Lecture 1 – Introduction and Number systems

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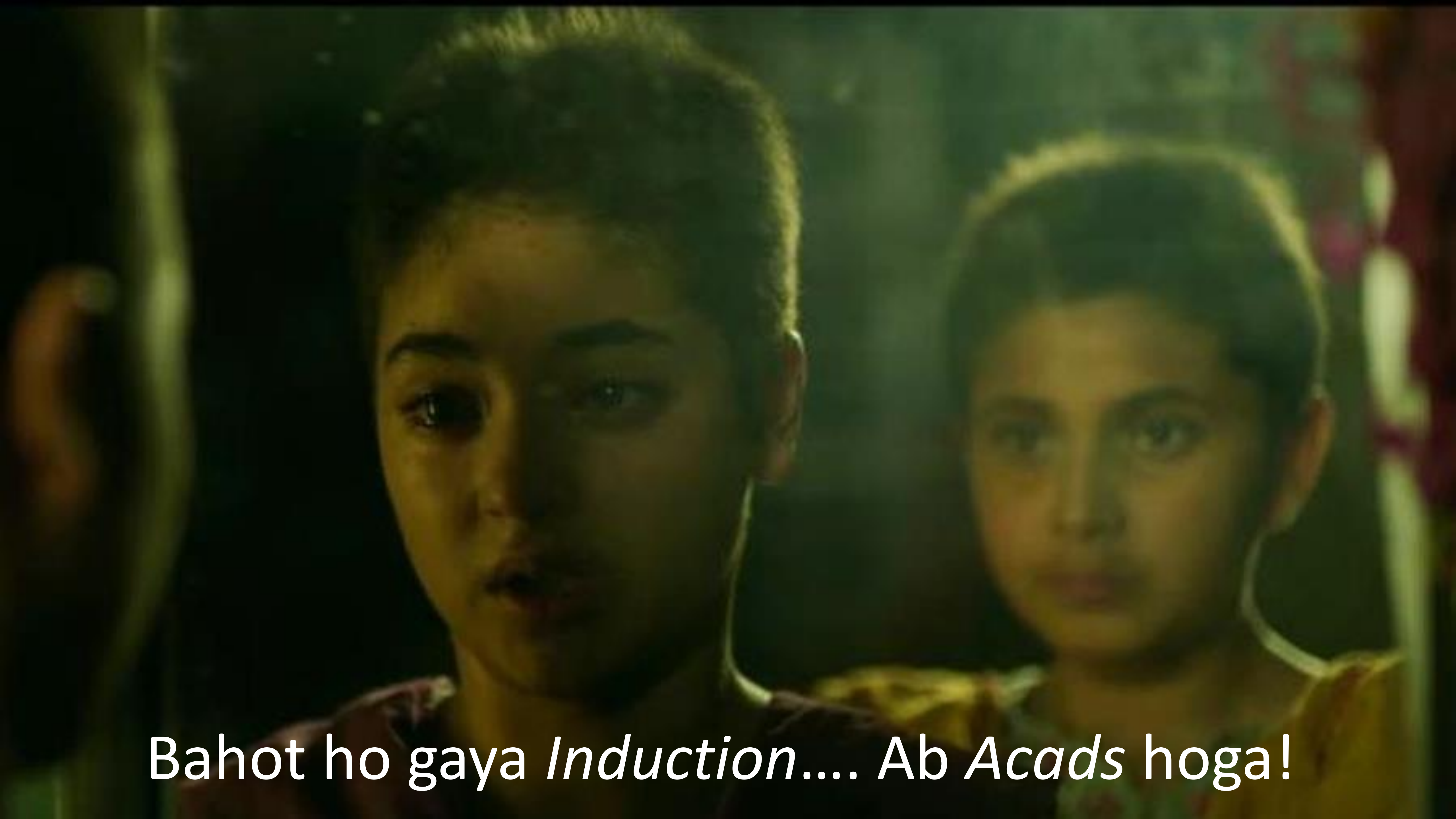
Chapter 1 (first half)


Bahot ho gaya *Induction*…. Ab *Acads* hoga!

Introductions

- B. Tech in IIT Roorkee (2009):
- After B. Tech.:
  - Design Engineer, Analog Devices India (2011)
- Joined KAUST as M.S. in 2011
- Continued as Ph.D. from Jan 2013
- Postdoc in Harvard University up to Jan 2018

- Total of 74 research papers and 7 patents in the last 6 years
  - 800+ citations in Google scholar

Courses

- Digital Systems and Microcontrollers (DSM) [UG1 core]
    - Digital logic
    - Basic digital circuits
    - Basics of microcontrollers
- Principles of Semiconductor Devices [Elective]
    - Quantum mechanics and physics of silicon lattice
    - Electron/hole motion in silicon
    - Function of pn junction and transistors from basic physics
- Flexible Electronics [Elective]
    - Semiconductor fabrication
    - Materials for flexible electronics
    - Processes and applications

About the course

- Name: Digital Systems and Microcontrollers (DSM)
- Textbook:
  - M. Morris Mano and Michael D. Ciletti, “Digital Design”, 6th edition
- Logistics:
  - Two 1.5 hour lectures per week
  - One 3 hour lab per week
  - One 1 hour Tut per week

- Faculty: Dr. Aftab M. Hussain
- Office: B6-306, Vindhaya
- Office timings: Prefer drop-ins if I am there or appointments through email

Digital systems and Microcontrollers

- Everything around us uses digital systems – phones, computers, TVs, internet, watches

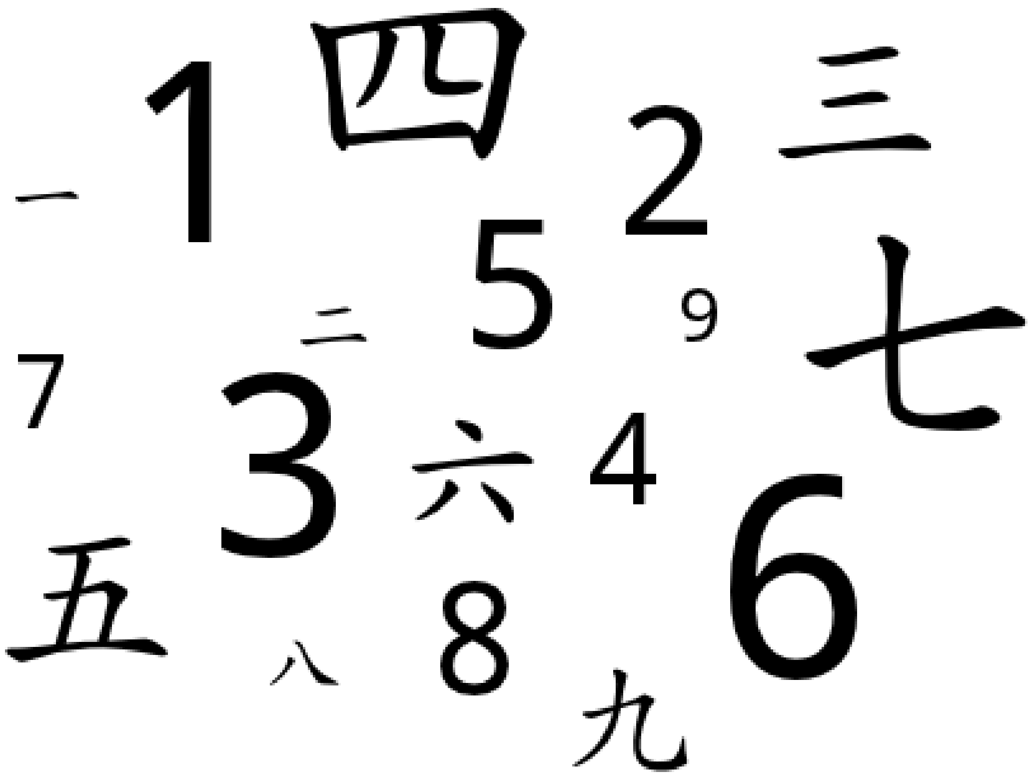
- Why digital? Information is harder to corrupt and corrupt information is easier to decorrupt in digital domain

- Some systems are naturally digital (or quantized) like cricket – each ball has a fixed number of runs associated with it
- Others are more continuous like football – harder to determine fixed moments in time when a particular event occured

Counting

- Lets relearn counting…

0 1 2 3 4 5 6 7 8 9 **10**



Counting

- Lets relearn counting…

0 1 2 3 4 5 6 7 8 9 **10**

- The number system:
  - Put symbols in specific places/positions to denote their "power"
  - The *base* or the *radix* of the decimal number system is 10

1	0	6	6
10^3	10^2	10^1	10^0
1000	100	10	1

1x1000+0x100+6x10+6x1 = 1066

1	9	4	0
10^3	10^2	10^1	10^0
1000	100	10	0

1x1000+9x100+4x10+0x1 = 1940

Various number systems

- Octal number system
  - The base or radix is 8
  - The symbols are: 0, 1, 2, 3, 4, 5, 6, 7

- Hexadecimal number system
  - The base or radix is 16
  - The symbols are: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

- Binary number system
  - The base or radix is 2
  - The symbols are: 0, 1

- We denote the base of the number using a suffix subscript: $(10395)_{10}$
- In general a number $(a_4 a_3 a_2 a_1 a_0)_r = a_4 r^4 + a_3 r^3 + a_2 r^2 + a_1 r^1 + a_0 r^0$

Conversions to decimal

- Octal number system
  - $(110)_8 = 1*8^2 + 1*8^1 + 0*8^0 = (72)_{10}$
  - $(777)_8 =$
  - $(11)_8 =$
- Hexadecimal number system
  - $(110)_{16} = 1*16^2 + 1*16^1 + 0*16^0 = (272)_{10}$
  - $(BAD)_{16} =$
  - $(DAD)_{16} =$
- Binary number system
  - $(110)_2 = 1*2^2 + 1*2^1 + 0*2^0 = (6)_{10}$
  - $(101010)_2 =$
  - $(1111)_2 =$

Conversions from decimal

- Algorithm:
  - Divide by radix
  - Save the remainder
  - Repeat
  - Arrange remainders in reverse order
- Octal number system
  - 912
  - 75
  - 22
- Hexadecimal number system
  - 1729
  - 133
  - 15
- Binary number system
  - 21
  - 10
  - 43

Conversions from Oct/Hex to Binary

- From Oct/Hex to binary, we can take a short cut because the bases are $(2)^3$ and $(2)^4$ respectively
- For octal: take each digit and convert it individually into *three* bits
- For hex: take each digit and convert it individually into *four* bits

- Octal number system
  - $(433)_8$
  - $(70)_8$
- Hexadecimal number system
  - $(DEAD)_{16}$
  - $(FEED)_{16}$

Conversions from Binary to Oct/Hex

- The reverse course can be taken for converting binary to oct or hex
- For octal: take *three* bits and convert it individually into a symbol
- For hex: take *four* bits and convert it individually into a symbol

- Octal number system
  - $(110101011)_2$
  - $(1010111101)_2$
- Hexadecimal number system
  - $(11101011)_2$
  - $(110000110)_2$
  - $(101011111)_2$

Addition

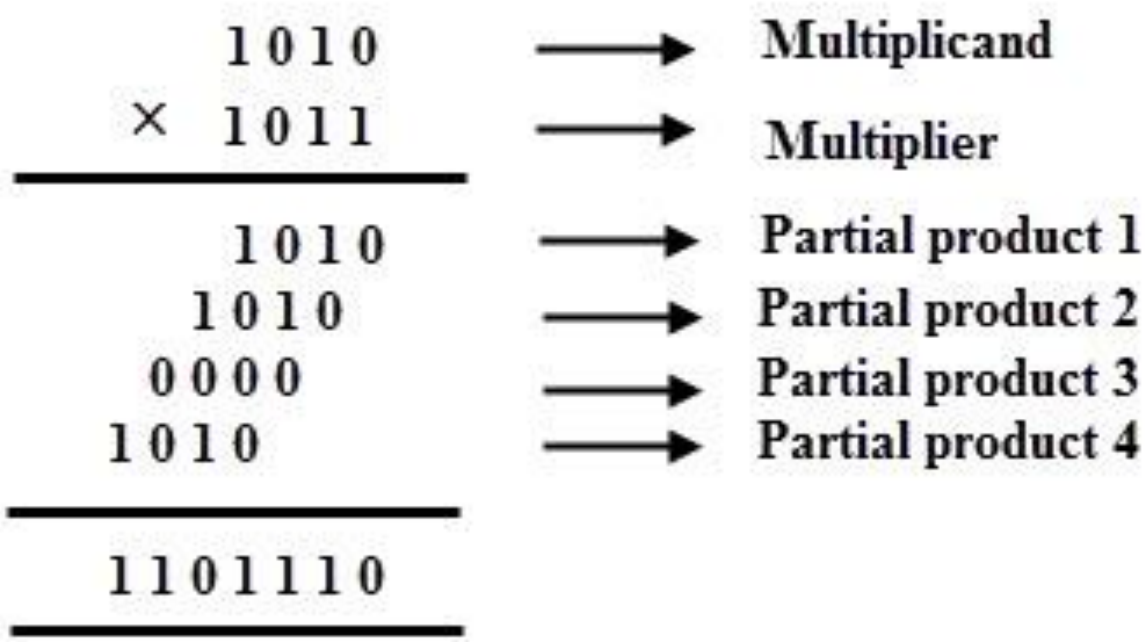
- Octal number system
  - $(73)_8 + (157)_8$
  - $(57)_8 + (23)_8$
  - $(113)_8 + (23)_8$
- Hexadecimal number system
  - $(AA)_{16} + (BB)_{16}$
  - $(BAD)_{16} + (DAD)_{16}$
  - $(93)_{16} + (157)_{16}$
- Binary number system
  - $(1101)_2 + (111)_2$
  - $(10101)_2 + (100)_2$
  - $(11)_2 + (111)_2$

Subtraction

- Octal number system
  - $(172)_8 - (161)_8$
  - $(32)_8 - (21)_8$
  - $(107)_8 - (67)_8$
- Hexadecimal number system
  - $(BB)_{16} - (AA)_{16}$
  - $(DAD)_{16} - (BAD)_{16}$
  - $(63)_{16} - (F)_{16}$
- Binary number system
  - $(1101)_2 - (111)_2$
  - $(10101)_2 - (100)_2$
  - $(1011)_2 - (111)_2$

Multiplication

- Binary number system



- Examples:
  - $(111)_2*(110)_2$
  - $(1011)_2*(1010)_2$

The “decimal” point

- The powers of radix decrease after the decimal point
- Binary to decimal:
  - $(1.011)_2 = 1*2^0+0*2^{-1}+1*2^{-2}+1*2^{-3}$

    $= 1+0.25+0.125$

    $= 1.375$
  - $(0.1101)_2$
- Decimal to binary:
  - $(0.75)_{10} = 0.75*2= 1.50$ 1

    $0.5*2 \ = 1.00$ 1

    $=(11)_2$
  - $(0.625)_{10}$