BASIC ELECTRONICS

1st Year of 4-year B.Tech

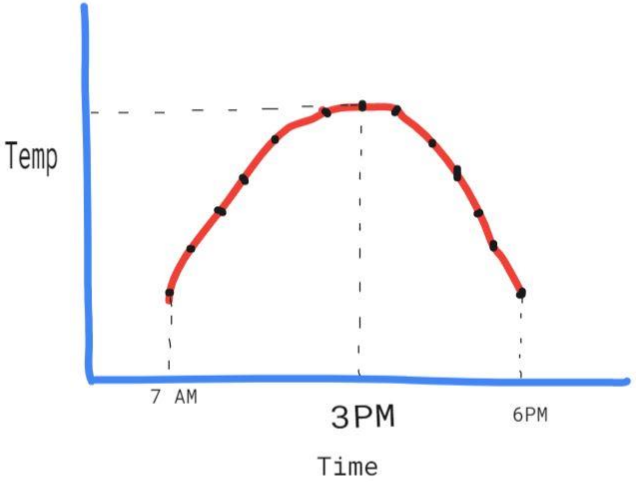
Topic: Digital Electronics

Number systems

Dt: 03.05.2021

What is a Signal?

- It is a function that represents the variation of a physical quantity with respect to any parameter
- The parameter is the independent variable, for eg., time, distance
- $f(x) = ax^2 + bx$



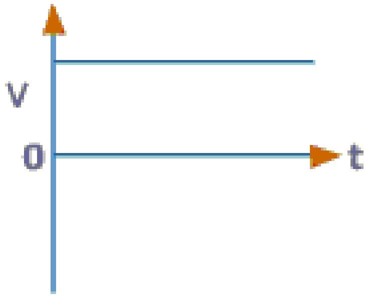
$f(t) = \cancel{-}+at^2 + bt + c$
where, $a>0$

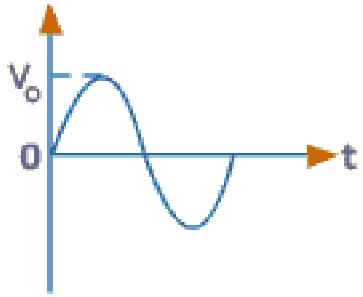
if $a=0$, it becomes a straight line

If $a<0$, it is an ~~up~~ down ward parabola

- In Electronics, it is usually the variation of an electrical quantity for eg, voltage with respect to an independent quantity, eg.time
- If signal does not change with time, it is no more a signal, it becomes

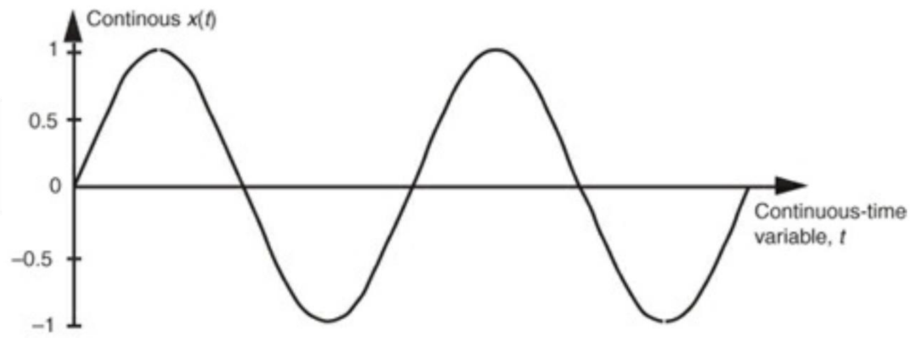
  a direct value
- Signal must vary with independent quantity

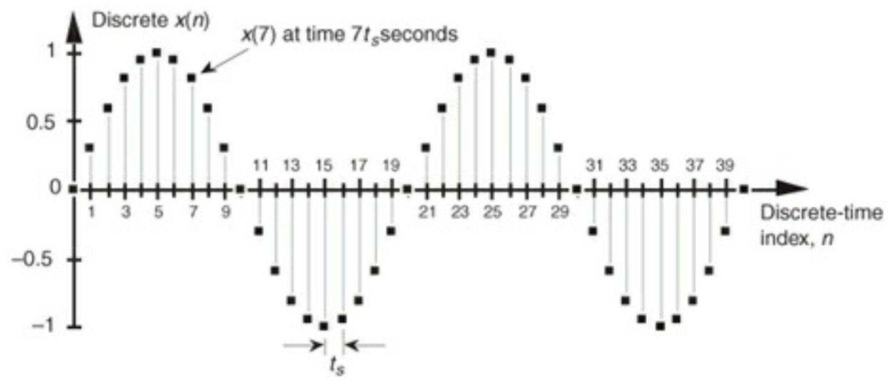




Analog signal vs digital signal

- Analog signal can take any value at any instant of time, there is a continuous variation
- If we discretize the time axis, and plot the signal at that instant of time, we get a discrete time signal. It is a subset of analog signal
- We have signal values at a particular instant of time. We do not know what happened between these two points
- Continuous signals or analog signals are represented by enclosing the independent parameter within (), e.g., V(t)
  discrete time signals are represented by enclosing the independent parameter in [], e.g., V[t]
- Suppose the signal has an upper value of +1V and lower value of -1V. It can assume any value between these limits
- All real life signals are analog in nature
- Sound waves serve as input to microphone, the transducer converts sound waves to electrical signal, amplifier present amplifies the signal, again converted back to sound waves which is what we hear





Analog signal vs digital signal

- Now, if I discretize the amplitude axis too, we get digital signal
- t=time in seconds, T = temperature in a city

- The picture shows a discrete time signal

- Now, we assign particular levels to the amplitude axis, 0, 15, 30, 45.
  Values will be assigned at those points only

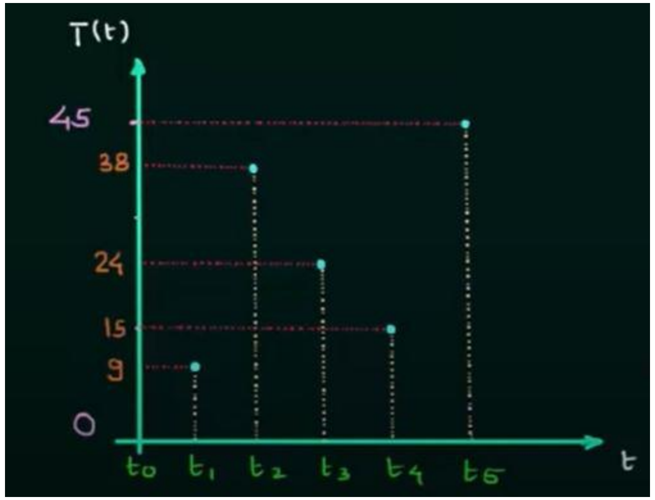
- The first level is 9,
  9-0 = 9 and 15 – 9 = 6

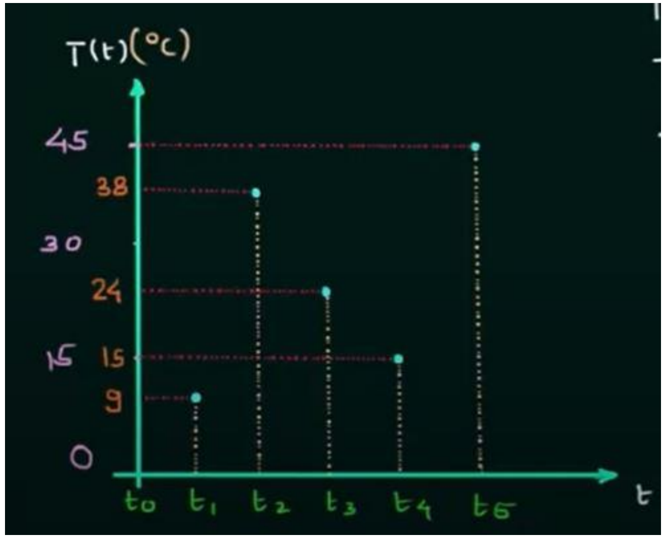
- The value seems closer to 15, hence we need to assign the level of 15

- But to avoid error we assign 0 value, we always select the lower value for a particular level
  So, T(t1) = 0 deg
  T(t2) = 30 deg
  T(t3) = 15 deg
  T(t4) = 15 deg
  T(t5) = 45 deg

- How to overcome the error?
  We need to increase the number of levels. Suppose we assign 5,10,15,20,25, 30 as the allowed values.

In this case the error reduces





Why do we need digital signals?

- What is noise?

  Any unwanted signal is noise

- Suppose we have a transmitter and a receiver system. The input to the transistor is a voltage of 2.5V

- Lets say the channel adds a noise of 0.2V , so at receiver end we obtain a distorted signal hence, 2.5 V + 0.2 V = 2.7 V

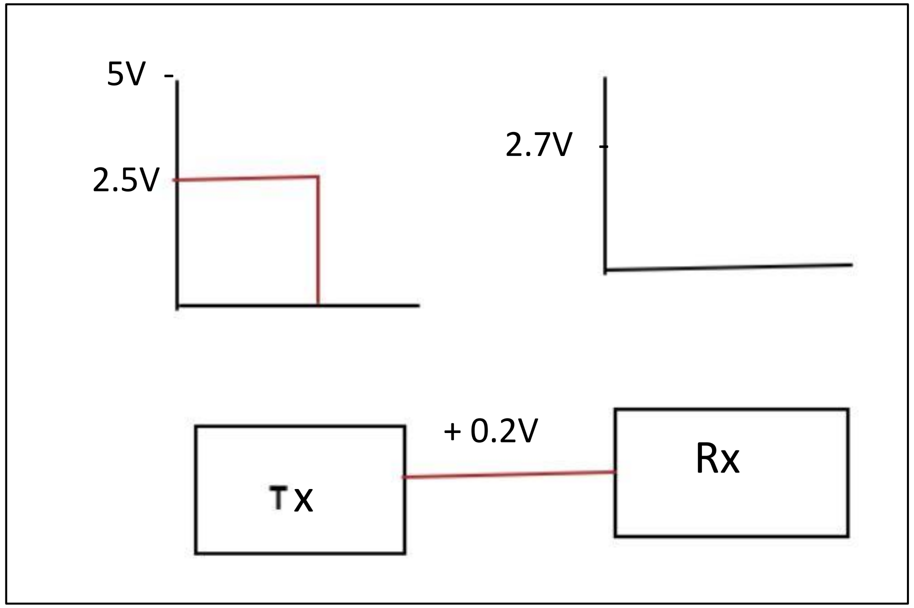
- Now, lets represent the same thing in digital form

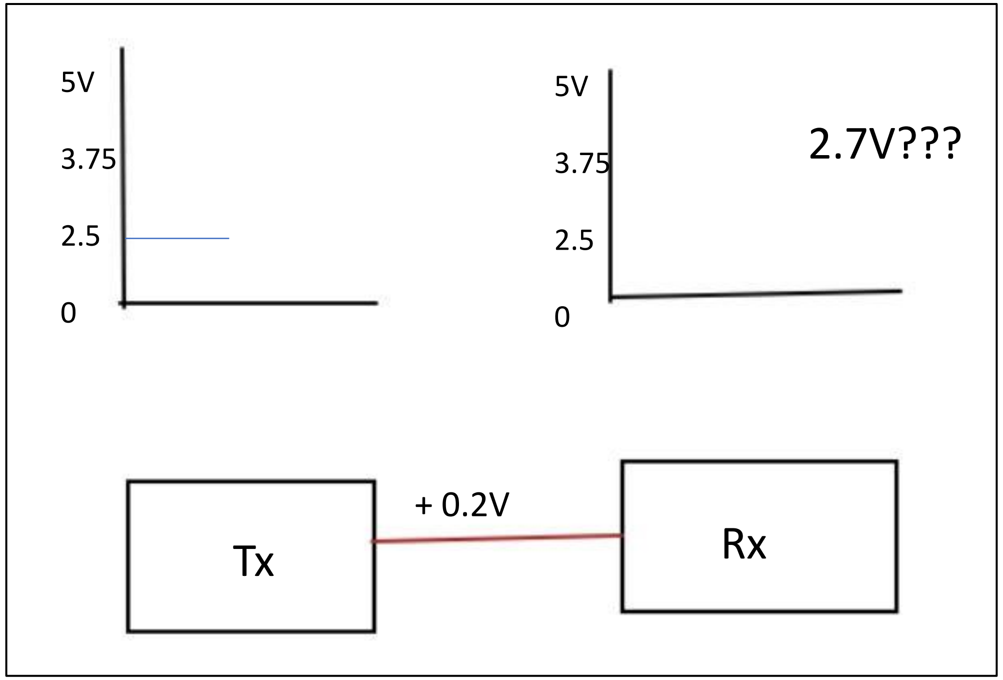
- Lets say we want to divide the whole range into 4 levels
  So, 5 – 0 = 5/4 = 1.25 V

- We do not have 2.7 level in the scale. We take the value below the scale

- So, we take the point at 2.5V. Hence, my transmitted and received signal is the same, noise eliminated

- What if noise is 1.25 volts??





Number System:

Decimal Number system: 74, 350, 650

Number of accepted digits: 0 to 9

Binary Number system: 101, 1010, 01

Accepted digits: 0 and 1

Hexadecimal number system: 20 H, BA H, 6E H

Accepted numbers: 0 to 9, A-H (10-16)

Octal number system: $(124)_8$

Accepted numbers: 0 to 7

Name	Base
Binary	2
Decimal	10
Octal	8
Hexadecimal	16

Base is also called Radix

Decimal Number system:

$$(246)_{10} = 2 \times 10^2 + 4 \times 10^1 + 6 \times 10^0$$

Hundreds Tens Units

Positional weights

- **Binary Number system**:

Decimal:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Binary:	0	1	10	11	100	101	110	111	1000	1001	1010	1011	1100	1101	1110	1111

Binary digits are called **'BITS'**

Decimal:	20	25	30	40	50	100	200	500
Binary:	10100	11001	11110	101000	110010	1100100	11001000	111110100

- **Decimal to Binary conversion**:

$(266)_{10}$ =

2	266	0
2	133	1
2	66	0
2	33	1
2	16	0
2	8	0
2	4	0
2	2	0
2	1	

Binary conversion – 1 0 0 0 0 1 0 1 0

MSB- Most significant bit
Bit position having the most significant value in a binary number system

LSB-Least Significant Bit
Bit position having the least significant value in a binary number system

1 0 0 0 0 1 0 1 0

MSB LSB

- Decimal number is converted to its binary equivalent by dividing the number progressively by 2 until quotient is zero. The result is obtained by taking the remainder after each division
- $(456)_{10}$

	456	
2	228	-0
2	114	-0
2	57	-0
2	28	-1
2	14	-0
2	7	-0
2	3	-1
2	1	-1

Binary equivalent: $(111001000)_2$

- $(0.375)_{10}$

$0.375 \times 2 = 0.75$	(MSB)
$0.75 \times 2 = 1.50$	
$0.50 \times 2 = 1.00$	(LSB)

Binary equivalent= $(0.011)_2$

- For fractional part, the binary equivalent is obtained by multiplying the number by 2, noting down the carry in the integer position each time. Bring down only the part after the decimal point. In the second line we had 1.50 but we bring only 0.50 to the next step
- If solution does not converge, continue till 4 or 5 steps
- $(458.692)_{10}$???

$(458.692)_{10} = (?)_2$

$.692 \times 2 = 1.384$	1	MSB
$.384 \times 2 = 0.768$	0	
$.768 \times 2 = 1.536$	1	
$.536 \times 2 = 1.072$	1	LSB

Binary to Decimal:

A binary number is converted to decimal number by multiplying the binary numbers by their positional weights and adding the products

Convert $(10110111)_2$ to Decimal number:

1 0 1 1 0 1 1 1

positional weights

$1 \times 2^0 = 1$

$1 \times 2^1 = 2$

$1 \times 2^2 = 4$

$0 \times 2^3 = 8$

$1 \times 2^4 = 16$

$1 \times 2^5 = 32$

$0 \times 2^6 = 0$

$1 \times 2^7 = 128$

$(183)_{10}$

Zero Point

0 . 1 0 1 1

$1 \times 2^{-4} = 0.0625$

$1 \times 2^{-3} = 0.125$

$0 \times 2^{-2} = 0$

$1 \times 2^{-1} = 0.5$

0.6875_{10}

- Convert 101111.1101 to its decimal equivalent

$$\underset{5}{1}\ \underset{4}{0}\ \underset{3}{1}\ \underset{2}{1}\ \underset{1}{1}\ \underset{0}{1}\ .\ \underset{-1}{1}\ \underset{-2}{1}\ \underset{-3}{0}\ \underset{-4}{1}$$

1 0 1 1 1 1

$1 \times 2^0 = 1$

$1 \times 2^1 = 2$

$1 \times 2^2 = 4$

$1 \times 2^3 = 8$

$0 \times 2^4 = 0$

$1 \times 2^5 = 32$

47

. 1 1 0 1

$1 \times 2^{-4} = 0.0625$

$0 \times 2^{-3} = 0.000$

$1 \times 2^{-2} = 0.2500$

$1 \times 2^{-1} = 0.5000$

0.8125

Therefore, $(101111.1101)_2$ is equivalent to $(47.8125)_{10}$

- ## Octal Number System:
- Octal number system uses digits 0, 1, 2, 3, 4, 5, 6 and 7 Radix is 8

Decimal to Octal:

- Octal equivalent of decimal number is obtained by dividing the decimal number by 8 repeatedly, until a quotient of 0 is obtained
- Convert $(359)_{10}$ to octal number

	quotient	remainder	
359 / 8 =	44	7	LSB
44 /8 =	5	4	
5 /8 =	0	5	MSB

Therefore, $(359)_{10} = (547)_8$

- For the fractional part, multiply each digit with 8 and add the products
- Convert $(0.356)_{10}$ to its octal equivalent

0.356 * 8 = 2.848 → integer part = 2 MSB
0.848 * 8 = 6.784 → integer part = 6
0.784 * 8 = 6.272 → integer part = 6
0.272 * 8 = 2.176 → integer part = 2
0.176 * 8 = 1.408 → integer part = 1
0.408 * 8 = 3.264 → integer part = 3, LSB

Therefore, $(0.356)_{10} = (0.266213)_8$

- **Octal to Decimal:**

Octal to Decimal conversion can be done my multiplying each significant digit of octal number by its respective weight and adding the products

- Convert $(2754)_8$ to decimal

2 7 5 4

$4 \times 8^0 = 4$

$5 \times 8^1 = 40$

$7 \times 8^2 = 448$

$2 \times 8^3 = 1024$

1516

Therefore, $(2754)_8 = (1516)_{10}$

- **Octal to Binary:**

Code
0 - 000
1 - 001
2 - 010
3 - 011
4 - 100
5 - 101
6 - 110
7 - 111

To convert 653_8 to binary, just substitute code:

$$6 \rightarrow 110 \quad 5 \rightarrow 101 \quad 3 \rightarrow 011$$

Therefore, $(653)_8 = (110\ 101\ 011)_2$

- # Hexadecimal numbers

Hexadecimal numbers uses 16 symbols- 0 to 9, A, B, C, D, E and F

Has radix 16

Hexadecimal to Decimal

Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Decimal to Hexadecimal:

- Convert $(540)_{10}$ to its hexadecimal equivalent

remainder

540 / 16 = 33	12 = C
33 / 16 = 2	1
2 / 16 = 0	2
0 / 16 = 0	0

Therefore, $(540)_{10} = (21C)_{16}$

- Convert $(235)_{10}$ to hexadecimal

remainder

235/ 16 = 14	11 = B
14/16 = 0	14 = E

Therefore, $(235)_{10} = (EB)_{16}$

- <u>Hexadecimal to Decimal</u>
- $(2A5)_{16}$

2 A 5

$5 \times 16^0 = 5$

$10 \times 16^1 = 160$

$2 \times 16^2 = 512$

677

Therefore, $(2A5)_{16} = (677)_{10}$

- (54.D2)16

5 4 . D 2

$2 \times 16^{-2} = 0.0078$

$13 \times 16^{-1} = 0.8125$

$4 \times 16^0 = 4$

$5 \times 16^1 = 80$

84.8203

Therefore, $(54.D2)_{16} = (84.8203)_{10}$

- Binary to Hexadecimal:
  - Convert $(11110110101)_2$ to hexadecimal

0 111   1011   0101

7   B   5

Therefore, $(11110110101)_2 = (7B5)_{16}$

Convert $(110001.0110110)_2$ to hexadecimal

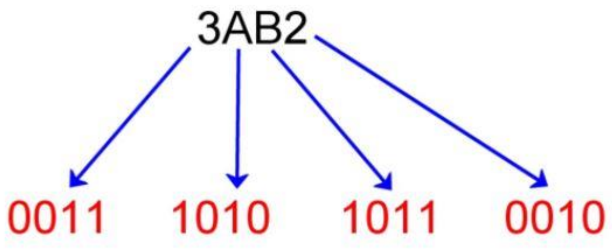
00 11   0001   .   0110   1100

3   1   6   C

Therefore, $(110001.0110110)_2 = (31.6C)_{16}$

Hexadecimal to Binary:

- Convert $(3AB2)_{16}$ to Binary



Therefore, $(3AB2)_{16} = (0011101010110010)_2$