Lecture 1

Introduction to Digital Electronics

SYLLABUS

EE:

Combinatorial and sequential logic circuits, multiplexers, demultiplexers, Schmitt triggers, sample and hold circuits, A/D and D/A converters.

analog

ECE:

Number Representations: binary, integer and floating-point- numbers; Combinatorial circuits: Boolean algebra, minimization of functions using Boolean identities and Karnaugh map, logic gates and their static CMOS implementations, arithmetic circuits, code converters, multiplexers, decoders; Sequential Circuits: latches and flip-flops, counters, shift-registers, finite state machines, propagation delay, setup and hold time, critical path delay; Data Converters: sample and hold circuits, ADCs and DACs; Semiconductor Memories: ROM, SRAM, DRAM; Computer Organization: Machine instructions and addressing modes, ALU, data-path and control unit, instruction pipelining.

later

SYLLABUS

IN:

logic family

Combinational logic circuits, minimization of Boolean functions. IC families: TTL and CMOS. Arithmetic circuits, comparators, Schmitt trigger, multi-vibrators, sequential circuits, flipflops, shift registers, timers and counters; sample-and-hold circuit, multiplexer, analog-to-digital (successive approximation, integrating, flash and sigma-delta) and digital-to-analog converters (weighted R, R2R ladder and current steering logic). Characteristics of ADC and DAC (resolution, quantization, significant bits, conversion/settling time); basics of number systems. Embedded Systems: Microprocessor and microcontroller applications, memory and input-output interfacing; basics of data acquisition systems, basics of distributed control systems (DCS) and programmable logic controllers.

↳ Microprocessor

Flow of Syllabus

1. Number Systems ← EC/IN
2. Logic Gates
3. Boolean Algebra
4. K-Map
5. Combinational circuits
   - arithmetic
   - code converters + comparators
   - MUX & DeMUX
   - Decoder & Encoder
6. Sequential circuits
   - latches
   - Flip Flops
   - Shift register
   - Counter
   - FSM
7. Data Converters (ADC, DAC)
8. Semiconductor memories (EC)
9. Logic Family (EC + IN)

Weightage in EE

Topic Name	2018	2019	2020	2021	2022	2023	2024
Number systems and Code Conversation	0	0	0	0	0	0	0
Boolean Algebra ~ 1	2	2	0	0	0	0	1
Logic Gates (0-1)	1	2	0	0	0	0	0
Combinational Logic Circuits	0	0	0	0	0	0	1
Sequential Logic Circuits **	2	0	1	3	2	2	1
Data Converters (1-2)	0	0	0	0	0	2	0
Semiconductor Memories	0	0	0	0	0	0	0
Logic Families	0	0	0	0	0	0	0
Microprocessor	0	0	2	0	0	2	0
Total	**5**	**4**	**3**	**3**	**2**	**6**	**3**

Weightage in ECE

Topic Name	2018	2019	2020	2021	2022	2023	2024
Number systems and Code Conversation	0	0	2	1	0	0	0
Boolean Algebra	1	0	0	0	1	0	1
Logic Gates	1	2	0	0	2	0	
Combinational Logic Circuits	2	0	1	2	1	1	3
Sequential Logic Circuits	3	3	4	2	4	4	2
Data Converters	0	0	1	1	2	3	0
Semiconductor Memories	2	1	0	1	0	0	0
Logic Families	2	0	0	0	0	0	0
Total	**10**	**4**	**8**	**7**	**10**	**8**	**6**

Weightage in IN

Topic Name	2018	2019	2020	2021	2022	2023	2024
Number systems and Code Conversation	1	0	2	1	0	0	0
Boolean Algebra	2	3	2	2	2	2	1
Logic Gates	2	0	0	0	1	1	
Combinational Logic Circuits	0	3	1	2	1	2	0
Sequential Logic Circuits	3	3	2	2	2	3	2
Data Converters	1	1	2	2	1	0	0
Semiconductor Memories	0	0	0	0	0	0	0
Logic Families	0	0	0	0	0	1	0
Total	**9**	**10**	**7**	**8**	**7**	**9**	**3**

RESOURCES

Theory → Class notes (PDF) ← no standard books (required)
Short notes (handwritten)
Questions: DPP → daily
Work book → after every topic (topic wise Questions)
PYQ → after a chapter (EE + EC + IN) ← otherwise during revision
Test: Weekly Quiz
↳ based on number of lectures
attempt on own convenience

How to follow Course?

- Attend live class daily
  - → running notes : sleepy students
  - → PDF : more focus on practice
- Download PDF and make short notes → (personalized)
- Solve DPP and work book (if applicable)
- Revise SN on Sunday and attempt test
- Doubts on Sundays /Saturday
  - ↳ Telegram group

DPP : must

workbook : weekends

PYQ : revision

Digital Logic

Digital has been derived from the word digit

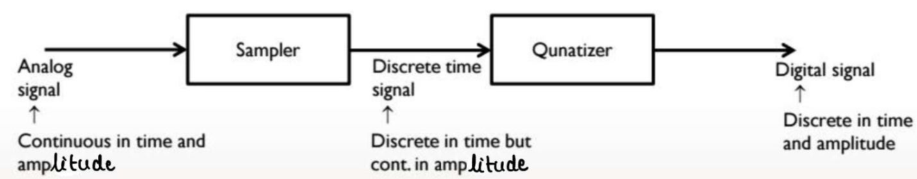
It represents a system with finite number of possibilities.

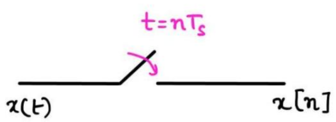
Analog : analogous or similar to real world signal
→ Infinite number of possibilities

Why to learn it ???

Analog Signal are naturally occurring, but to process them, digital circuitry is required due to memory constraint.

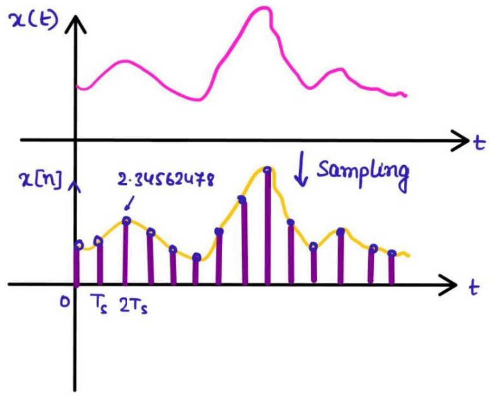
Digital processing is definitely better; like in less storage, high speed, better conversion and easy measurement and security of the data (with encryption).





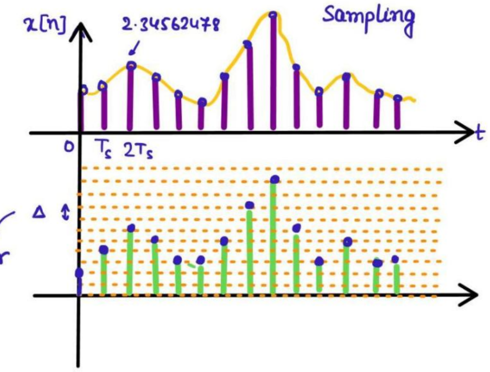
T_s : sampling interval

$f_s = 1/T_s$: sampling frequency

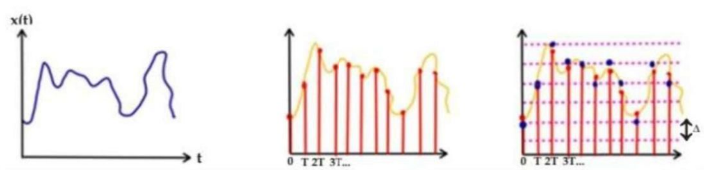


Quantization

all the sample values of DT signal are rounded off to the nearest pre-defined level.



resolution or step size



To minimize Quantization error, we must reduce Δ
→ noise margin ↓
→ as Δ ↓ number of level ↑ memory requirement ↑

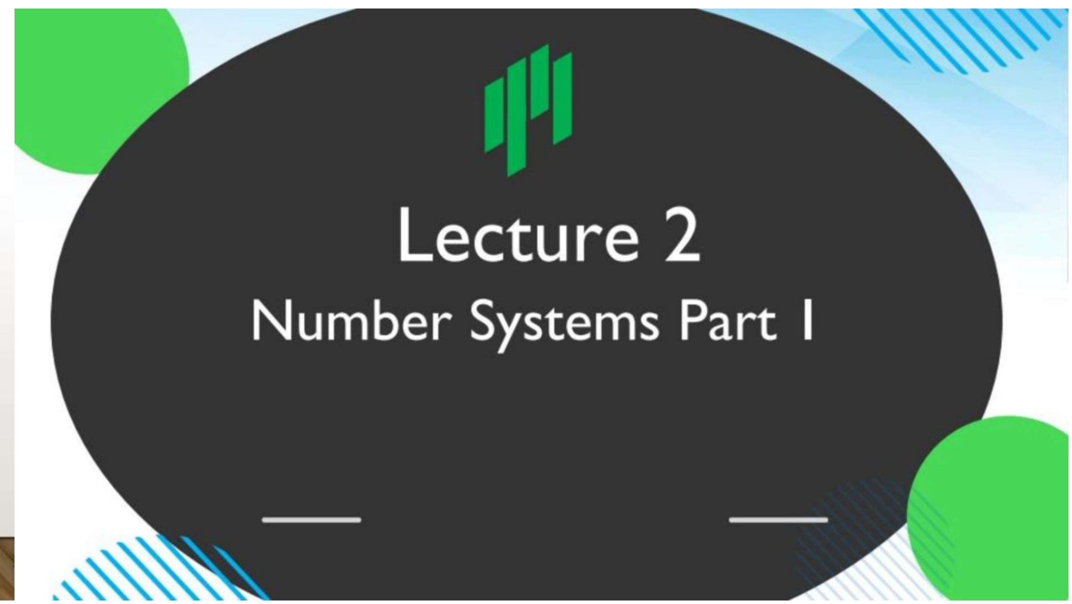
We approximate value of each sample to the nearest allowed level.
→ Introduces an error called as Quantization error.
Δ = step size
Maximum error = Δ/2

Δ : 0.5V

actual: 9.23 ⟶ 9V (transmitter)

noise: 9 → 9.26 error

receiver 9.26 ⟶ 9.5V



NUMBER SYSTEMS

A number system with base '*b*', will have b different digits, ranging from '*0*' to '*b-1*'

eg : decimal number system
Base = 10
Digits : 0, 1, 2, …, 9
$\boxed{\rightarrow \text{Positional number system}}$
Position of a digit defines weightage given to a digit.

eg $\begin{pmatrix} \overset{3\,2\,1\,0}{8357} \end{pmatrix}_{10}$ weightage ↑ as we move from right to left

$8 \times 1000 + 3 \times 100 + 5 \times 10 + 7 \times 1$
$8 \times 10^3 + 3 \times 10^2 + 5 \times 10^1 + 7 \times 10^0$

CONVERSION OF NUMBER SYSTEMS

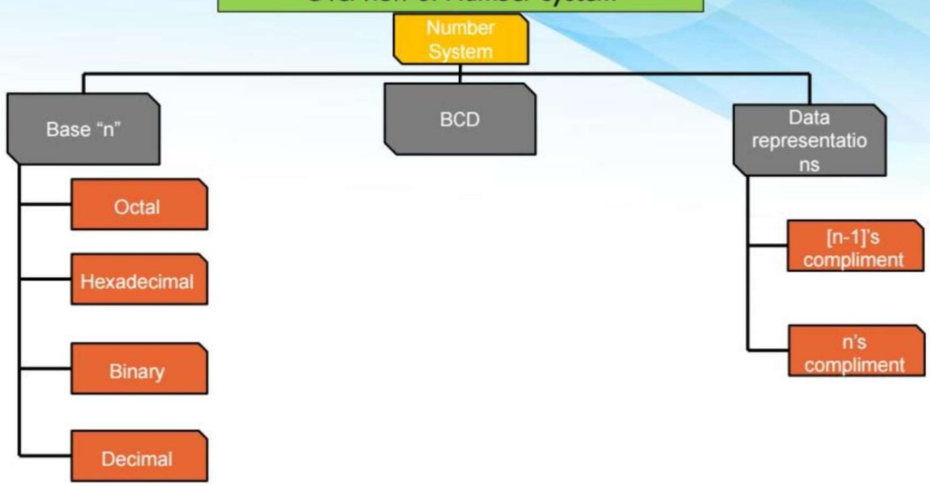
(1) Decimal to Any Base
$[N]10 \rightarrow [?]b$

(2) Any base to Decimal
$[N]b \rightarrow [?]10$

(3) One base to another base
$[N_1]_{b_1} \rightarrow [?]_{b_2}$

(4) Required base = (Given Base)$^{\text{integer}}$

Overview of Number System



**SN

Number systems of different Base

Base : In a positional numeral system, the radix or base is the number of unique digits, including the digit zero, used to represent numbers.

Base	Terminology	Range
2	Binary	0,1
3	Ternary	0,1,2
8	Octal	0 – 7
10	Decimal	0 – 9
16	Hexadecimal	0 – 9 , A – F

Decimal to Other Base System

Steps to follow:

- Step 1- Divide the decimal number to be converted by the value of the new base.
- Step 2 - Get the remainder from Step 1 as the rightmost digit (least significant digit) of new base number.
- Step 3 - Divide the quotient of the previous divide by the new base.
- Step 4 - Record the remainder from Step 3 as the next digit (to the left) of the new base number.

Repeat Steps 3 and 4, getting remainders from right to left, until the quotient becomes zero in Step 3.

The last remainder thus obtained will be the Most Significant Digit (MSD) of the new base number.

Decimal to Other Base System

- If the decimal number contains a few digits after decimal point
  → multiply decimal part by new base and note the integer part
  → again multiply decimal part by new base and keep on doing it till decimal part becomes 0
  → the integer parts obtained are written left to right after decimal point.

Any Base to Decimal

** SN

$(\overset{3}{d_3}\,\overset{2}{d_2}\,\overset{1}{d_1}\,\overset{0}{d_0}\,.\,\overset{-1}{d_{-1}}\,\overset{-2}{d_{-2}}\,\overset{-3}{d_{-3}})_r$

$d_3 \cdot r^3 + d_2 r^2 + d_1 r^1 + d_0 r^0 + d_{-1} r^{-1} + d_{-2} r^{-2} + d_{-3} r^{-3}$

- multiply each digit by base raised to an appropriate power based on position of digit & then take the sum.

Question-01

** SN

Convert the following numbers from Decimal Number System to desired base

(1) 56.625 to Binary

(2) 712 to octal

(3) 4096 to Hexadecimal

(1)

	Q	R
$\frac{56}{2}$ =	28	0
$\frac{28}{2}$	14	0
$\frac{14}{2}$	7	0
$7/2$	3	1
$3/2$	1 < 2	1
		1

		f
0.625 x 2	1.25	1
0.25 x 2	0.50	0
0.50 x 2	1.00	1
0.00 x 2	0	0

$(111000.1010)_2$

②

	Q	R
$\frac{712}{8}$	89	0
$89/8$	11	1
$11/8$	$1<8$	3
		1

$(1310)_8$

③

	Q	R
$\frac{4096}{16}$	256	0
$256/16$	16	0
$16/16$	$1<16$	0
		1

$(1000)_{16}$

Question-02 **

Convert the following numbers from given Number System to Decimal Number System

(1) $(111.011)_2$

(2) $(527.1)_8$

①

$$\begin{array}{ccccccc} 2^2 & 2^1 & 2^0 & & 2^{-1} & 2^{-2} & 2^{-3} \\ 1 & 1 & 1 & . & 0 & 1 & 1 \end{array}$$

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

$= 4 + 2 + 1 + 0.25 + 0.125 = (7.375)_{10}$

②

$$\begin{array}{ccccc} 8^2 & 8^1 & 8^0 & & 8^{-1} \\ 5 & 2 & 7 & . & 1 \end{array}$$

$5 \times 8^2 + 2 \times 8^1 + 7 \times 8^0 + 8^{-1}$

$5 \times 64 + 16 + 7 + 0.125$

$(343.125)_{10}$

Other Base System to Non-Decimal System

base-b_1 base-b_2

Steps to follow:

- **Step 1** – Convert the original number to a decimal number (base 10).
- **Step 2** – Convert the decimal number so obtained to the new base number.

Binary to Octal

** SN

base-2 base-$8 = 2^3$

Steps

- Step 1 – Divide the binary digits into groups of three (starting from the right).
- Step 2 – Convert each group of three binary digits to one octal digit.

If number of digits are insufficient in last group

→ Add 0's to the left if group is left of decimal pt.

→ Add 0's to the right if group is right of decimal pt.

Octal to Binary

**SN

Steps

- **Step 1** – Convert each octal digit to a 3 digit binary number (the octal digits may be treated as decimal for this conversion).
- **Step 2** – Combine all the resulting binary groups (of 3 digits each) into a single binary number.

**SN

Octal : base = 8
Binary : base = 2
$8 = 2^3$
Each octal
Digit can be represented as 3 binary digit

Octal	Binary (4 2 1)
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Octal → Binary

$(713.42)_8$

$(111\ 001\ 011 . 100\ 010)_2$

Binary → octal

$(1101.0101)_2$

$\underbrace{001}\ \underbrace{101} . \underbrace{010}\ \underbrace{100}$

$(15.24)_8$

Binary to Hexadecimal

base-2 base-16 = 2^4

Steps

- **Step 1 –** Divide the binary digits into groups of four (starting from the right).
- **Step 2 –** Convert each group of four binary digits to one hexadecimal symbol.

Hexadecimal Digits in Binary System

** SN

Hexa	Binary	Hexa	Binary (8421)
0	0000	8	1000
1	0001	9	1001
2	0010	10 A	1010
3	0011	11 B	1011
4	0100	12 C	1100
5	0101	13 D	1101
6	0110	14 E	1110
7	0111	15 F	1111

Hexadecimal → Binary

$(2AE.7D)_{16}$

$(0010\ 1010\ 1110 . 0111\ 1101)_2$

(Binary → Hexadecimal)

$(10101 1001 . 1010 1111 01)_2$

8 4 2 1

$0001\ 0101\ 1001 . 1010\ 1111\ 0100$

$(159.AF4)_{16}$

Hexadecimal to Binary

Steps

- **Step 1** – Convert each hexadecimal digit to a 4 digit binary number (the hexadecimal digits may be treated as decimal for this conversion).
- **Step 2** – Combine all the resulting binary groups (of 4 digits each) into a single binary number.

Question-03

** SN

base value > any of the digit given in expression

Given $(135)_{baseX} + (144)_{baseX} = (323)_{baseX}$
What is the value of base X?

(a) 5
(b) 3
(c) 12
(d) 6

convert each number to decimal

$\overset{2\,1\,0}{135} = x^2 \cdot 1 + x^1 \cdot 3 + x^0 \cdot 5 = x^2+3x+5$

$\overset{2\,1\,0}{144} = x^2+4x+4$

$\overset{2\,1\,0}{323} = 3x^2+2x+3$

$(x^2+3x+5) + (x^2+4x+4) = (3x^2+2x+3)$

$x^2-5x-6=0$

$x^2-6x+x-6=0$

$(x+1)(x-6)=0$

$x=-1, 6$

Question-04

$x \geq 5$ $y \leq 7$ digit $\leq (b-1)$

Consider the equation $(43)_x = (y3)_8$ where x and y are unknown. The number of possible solutions is

(5 possible solutions)

$4 \cdot x^1 + 3 \cdot x^0 = y \cdot 8^1 + 3 \cdot 8^0$

$4x + 3 = 8y + 3$

$4x = 8y$

$x = 2y$

$x = 6$ $y = 3$ $x = 12$ $y = 6$

$x = 8$ $y = 4$ $x = 14$ $y = 7$

$x = 10$ $y = 5$

Question-05

What is the addition of $(-64)_{10}$ and $(80)_{16}$?

(a) $(-16)_{10}$ ✗
(b) $(16)_{16}$ ✗
(c) $(1100000)_2$
~~(d)~~ $(01000000)_2$

$(80)_{16} = 16^1 \times 8 + 16^0 \times 0 = (128)_{10}$

$(-64)_{10} + (128)_{10} = (64)_{10}$

$= (40)_{16}$

$= (0100\ 0000)_2$

Question-06

If 73_x (in base x number system) is equal to 54_y (in base y number system), the possible values of x and y are

$x \geq 8$ $y \geq 6$

(a) 8 and 16
(b) 10 and 12
(c) 9 and 13
~~(d)~~ 8 and 11

$(73)_x = 7x + 3$

$(54)_y = 5y + 4$

$7x + 3 = 5y + 4$

$7x - 5y = 1$

verify options

$7 \times 8 - 16 \times 5 \neq 1$ $7 \times 9 - 5 \times 13 \neq 1$

$7 \times 10 - 5 \times 12 \neq 1$ $7 \times 8 - 5 \times 11 = 1$

Question-07

If $(11X1Y)_8 = (12C9)_{16}$ then the values X and Y are

(a) 5 and 1
(b) 5 and 7
(c) 7 and 5
(d) 1 and 5

hexa → oct

NOT

$(12C9)_{16} = (\underbrace{0001}_{1}\ \underbrace{0010}_{2}\ \underbrace{1100}_{C}\ \underbrace{1001}_{9})_2$

$(1\ 1\ 3\ 1\ 1)_8$

$X = 3$ $Y = 1$