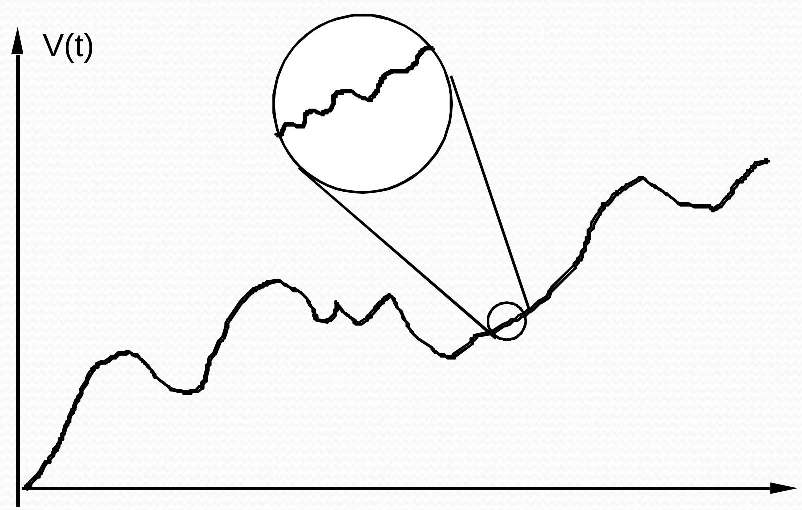
Unit 1
Lecture 1
Digital system and binary numbers

Dronacharya Group of Institutions

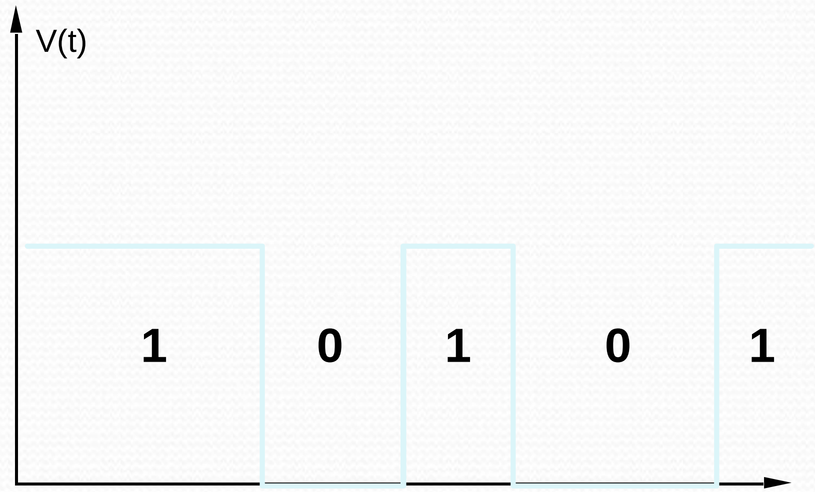
Analog/Analogue Systems

- Analogue Systems
  - V(t) can have *any value* between its minimum and maximum value



Digital Systems

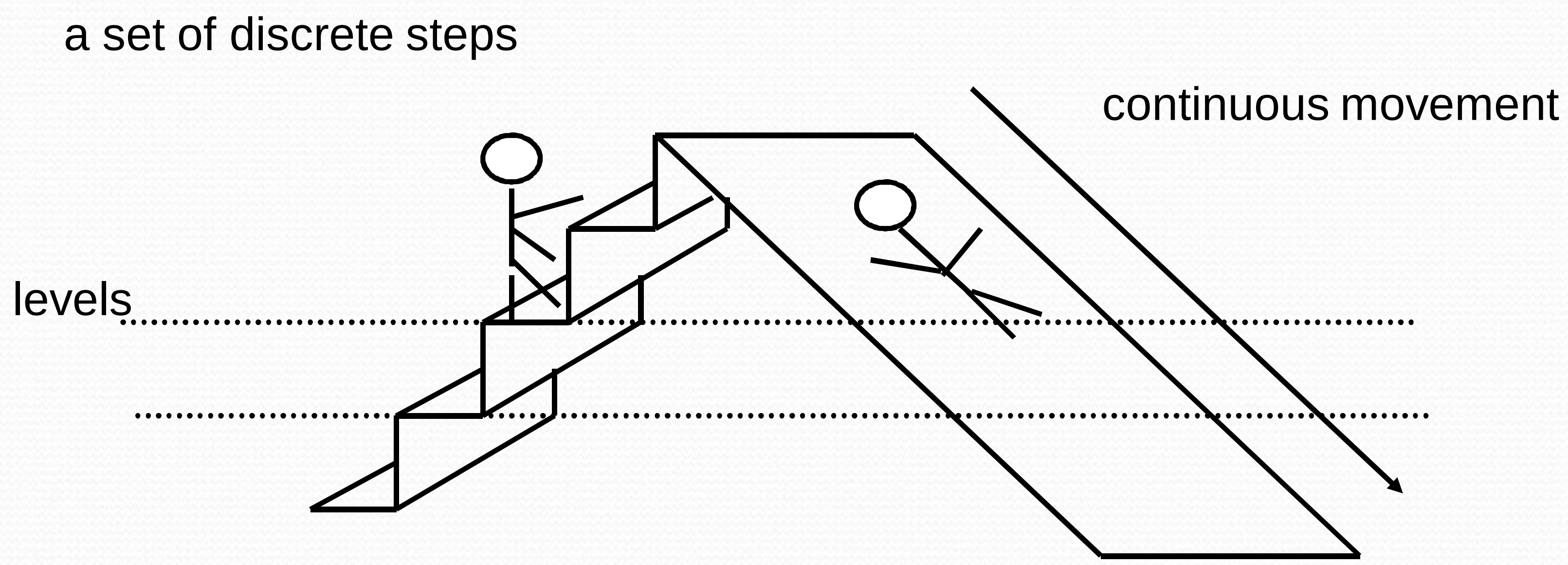
- Digital Systems
  - V(t) must take a value selected from a set of values called an alphabet
  - Binary digital systems form the basis of almost all hardware systems currently



For example, Binary Alpha

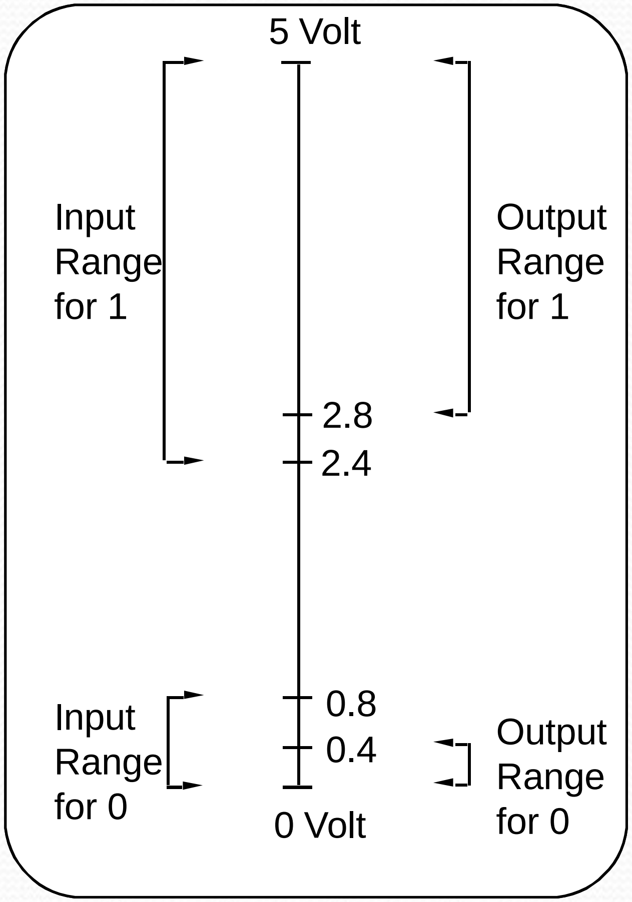
Slide example

- Consider a child's slide in a playground:



Relationship between Analogue and Digital systems

- **Advantages of Digital Systems**
  - Analogue systems: slight error in input yields large error in output
  - Digital systems more accurate and reliable
  - Computers use digital circuits internally
  - Interface circuits (for instance, sensors and actuators) are often analogue

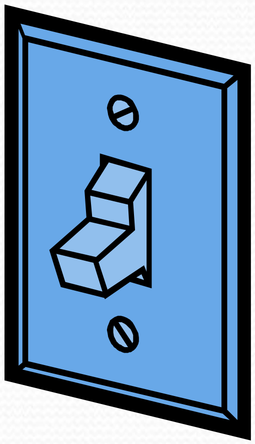


Exercise

- Explain whether the following are analog or digital:
  - A photograph or painting
  - A scanned image
  - Sound from a computer’s loud speaker
  - Sound file stored on disc

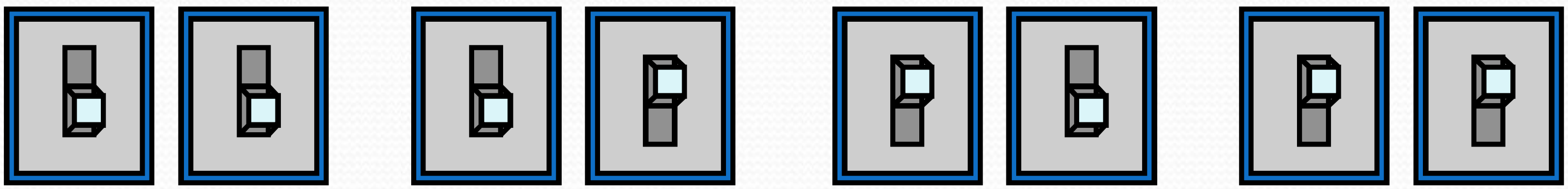
Binary Inputs and Outputs

- Coding:
  - A single binary input can only have two values: True or False (Yes or No) (1 or 0)



Binary

- **More bits = more combinations**



0 0 0 1 1 0 1 1

Each additional input doubles the number of combinations we can represent i.e. with *n* inputs it is possible to represent 2^n combinations

Combinations

- Example 1:
  - How many combinations are possible with 10 binary inputs?
- Example 2:
  - What is the minimum number of bits needed to represent the digits ‘0’ to ‘9’ as a binary code?”

Decimal systems

- Number Representation
  - Difficult to represent Decimal numbers directly in a digital system
  - Easier to convert them to binary
  - There is a weighting system:

403 = 4 x 100 + 0 x 10 + 3 x 1

or in, powers of 10:

$$403_{10} = 4 \times 10^2 + 0 \times 10^1 + 3 \times 10^0 = 400 + 0 + 3$$

Binary Inputs and Outputs

- **Both Decimal and Binary numbers use a positional weighting system, eg:**

$$1010_2 = 1x2^3+0x2^2+1x2^1+0x2^0 = 1x8 + 0x4 + 1x2 + 0x1 = 10_{10}$$

decimal		100 (10^2)	10 (10^1)	1 (10^0)	
		4	0	3	400 + 0 + 3
binary	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)	
	1	0	0	1	8 + 0 + 0 + 1

Binary to decimal

- **Multiply each 1 bit by the appropriate power of 2 and add them together.**

?	?	128	64	32	16	8	4	2	1
		1	0	0	0	0	0	1	1
	1	0	1	0	0	1	1	0	0

10000011_2 = ………………… $_{10}$?

101001100_2 = …………………… $_{10}$?

Decimal to Binary

An alternative way is to use the “placement” method

128	64	32	16	8	4	2	1

128 goes into 155 once leaving 27 to be placed

So 64 and 32 are too big (make them zero) 16 goes in once leaving 11

1							

and so on...

1	0	0	1				

Binary Inputs and Outputs

- 6 of the possible 16 values unused
- example 453_{10} = $0100\ 0101\ 0011_{BCD}$
- Note that BCD code is longer than a direct representation in natural binary code:
- 453 = 111000101

Decimal	BCD
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

Binary Inputs and Outputs

- Hexadecimal and Octal
  - Writing binary numbers as strings of 1s and 0s can be very tedious
  - Octal (base 8) and Hexadecimal (base 16) notations can be used to reduce a long string of binary digits.

octal	**512 (8^3)**	**64 (8^2)**	**8 (8^1)**	**1 (8^0)**	
	1	**2**	**0**	**7**	**512 + 128 + 7**
hexadecimal		**256 (16^2)**	**16 (16^1)**	**1 (16^0)**	
		1	**A**	**F**	**256 + 160 + 15**

Notice that hexadecimal requires 15 symbols (each number system needs 0 – base-1 symbols) and therefore A – F are used after 9.

Octal as shorthand for Binary

- **Each octal digit corresponds to 3 binary bits**

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

To convert a binary string:
10011101010011

Split into groups of 3:

010 011 101 010 011

2 3 5 2 3

Thus $10011101010011_2 = 23523_8$

Similarly with Hexadecimal

- Each hex digit corresponds to 4 binary bits

binary	hex
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7

binary	hex
1000	8
1001	9
1010	A
1011	B
1100	C
1101	D
1110	E
1111	F

To convert a binary string: 10011101010011

Split into groups of 4:

0010 0111 0101 0011

Thus 10011101010011_2 = ……………$_{16}$?