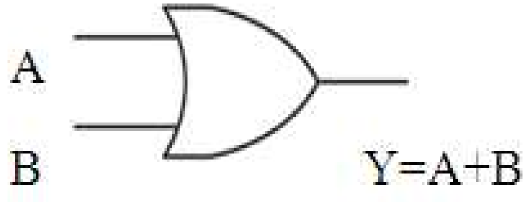


Input A (logic)	Input B (logic)	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

Basic logic gates

OR gate

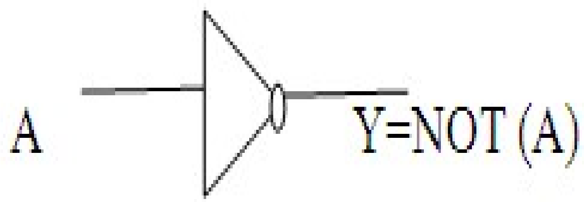
- Logical Addition
- Two input gate shown



Input A (logic)	Input B (logic)	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

NOT/Inversion gate

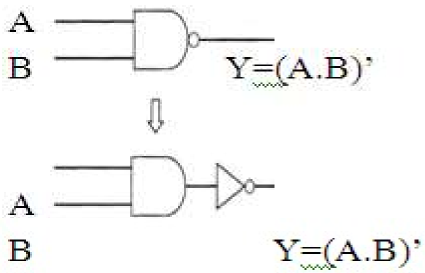
- Logical inversion
- Single input single output gate



Input A (Logic)	Y
0	1
1	0

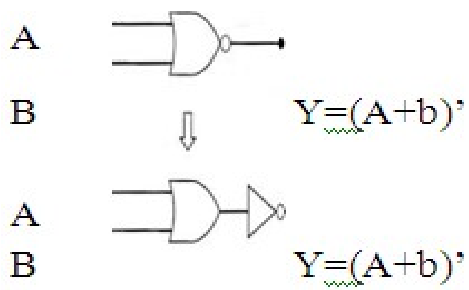
•Universal logic gates

- **NAND gate**
  - Two input gate shown



Input A (logic)	Input B (logic)	Y=(A.B)'
0	0	1
0	1	1
1	0	1
1	1	0

- **NOR gate**
  - Two input gate shown



Input A (logic)	Input B (logic)	Y=(A.B)'
0	0	1
0	1	0
1	0	0
1	1	0

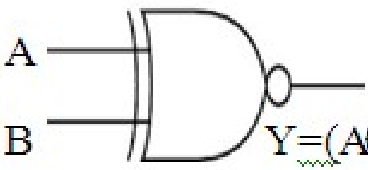
Special gates

- **Ex-OR gate**
  - Two input gate shown

$Y = A \oplus B$

Input A (logic)	Input B (logic)	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	0

- **Ex-NOR gate**
  - Two input gate shown



$Y = (A \oplus B)'$

Input A (logic)	Input B (logic)	Y=A+B
0	0	1
0	1	0
1	0	0
1	1	1

Boolean Algebra

- Mathematician George Boole developed rules for manipulation of binary variables.
- Rules :
  - $A+0=A$
  - $A+1=1$
  - $A+A=A$
  - $A+A'=1$
  - $A.0=0$
  - $A.1=A$
  - $A.A=A$
  - $A.A'=0$
  - $A.(B+C)=AB+AC$

Boolean Algebra

- A+BC=(A+B).(A+C)
- A+A.B=A
- A.(A+B)=A
- A+A’.B=A+B
- A.(A’+B)=A.B
- A.B+A’.B’=A
- (A+B).(A+B’)=A
- A.B+A.C’=(A+C).(A’+B)
- (A+B).(A’+C)=AC+A’B
- AB+A’C+BC=AB+A’C
- (A+b).(A’+C).(B+C)=(A+B).(A’+C)

De Morgan's Theorem

- $(A.B)' = A' + B'$
- $(A+B)' = A'.B'$

Number System

Number System	Base or radix	Symbols used (d_i or d_{-f})	Weight assigned to position		Example
			i	-f	
Binary	2	0,1	2^i	2^{-f}	10101.10
Octal	8	0,1,2,3,4,5,6,7	8^i	8^{-f}	3547.25
Decimal	10	0,1,2,3,4,5,6,7,8,9	10^i	10^{-f}	974.27
Hexadecimal	16	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F	16^i	16^{-f}	FA9.46

Quantities/Counting

Decimal	Binary	Octal	Hexadecimal
0	0000	00	0
1	0001	01	1
2	0010	02	2
3	0011	03	3
4	0100	04	4
5	0101	05	5
6	0110	06	6
7	0111	07	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
16	1111	17	F

Number System conversion

- Binary to decimal
  - Multiply each bit by 2^n, n is the "weight" of the bit
  - The weight is the position of the bit, starting from 0 on the right
  - Add the results

Example

$(110101)_2 = (\ )_{10}$

$= 1x2^5+1x2^4+0x2^3+1x2^2+0x2^1+1x2^0$

$= 32+16+0+4+0+1$

$= (53)_{10}$

Number System conversion

- Binary to octal
  - Group bits in threes, starting on right
  - Convert to octal number

Example

$$(110101)_2 = (\ )_8$$
$$= \underline{110}\ \underline{101}$$
$$= 6 \quad 5$$
$$= (65)_8$$

Number System conversion

- Binary to hexadecimal
  - Group bits in fours, starting on right
  - Convert to hexadecimal number

Example

$$(110101)_2 = (\ )_{16}$$

$$= \underline{11}\ \ \underline{0101}$$

$$= \underline{0011}\ \ \underline{0101}$$

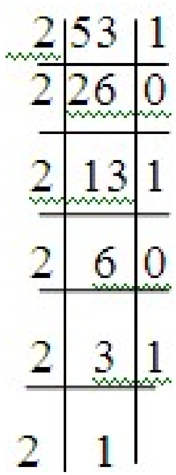
$$= (35)_{16}$$

Number System conversion

- Decimal to binary
  - Divide by two, keep track of the remainder
  - First remainder is bit 0 (LSB, least-significant bit)
  - Second remainder is bit 1Group bits in fours, starting on right

Example

$(53)_{10} = (\ )_2$



$= (110101)_2$

Number System conversion

- Decimal to octal
  - Divide by eight, keep track of the remainder
  - First remainder is bit 0 (LSB, least-significant bit)
  - Second remainder is bit 1Group bits in fours, starting on right

Example

$$(53)_{10} = (\ )_8$$

8	53	5
	6	

$$= (65)_8$$

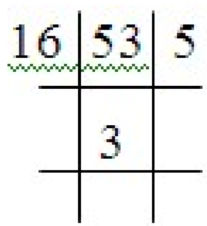
Number System conversion

- Decimal to hexadecimal
  - Divide by 16, keep track of the remainder
  - First remainder is bit 0 (LSB, least-significant bit)
  - Second remainder is bit 1Group bits in fours, starting on right

Example

$(53)_{10} = (\ )_{16}$

=



$= (35)_{16}$ `

Number System conversion

- Octal to binary
  - Convert each octal digit to a 3-bit equivalent binary representation

Example

$$(65)_8 = (\ )_2$$

$$= \underline{110}\ \underline{101}$$

$$= (110101)_2$$

Number System conversion

- Octal to decimal
  - Multiply each bit by 8^n, n is the "weight" of the bit
  - The weight is the position of the bit, starting from 0 on the right
  - Add the results

Example

$$(65)_8 = (\ )_{10}$$

$$= 6 \times 8^1 + 5 \times 8^0$$

$$= 48 + 5$$

$$= (53)_{10}$$

Number System conversion

- Octal to hexadecimal
  - Use binary as an intermediary.

Example

$$(65)_8 = (\ )_{16}$$

$$= \underline{110}\ \underline{101}$$

$$= \underline{11}\ \underline{0101}$$

$$= \underline{0011}\ \underline{0101}$$

$$= (35)_{16}$$

Number System conversion

- Hexadecimal to binary
  - Convert each hexadecimal digit to a 4-bit equivalent binary representation.

Example

$$(6A)_{16} = (\ )_2$$

$$= \underline{0110}\ \underline{1010}$$

$$= (1101010)_2$$

Number System conversion

- Hexadecimal to octal
  - Use binary as an intermediary.

Example

$$(6A)_{16} = (\ )_8$$
$$= \underline{0110}\ \underline{1010}$$
$$= \underline{1}\ \underline{101}\ \underline{010}$$
$$= \underline{001}\ \underline{101}\ \underline{010}$$
$$= (152)_8$$

Number System conversion

- Hexadecimal to decimal
  - Multiply each bit by 8^n, n is the "weight" of the bit
  - The weight is the position of the bit, starting from 0 on the right
  - Add the results

Example

$$(6A)_{16} = (\ )_{10}$$
$$= 6x16^1+Ax16^0$$
$$= 6x16^1+10x16^0$$
$$= 96 + 10$$
$$= (106)_{10}$$

Complement representation

- One's complement format
  - In binary number system, each bit is complimented.

    Example

    $(0100101)_2 = (1011010)$ one's complement form
- Two's complement format
  - In binary number system, each bit is complimented and binary 1 is added.
  - Used to represent negative number.

    Example

    $(0100101)_2 = (90)_{10}$

    $= (1011010)_2$ one's complement form

    $= (1011010 + 1)_2$

    $= (1011011)_2 = (-90)_{10}$ 2's complement