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 ckts often called switching ckts

Switching ckts → Combinational circuits.

Combinational → O/p depends on present i/ps

Switching ckts → 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

4526.075

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

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2) Find the 10s complement

(a) 4069

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

9531 → 10's complement

(b) 1056.074

$$\begin{array}{r} 9999.999 \\ -\ 1056.074 \\ \hline 8943.925 \\ +\ \ \ \ \ \ \ \ \ 1 \\ \hline 8943.926 \end{array}$$

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.

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

$(1\times2^4)+(0\times2^3)+(1\times2^2)+(0\times2^1)+(1\times2^0)$

$16+4+1=21$

1 0 1 0 1

$1\times2^0 = 1$

$0\times2^1 = 0$

$1\times2^2 = 4$

$0\times2^3 = 0$

$1\times2^4 = 16$

21

2) Convert 11011.101_2 to decimal.

$2^4 \; 2^3 \; 2^2 \; 2^1 \; 2^0 \; . \; 2^{-1} \; 2^{-2} \; 2^{-3}$

$1 \; 1 \; 0 \; 1 \; 1 \; . \; 1 \; 0 \; 1$

1×2^{-3}
0×2^{-2}
1×2^{-2}
1×2^{0}
1×2^{1}
0×2^{2}
1×2^{3}
1×2^{4}

$(1\times2^4)+(1\times2^3)+(0*2^2)+(1\times2^1)+(1\times2^0)+(1\times2^{-1})+(0\times2^{-2})+(1\times2^{-3})$

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

3) Convert 1001011_2 to decimal

$2^6 . 2^5 \; 2^4 \; 2^3 \; 2^2 \; 2^1 \; 2^0$

$1 \; 0 \; 0 \; 1 \; 0 \; 1 \; 1$

$(1\times64)+(0*32)+(0\times16)+(1\times8)+(0\times4)+(1\times2)+(1\times1)$

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

(or)

MSB = 1. $(1\times2)+0 = 2$

$(2\times2)+0 = 4$

$(4\times2)+1 = 9$

$(9\times2)+0 = 18$

$(18\times2)+1 = 37$

$(37\times2)+1 = 75$

$(75)_{10}$

Copy MSB (ie) = 1.
Multiply by 2 & add next bit.

4) Convert the decimal whole number ~~to binary~~ 1101101 to decimal.

$2^6 \; 2^5 \; 2^4 \; 2^3 \; 2^2 \; 2^1 \; 2^0$

$1101101 = (1\times2^6)+(1\times2^5)+(0\times2^4)+(1\times2^3)+(1\times2^2)+(0\times2^1)+(1\times2^0).$

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

Exercise

① Convert the binary 10010001 to decimal.

$2^7\ 2^6\ 2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0$

$1\ 0\ 0\ 1\ 0\ 0\ 0\ 1$

$(1\times128) + (0) + (0) + (1\times16) + 0 + 0 + 1 = 145$

5). Convert the fractional binary number 0.1011 to decimal.

$2^0 .\ 2^{-1}\ 2^{-2}\ 2^{-3}\ 2^{-4}$

$0 .\ 1\ 0\ 1\ 1$

$.\ (1\times 2^{-1}) + 0 + (1\times2^{-3}) + (1\times2^{-4})$

0.6875

Decimal to binary Conversion :-

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

successive division by 2.

$$\begin{array}{r|l}
2 & 52 \\
2 & 26 - 0 \\
2 & 13 - 0 \\
2 & 6 - 1 \\
2 & 3 - 0 \\
 & 1 - 1
\end{array}$$

110100_2

MSB LSB

Sum of weight Methods.

2^6	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.

$$\begin{array}{r} 52 \\ -32 \\ \hline 20 \end{array}$$

2) Convert 163.875_{10} to binary.

$$\begin{array}{r|l}
2 & 163 \\
2 & 81 - 1 \\
2 & 40 - 1 \\
2 & 20 - 0 \\
2 & 10 - 0 \\
2 & 5 - 0 \\
2 & 2 - 1 \\
 & 1 - 0
\end{array}$$

10100011_2

$0.875 \times 2 = 1.75$

$0.75 \times 2 = 1.5$

$0.5 \times 2 = 1.0$

10100011.111_2

163

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.

$0.75 \times 2 = 1.5$

$0.5 \times 2 = 1.0$

11_2

4). Convert 105.15_{10} to binary

$2 \,|\, 105$
$2 \,|\, 52 - 1$
$2 \,|\, 26 - 0$
$2 \,|\, 13 - 0$
$2 \,|\, 6 - 1$
$2 \,|\, 3 - 0$
$1 - 1$

1101001.

$0.15 \times 2 = 0.3$

$0.3 \times 2 = 0.6$

$0.6 \times 2 = 1.2$

$0.2 \times 2 = 0.4$

$0.4 \times 2 = 0.8$

$0.8 \times 2 = 1.6$

1101001.001001_2

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

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

3 6 7 . 5 2

011 110 111 . 101 0100

011110111.101010_2

Binary to Octal Conversion

To convert a binary number to an octal number, starting from the binary point make group 3 bits each, on either side of the binary point, and replace each 3-bit binary group by the equivalent octal digit

1) Convert 110101.101010_2 to octal

110101.101010_2

	4	2	1	4	2	1		4	2	1	4	2	1
Group of 3 bits	1	1	0	1	0	1	.	1	0	1	0	1	0

65.52_8.

Octal to decimal:

2374

8^3	8^2	8^1	8^0
2	3	7	4

$= (2\times 8^3) + (3\times 8^2) + (7\times 8^1) + (4\times 8^0)$

$= 1024 + 192 + 56 + 4 = 1276$.

Decimal to Octal Conversion:

359_{10}.

$$\begin{array}{r|l} 8 & 359 \\ 8 & 44 - 7 \\ & 5 - 4 \end{array}$$

547_8

Octal to binary Conversion:

1) 13_8

1	3
001	011

2) 25_8

2	5
010	101

3) 140_8

1	4	0
001	100	000

4) 7526

7	5	2	6
111	101	010	110

Convert each of the following binary numbers to octal:

a) 110|101 = 65_8

b) 101|111|001 = 4571_8

c) 100|110|011|010 = 4632_8

d) 011|010|000|100 = 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 → 16.

Decimal	Binary	Hexadecimal
0	0000	0
1	0001	~~2~~ 1
2	0010	~~3~~ 2
3	0011	~~4~~ 3
4	0100	~~4~~ 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) ~~110101010010100111.~~

8 4 2 1

1) 1100|0101|0101|0111 ⇒ $CA57_{16}$

C A 5 7

8 4 2 1

2) ~~00~~0011|1111|0001|0110|1001 = $3F169_{16}$.

3 F 1 6 9

3) 1001111011110011100

Hexadecimal to binary:

(a) $10A4_{16}$ = 1 0 A 4.

0001 0000 1010 0100

(b) CF8E = C F 8 E

1100 1111 1000 1110.

(c) 9742_{10} = 9 7 4 2

1001 0111 ~~0010~~ 0010.

0100

Hexadecimal to ~~binary~~ decimal:-

(a) $1C_{16}$.

16^1 16^0

$(1\times16)+(12\times1) = 28_{10}$

(b) $A85_{16}$.

16^2 16^1 16^0

A 8 5

$(16^2\times A)+(16^1\times8)+(16^0\times5)=$

$2560+128+5 = 2693_{10}$.

Convert hexadecimal numbers to decimal.

(a) $E5_{16}$

16^1 16^0

E 5

$(16\times14)+(5\times1)$

$= 229_{10}$.

(b) $B2F8_{16}$

16^3 16^2 16^1 16^0

B 2 F 8

$(B\times16^3)+(2\times16^2)+(F\times16)+(8\times1)$

$= \cancel{57344}\ \cancel{4096} + 512 + 240 + 8$

45056.

$= 45816_{10}$

Decimal to Hexadecimal Conversion:

(a) 650

16 | 650

16 | 40 - A

2 - 8

$28A_{16}$

16×1=16

16×2=32

16×3=48

16×4=64

Binary Addition

1's Complement :

Binary Addition:

0 + 0 ⇒ 0 Sum of 0 with a carry of 0

0 + 1 ⇒ 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

11 + 1

$$\begin{array}{r} 1 \\ 11 \\ + 1 \\ \hline 1.00 \end{array}$$

11 Augend
1 Addend
Sum

Add the following binary numbers:

(a) 11 + 11

$$\begin{array}{r} 1 \\ 1\;1 \\ 1\;1 \\ \hline 1\;1\;0 \end{array}$$

$$\begin{array}{r} 3 \\ 3 \\ \hline 6 \end{array}$$

6 ← 110

(b) 100 + 10

$$\begin{array}{r} 1\;0\;0 \\ +\;\;1\;0 \\ \hline 1\;1\;0 \end{array}$$

(c) 111 + 11

$$\begin{array}{r} 1\;1 \\ 1\;1\;1 \\ 1\;1 \\ \hline 1\;0\;1\;0 \end{array}$$

(d) 110 + 100

$$\begin{array}{r} 1\;1\;0 \\ (+)\;1\;0\;0 \\ \hline 1\;0\;1\;0 \end{array}$$

Binary Subtraction:

0 − 0 = 0

1 − 1 = 0

1 − 0 = 1

10 − 1 = 1 0 − 1 with a borrow of 1.

0 − 1 = null

1) Perform the following binary subtractions.

(a) 11 − 01

```
     1   1
(−)  0   1
---------
     1   0
```

```
  1 0
+   1
-----
  1 1
```

```
      1
    1 1
+ 1 0 1
-------
  1 1 0
```

(b) 11 − 10

```
  1 1  Minuend
− 1 0  Subtrahend
-----
  0 1  Difference
```

Subtract 0011 from 101.

```
 0  10
 ̸1  0 1
 0  1 1
-------
   0 1 0
```

Binary Multiplication:

0 × 0 = 0

0 × 1 = 0

1 × 0 = 0

1 × 1 = 1

Perform following binary Multiplication.

(a) 11 × 11

```
    1 1   Multiplicand
×   1 1   Multiplier
-------
    1 1
  1 1
-------
1 0 0 1   Product
```

(b) 101 × 111

```
        1 0 1
        1 1 1
      -------
        1 0 1
      1 0 1
    1 0 1
  -----------
  1 0 0 0 1 1
```

Binary Division:

(a) 110 ÷ 11

```
       10
    -----
11 ) 110
     11
    ---
      0
```

10

(b) 110 ÷ 10

```
       11
    -----
10 ) 110
     10↓
    ----
      10
      10
     ---
       0
```

11.

$1100 \div 100$

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

$$\begin{array}{r|l} & 11 \\ \hline 100 & 1100 \\ & 100 \\ \hline & 100 \\ & 100 \\ \hline & 0 \end{array}$$

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

$$\begin{array}{r} 9 \\ -7 \\ \hline 2 \end{array}$$

$$\begin{array}{r} 1\cancel{0}01 \\ 0111 \\ \hline 0 \end{array}$$

3. Perform the indicated binary operations:

(a) 110 × 111

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

(b) 1100 ÷ 011

$$\begin{array}{r|l} & 100 \\ \hline 011 & 1100 \\ & 11 \\ \hline & 0 \end{array}$$

⇒ 100.

1's Complement

1s → 0s.

0s → 1s.

2s Complement

↳ 1's Complement +1.

1) Find the 2's Complement of 10110010.

10110010 → 1's complement ⇒ 01001101

$$\begin{array}{r} 01001101 \\ +\quad 1 \\ \hline 01001110 \end{array}$$

2's Complement 01001110

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

1011|1000 → till 1 comes write as such

Take 1's C.

01001000

2) 11000000

Find 1's Complement

(a) 00011010

(b) 1110111

(c) 10001101.

Determine 2's complement of each binary numbers.

(a) 00010110

(b) 11111100

(c) 10010001.

Signed Numbers: -

The left most bit in a signed number is the sign bit, which tells whether the number is +ve (or) -ve

0 for +ve & 1 for -ve

$+25_{10} \Rightarrow$ 011001

Sign bit

$$\begin{array}{r|ll} 2 & 25 & \\ 2 & 12 & -1 \\ 2 & 6 & -0 \\ 2 & 3 & -0 \\ & 1 & -1 \end{array}$$

1's Complement form for signed bit:

In 1's complement form, a negative number is the 1's complement of corresponding +ve number.

1's c of +25 = 011001.

1's c of -25 = 100110.

2's Complement form

In the 2's complement form, a negative number is the 2's complement of the corresponding +ve number

Add the following hexadecimal numbers

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

$$\begin{array}{r} 2\ 3 \\ (+)\ 1\ 6 \\ \hline 3\ 9 \end{array}$$

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

$$\begin{array}{r} 5\ 8 \\ 2\ 2 \\ \hline 7\ A_{16} \end{array}$$

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

$$\begin{array}{r} 2\ B \\ 8\ 4 \\ \hline A\ F_{16} \end{array}$$

$B \rightarrow 11_{10} + 4_{10} = 15_{10} \Rightarrow F_{16}$

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

$$\begin{array}{r} D\ F \\ A\ C \\ \hline 1\ 8\ B_{16}. \end{array}$$

$$\begin{array}{r} 15 \\ +12 \\ \hline 27 \\ \cancel{16} \\ \hline 13 \end{array}$$

$F_{16} + C_{16} = 15_{10} + 12_{10}$

$= 27_{10} - 16_{10}$

$= 11_{10} = B_{16}$

with a 1 carry.

$12 + 10 + 1 = \cancel{23}\ 24.$

$24 - 16 = 8.$

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 $3A_{16}$.

$$\begin{array}{r} 1\ \ \ \\ 4\ C \\ 3\ A \\ \hline 8\ 6_{16} \end{array}$$

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

Subtract the following hexadecimal numbers:

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

$$\begin{array}{r} 8\ 4 \\ 2\ A \\ \hline \end{array}$$

a) 1010100 − 1000011

$$\begin{array}{r} 1010\cancel{1}\cancel{0}\cancel{0} \\ (-)\ 1000011 \\ \hline 0010001 \end{array}$$

$$\begin{array}{r} 1010100 \\ 0111100 \\ \hline 10000000 \\ +\quad 1 \end{array}$$

b)

$$\begin{array}{r} \cancel{1}\ \cancel{0}\ \cancel{1}\ \cancel{1}\ \cancel{0}\ 1\ 0 \\ -\ 0\ 1\ 0\ 1\ 1\ 1\ 0_2 \\ \hline 0\ 1\ 0\ 1\ 1\ 0\ 0 \end{array}$$