

# Electronic Circuits

Analog

voltage & currents vary continuously through given range. They can take infinite values within the specified range.  
Eg: Analog devices like signal generators, radio frequency transmitters & receivers.

Digital.

A digital ckt is one in which the voltage levels assume a finite number of distinct values

∴ Digital ckt often called switching ckt

Switching ckt ∴ Combinational circuits.

Sequential Circuits → O/p depends on the present i/ps and past i/ps (present state of the ckt)

## Number System

Base or Radix → Max. number of digits or symbols.

MSB → Most Significant Bit → Leftmost digit

LSB → Least Significant bit → Rightmost digit

9's & 10's Complement:

Eg: Find the 9's Complement of the following decimal numbers.

(a) 3465

$$\begin{array}{r} 9999 \\ - 3465 \\ \hline 6534 \end{array}$$

(b) 782.54

$$\begin{array}{r} 999.99 \\ - 782.54 \\ \hline 217.45 \end{array}$$

(c) 4526.075

$$\begin{array}{r} 9999.999 \\ (-) 4526.075 \\ \hline 5473.924 \end{array}$$

4526.075



2) Find the 10's complement

$$\begin{array}{r}
 (a) \quad 4069 \\
 \quad 9999 \\
 - 4069 \\
 \hline
 5930 \text{ (9's complement)} \\
 \quad + 1 \\
 \hline
 \underline{9531} \rightarrow 10\text{'s complement}
 \end{array}$$

$$\begin{array}{r}
 (b) \quad 1056.074 \\
 \quad 9999.999 \\
 - 1056.074 \\
 \hline
 8943.925 \\
 \quad + 1 \\
 \hline
 \underline{8943.926}
 \end{array}$$

### Binary Numbers:

The binary number system is a positional weighted system.

The base or radix of this number system is 2.

(ie) 0 & 1

A binary digit is called bit.

A binary number consists of sequence of bits, each of which either 0 or 1.

A binary point separates the integer & fraction parts.

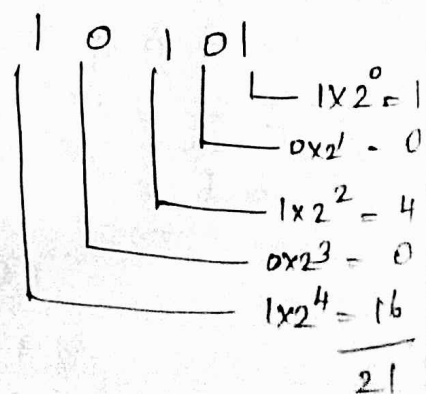
The weight of each bit position is one power of 2 greater than the weight of the position to its immediate right.

### Binary to decimal conversion:

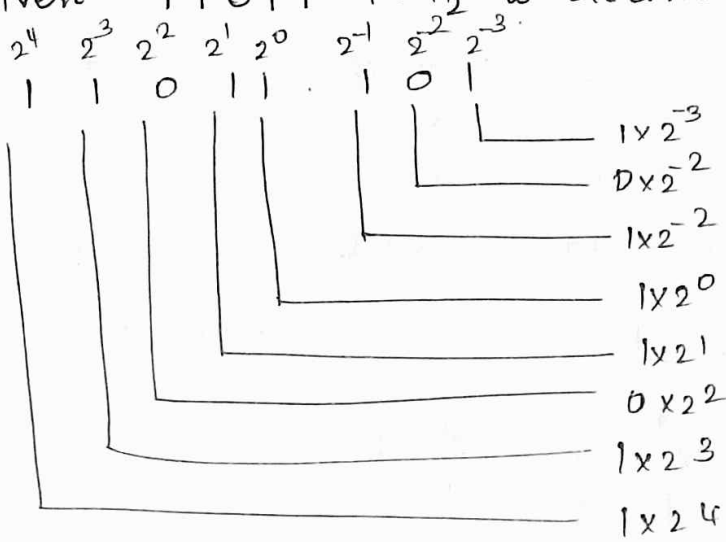
1) Convert  $10101_2$  to decimal.

$$\begin{array}{cccccc}
 2^4 & 2^3 & 2^2 & 2^1 & 2^0 & \\
 1 & 0 & 1 & 0 & 1 & \\
 \end{array}$$

$$(1 \times 2^4) + (0 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0) \\
 16 + 4 + 0 + 0 + 1 = 21$$



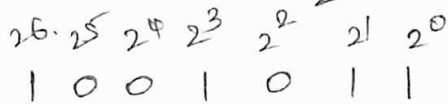
2) Convert  $11011.101_2$  to decimal.



$$(1 \times 2^4) + (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) + (1 \times 2^{-1}) + (0 \times 2^{-2}) + (1 \times 2^{-3})$$

$$\Rightarrow 16 + 8 + 0 + 2 + 1 + 0.5 + 0 + 0.125 = 27.625_{10}$$

3) Convert  $1001011_2$  to decimal



$$(1 \times 64) + (0 \times 32) + (0 \times 16) + (1 \times 8) + (0 \times 4) + (1 \times 2) + (1 \times 1)$$

$$\Rightarrow 64 + 8 + 2 + 1 = 75_{10}$$

MSB = 1.  $(1 \times 2) = 2$

$$(2 \times 2) + 0 = 4$$

$$(4 \times 2) + 1 = 9$$

$$(9 \times 2) + 0 = 18$$

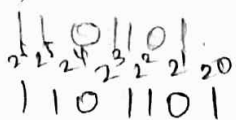
$$(18 \times 2) + 1 = 37$$

$$(37 \times 2) + 1 = 75$$

$$(75)_{10}$$

Copy MSB dec = 1.  
Multiply by 2 &  
add next bit.

4) Convert the decimal whole number ~~to~~ binary to decimal.



$$= (1 \times 2^6) + (1 \times 2^5) + (0 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$$

$$= 64 + 32 + 0 + 8 + 4 + 0 + 1 = 109$$

Exercise.

① Convert the binary 10010001 to decimal.

$$\begin{array}{cccccccc} 2^7 & 2^6 & 2^5 & 2^4 & 2^3 & 2^2 & 2^1 & 2^0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \end{array}$$

$$(1 \times 128) + (0) + (0) + (1 \times 16) + 0 + 0 + 0 + 1 = 145$$

5) Convert the fractional binary number 0.1011 to decimal.

$$\begin{array}{cccc} 2^{-1} & 2^{-2} & 2^{-3} & 2^{-4} \\ 0 & 1 & 0 & 1 \end{array}$$

$$(1 \times 2^{-1}) + 0 + (1 \times 2^{-3}) + (1 \times 2^{-4}) = 0.6875$$

Decimal to binary Conversion:-

1) Convert  $52_{10}$  to binary using the double-dabble method.

Successive division by 2.

$$\begin{array}{r} 2 \overline{) 52} \\ \underline{26} \quad 0 \\ 2 \overline{) 26} \\ \underline{13} \quad 0 \\ 2 \overline{) 13} \\ \underline{6} \quad 1 \\ 2 \overline{) 6} \\ \underline{3} \quad 0 \\ 2 \overline{) 3} \\ \underline{1} \quad 1 \end{array}$$

$$110100_2$$

MSB ←                      → LSB

Sum of weight Methods:

$$\begin{array}{ccccccc} 2^4 & 2^5 & 2^4 & 2^3 & 2^2 & 2^1 & 2^0 \\ 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 & 0 \end{array}$$

$$\begin{array}{r} 50 \\ 32 \\ \hline 20 \end{array}$$

2) Convert  $163.875_{10}$  to binary.

$$\begin{array}{r} 2 \overline{) 163} \\ \underline{81} \quad 1 \\ 2 \overline{) 81} \\ \underline{40} \quad 1 \\ 2 \overline{) 40} \\ \underline{20} \quad 0 \\ 2 \overline{) 20} \\ \underline{10} \quad 0 \\ 2 \overline{) 10} \\ \underline{5} \quad 0 \\ 2 \overline{) 5} \\ \underline{2} \quad 1 \\ 1 \quad 0 \end{array}$$

$$10100011_2$$

$$\begin{array}{l} 0.875 \times 2 = 1.75 \\ 0.75 \times 2 = 1.5 \\ 0.5 \times 2 = 1.0 \end{array}$$

$$10100011.110_2$$

	16	8	4	2	1			
$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
256	128	64	32	16	8	4	2	1
	1	0	1	0	0	0	1	1

$2^{-1}$	$2^{-2}$	$2^{-3}$
0.5	0.25	0.125
1	1	1

3) Convert  $0.75_{10}$  to binary using double-dabble method.

$$0.75 \times 2 = 1.5 \quad \text{11}_2$$

$$0.5 \times 2 = 1.0$$

4) Convert  $105.15_{10}$  to binary

2	105
2	52 - 1
2	26 - 0
2	13 - 0
2	6 - 1
2	3 - 0
1	1 - 1

$$1101001.001001_2$$

$$0.15 \times 2 = 0.3$$

$$0.3 \times 2 = 0.6$$

$$0.6 \times 2 = 1.2$$

$$0.2 \times 2 = 0.4$$

$$0.4 \times 2 = 0.8$$

$$0.8 \times 2 = 1.6$$

### Octal Number system:

Base - 8

### Octal to binary Conversion:

To convert a given octal number to binary just replace each octal digit by its 3-bit equivalent.

Convert  $367.52_8$  to binary

3	6	7	.	5	2
011	110	111	.	101	0100

$2^2$	$2^1$	$2^0$
4	2	1

$$011110111.101010_2$$



Convert each of the following binary numbers to octal:

$$a) \overset{1}{1} \overset{2}{1} \overset{1}{0} | \overset{1}{1} \overset{2}{0} \overset{1}{1} = 65_8$$

$$b) 101111001 = 1571_8$$

$$c) 100110011010 = 4632_8$$

$$d) 011010000100 = 3204_8$$

Convert the following octal numbers to decimal.

$$(a) 73_8$$

$$(b) 125_8$$

Convert the following decimal numbers to octal.

$$(a) 98_{10}$$

$$(b) 163_{10}$$

Convert the following octal numbers to binary.

$$(a) 46_8$$

$$(b) 723_8$$

$$(c) 5624_8$$

Convert the following binary numbers to octal.

$$(a) 110101111$$

$$(b) 1001100010$$

$$(c) 10111111001$$



Hexadecimal numbers :-

base (or) Radix  $\rightarrow 16$ .

Decimal	Binary	Hexadecimal
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
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Binary to Hexadecimal.

1) ~~110101001010111~~

1) 110010101010111  $\Rightarrow$  CA57<sub>16</sub>  
C A 5 7

2) ~~0011111000101101001~~  $\Rightarrow$  3F169<sub>16</sub>  
3 F 1 6 9

3) 100111011110011100

## Hexadecimal to binary:

$$(a) 10A4_{16} = \begin{array}{cccc} & 1 & 0 & A & 4 \\ & 0001 & 0000 & 1010 & 0100 \end{array}$$

$$(b) CF8E = \begin{array}{cccc} C & F & 8 & E \\ 1100 & 1111 & 1000 & 1110 \end{array}$$

$$(c) 9742_{10} = \begin{array}{cccc} 9 & 7 & 4 & 2 \\ 1001 & 0111 & 0100 & 0010 \\ & & 0100 & \end{array}$$

## Hexadecimal to binary decimal:-

$$(a) 1C_{16}$$

$$\begin{array}{cc} 16^1 & 16^0 \\ (1 \times 16) + (12 \times 1) & = 28_{10} \end{array}$$

$$(b) A85_{16}$$

$$\begin{array}{ccc} 16^2 & 16^1 & 16^0 \\ A & 8 & 5 \\ (16^2 \times A) + (16^1 \times 8) + (16^0 \times 5) & = \\ 2560 + 128 + 5 & = 2693_{10} \end{array}$$

Convert hexadecimal numbers to decimal.

$$(a) E5_{16}$$

$$\begin{array}{cc} 16^1 & 16^0 \\ E & 5 \end{array}$$

$$(16 \times 14) + (5 \times 1) = 229_{10}$$

$$(b) B2F8_{16}$$

$$\begin{array}{cccc} 16^3 & 16^2 & 16^1 & 16^0 \\ B & 2 & F & 8 \end{array}$$

$$(B \times 16^3) + (2 \times 16^2) + (F \times 16) + (8 \times 1)$$

$$= \begin{array}{r} 57344 \\ 4096 \\ \hline 45856 \end{array} + 512 + 240 + 8 = 45816_{10}$$

## Decimal to Hexadecimal Conversion:

$$(a) 650$$

$$\begin{array}{r} 16 \overline{) 650} \\ \underline{16 \quad 40} \quad - A \\ \quad \quad \quad 2 \quad - 8 \end{array}$$

$$28A_{16}$$

$$16 \times 1 = 16$$

$$16 \times 2 = 32$$

$$16 \times 3 = 48$$

$$16 \times 4 = 64$$

Binary Addition  
1's Complement :-

Binary Addition:

$0 + 0 \Rightarrow 0$  Sum of 0 with a carry of 0

$0 + 1 \Rightarrow 1$  " " 1 " " " " 0

$1 + 0 = 1$  Sum of 1 with a carry of 0

$1 + 1 = 1$  Sum of 1 with a carry of 1

$$\begin{array}{r}
 11 + 1 \\
 \quad \quad \quad 1 \text{ Augend} \\
 \quad \quad \quad + 1 \text{ Addend} \\
 \hline
 1.00 \text{ Sum}
 \end{array}$$

Add the following binary numbers:

(a)  $11 + 11$

$$\begin{array}{r}
 11 \\
 + 11 \\
 \hline
 110
 \end{array}$$

(b)  $100 + 10$

$$\begin{array}{r}
 100 \\
 + 10 \\
 \hline
 110
 \end{array}$$

(c)  $111 + 11$

$$\begin{array}{r}
 111 \\
 + 11 \\
 \hline
 1010
 \end{array}$$

(d)  $110 + 100$

$$\begin{array}{r}
 110 \\
 + 100 \\
 \hline
 1010
 \end{array}$$

Binary Subtraction:

$0 - 0 = 0$

$1 - 1 = 0$

$1 - 0 = 1$

$10 - 1 = 1$

$0 - 1$  with a borrow of 1.

$0 - 1 = \text{will}$

1) Perform the following binary subtractions.

(a)  $11 - 01$

$$\begin{array}{r} 11 \\ (-) 01 \\ \hline 10 \end{array}$$

$$\begin{array}{r} 10 \\ + 1 \\ \hline 11 \end{array}$$

$$\begin{array}{r} 11 \\ + 10 \\ \hline 110 \end{array}$$

(b)  $11 - 10$

$$\begin{array}{r} 11 \text{ Minuend} \\ - 10 \text{ Subtrahend} \\ \hline 01 \text{ Difference} \end{array}$$

Subtract  $0011$  from  $101$ .

$$\begin{array}{r} 0111 \\ 101 \\ \hline 010 \end{array}$$

$$\begin{array}{r} 010 \\ + 011 \\ \hline 010 \end{array}$$

Binary Multiplication:

$0 \times 0 = 0$

$0 \times 1 = 0$

$1 \times 0 = 0$

$1 \times 1 = 1$

Perform following binary Multiplication.

(a)  $11 \times 11$

$$\begin{array}{r} 11 \text{ Multiplicand} \\ \times 11 \text{ Multiplier} \\ \hline 11 \\ 11 \\ \hline 1001 \text{ Product} \end{array}$$

(b)  $101 \times 111$

$$\begin{array}{r} 101 \\ \times 111 \\ \hline 101 \\ 1010 \\ 10100 \\ \hline 100011 \end{array}$$

Binary Division:

(a)  $110 \div 11$

$$\begin{array}{r} 10 \\ 11 \overline{) 110} \\ \underline{11} \\ 0 \end{array}$$

10

(b)  $110 \div 10$

$$\begin{array}{r} 11 \\ 10 \overline{) 110} \\ \underline{10} \\ 10 \\ \underline{10} \\ 0 \end{array}$$

11

$$1100 \div 100$$

$$\begin{array}{r} 11 \\ 100 \overline{) 1100} \\ \underline{100} \\ 100 \\ \underline{100} \\ 0 \end{array}$$

$$\frac{12}{4} = 3$$

11

1) Perform following binary additions.

(a)  $1101 + 1010$

$$\begin{array}{r} 1101 \\ 1010 \\ \hline 10111 \end{array}$$

(b)  $10111 + 01101$

$$\begin{array}{r} 10111 \\ 01101 \\ \hline 100100 \end{array}$$

2. Perform the following binary subtractions

(a)  $1101 - 0100$

$$\begin{array}{r} 1101 \\ 0100 \\ \hline 1001 \end{array}$$

(b)  $1001 - 0111$

$$\begin{array}{r} 1001 \\ - 0111 \\ \hline 0 \end{array}$$

3. Perform the indicated binary operations:

(a)  $110 \times 111$

$$\begin{array}{r} 110 \\ 111 \\ \hline 1110 \\ 1100 \\ \hline 101010 \end{array}$$

(b)  $1100 \div 011$

$$\begin{array}{r} 100 \\ 011 \overline{) 1100} \\ \underline{11} \\ 0 \end{array}$$

$\Rightarrow 100$

## 1's Complement

1s  $\rightarrow$  0s.

0s  $\rightarrow$  1s.

## 2's Complement

$\rightarrow$  1's Complement + 1.

$\rightarrow$  01001110

1) Find the 2's Complement of 10110010.

$$\begin{array}{r} 10110010 \rightarrow \text{1's Complement} \rightarrow 01001101 \\ + \phantom{0100110} 1 \\ \hline \text{2's Complement} \quad \underline{01001110} \end{array}$$

2) Determine 2's Complement. 11001011

## Alternative Method:

Start at the right with LSB & write the bits as they are up to and including the first 1

Take 1's Comp for the remaining bits

Find the 2's complement

Take 1's  $\leftarrow$   $10111000$   $\rightarrow$  till 01 comes write as such

C.  $01001000$

2) 11000000

Find 1's Complement

(a) 00011010

(b) 11110111

(c) 10001101.



Add the following hexadecimal numbers

(a)  $23_{16} + 16_{16}$

$$\begin{array}{r} 23 \\ (+) 16 \\ \hline 39 \end{array}$$

(b)  $58_{16} + 22_{16}$

$$\begin{array}{r} 58 \\ 22 \\ \hline 7A_{16} \end{array}$$

(c)  $2B_{16} + 84_{16}$

$$\begin{array}{r} 2B \rightarrow 11_{10} + 4_{10} = 15_{10} \rightarrow F_{16} \\ 84 \\ \hline AF_{16} \end{array}$$

(d)  $DF_{16} + AC_{16}$

$$\begin{array}{r} DF \\ AC \\ \hline 18B_{16} \end{array} \quad \begin{array}{r} 15 \\ +12 \\ \hline 27 \\ -14 \\ \hline 13 \end{array}$$

$$\begin{aligned} F_{16} + C_{16} &= 15_{10} + 12_{10} \\ &= 27_{10} - 16_{10} \\ &= 11_{10} = B_{16} \\ &\text{with a 1 carry.} \end{aligned}$$

$$\begin{aligned} 12 + 10 &= 22 \\ 22 + 1 &= 23 \\ 23 &= 16 + 7 \\ &= 10_{16} + 7_{16} \\ &= 17_{16} \end{aligned}$$

If the sum of two digits is greater than  $15_{10}$  bring down the amount of the sum that exceeds  $16_{10}$  & carry a 1 to next column.

(a) Add  $AC_{16}$  and  $3A_{16}$ .

$$\begin{array}{r} 1 \\ AC \\ 3A \\ \hline 86_{16} \end{array}$$

$$\begin{array}{r} 12 \\ +10 \\ \hline 22 \\ -16 \\ \hline 6 \end{array}$$

Subtract the following hexadecimal numbers:

(a)  $84_{16} - 2A_{16}$

$$\begin{array}{r} 84 \\ -2A \\ \hline \end{array}$$



$$a) 1010100 - 1000011$$

$$\begin{array}{r}
 1010100 \\
 (-) 1000011 \\
 \hline
 0010001
 \end{array}$$

$$\begin{array}{r}
 1010100 \\
 0111100 \\
 \hline
 1000000
 \end{array}$$

$$\begin{array}{r}
 1010100 \\
 - 0101110_2 \\
 \hline
 0101100
 \end{array}$$