Digital to Analogue Converter
DAC

DAC and ADC

- DAC converts a digital signal into an analogue voltage or current
- ADC converts an analogue voltage or current to digital signal.
- Digital-to-analogue (D/A) and analogue-to-digital (A/D) converters constitute an essential link when digital devices interface with analogue devices, and vice versa.
- They are important building blocks of any digital system, including both communication and noncommunication systems.

BINARY TO DECIMAL

Convert binary number 10101 to decimal

Step-1: Find bit position start the LSB with position 0.

here

Binary number	1	0	1	0	1
Bit positions	4	3	2	1	0

Step-2: Multiply each bits with base

here

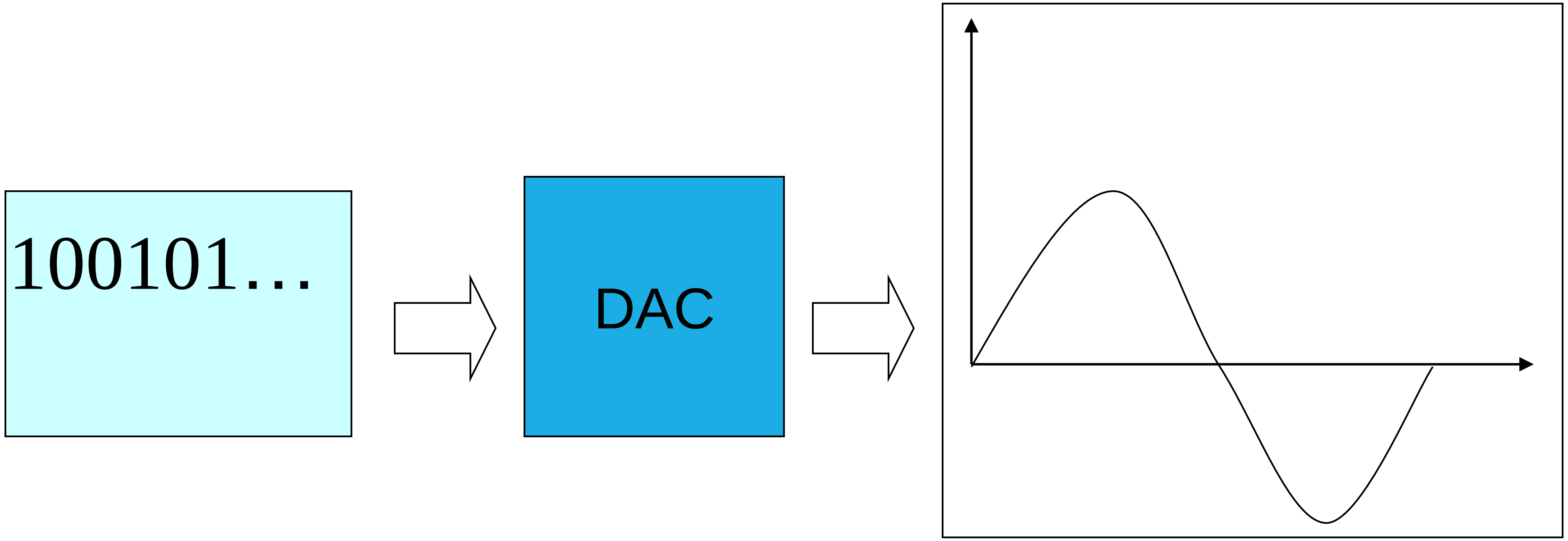
Binary number	1	0	1	0	1
Base	2^4	2^3	2^2	2^1	2^0

Step-3: Add to find the result

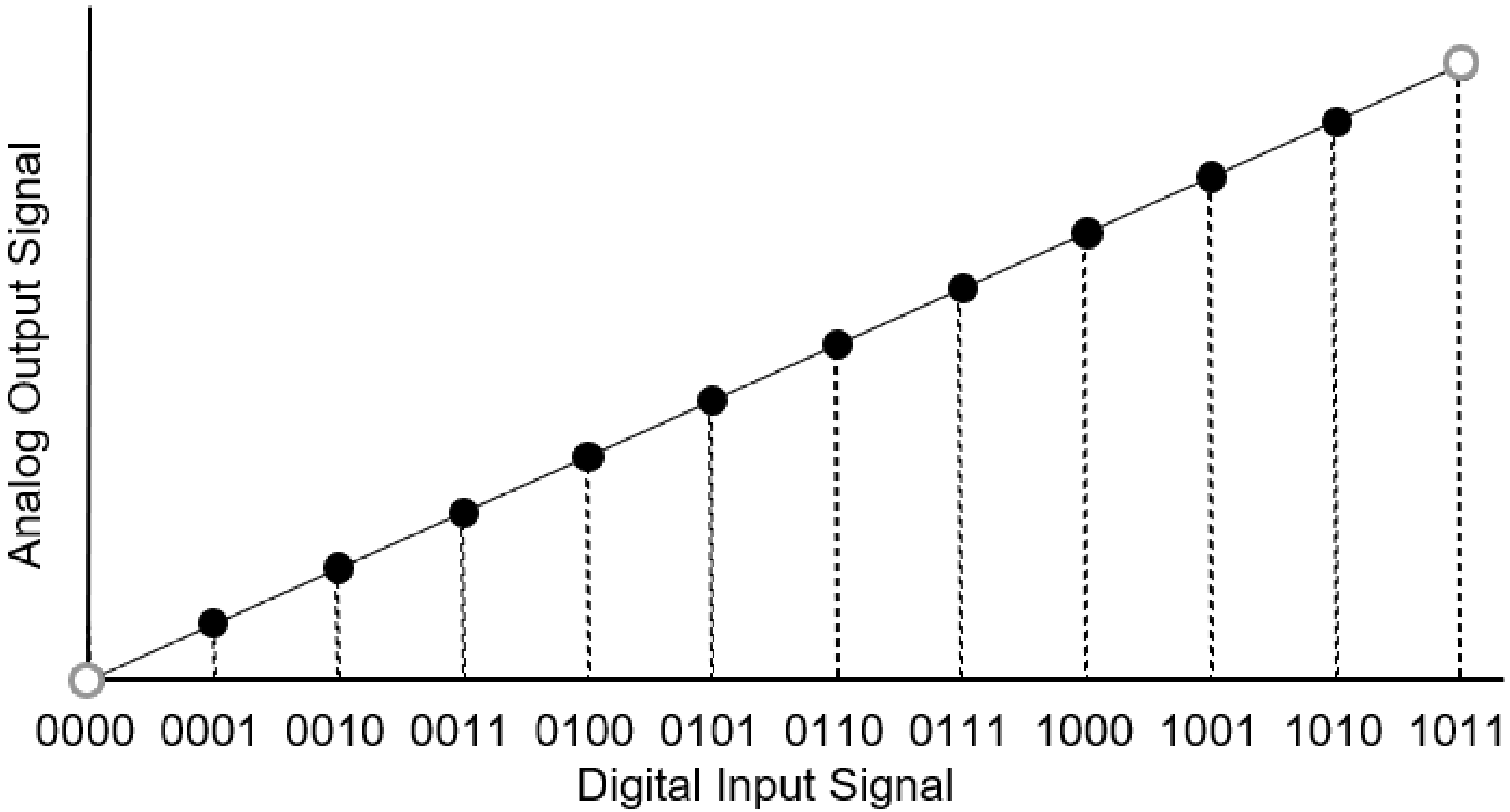
here $(1\bullet 2^4)+(0\bullet 2^3)+(1\bullet 2^2)+(0\bullet 2^1)+(1\bullet 2^0)=$**21**

What is a DAC?

- A digital to analog converter (DAC) converts a digital signal to an analog voltage or current output.



What is a DAC?



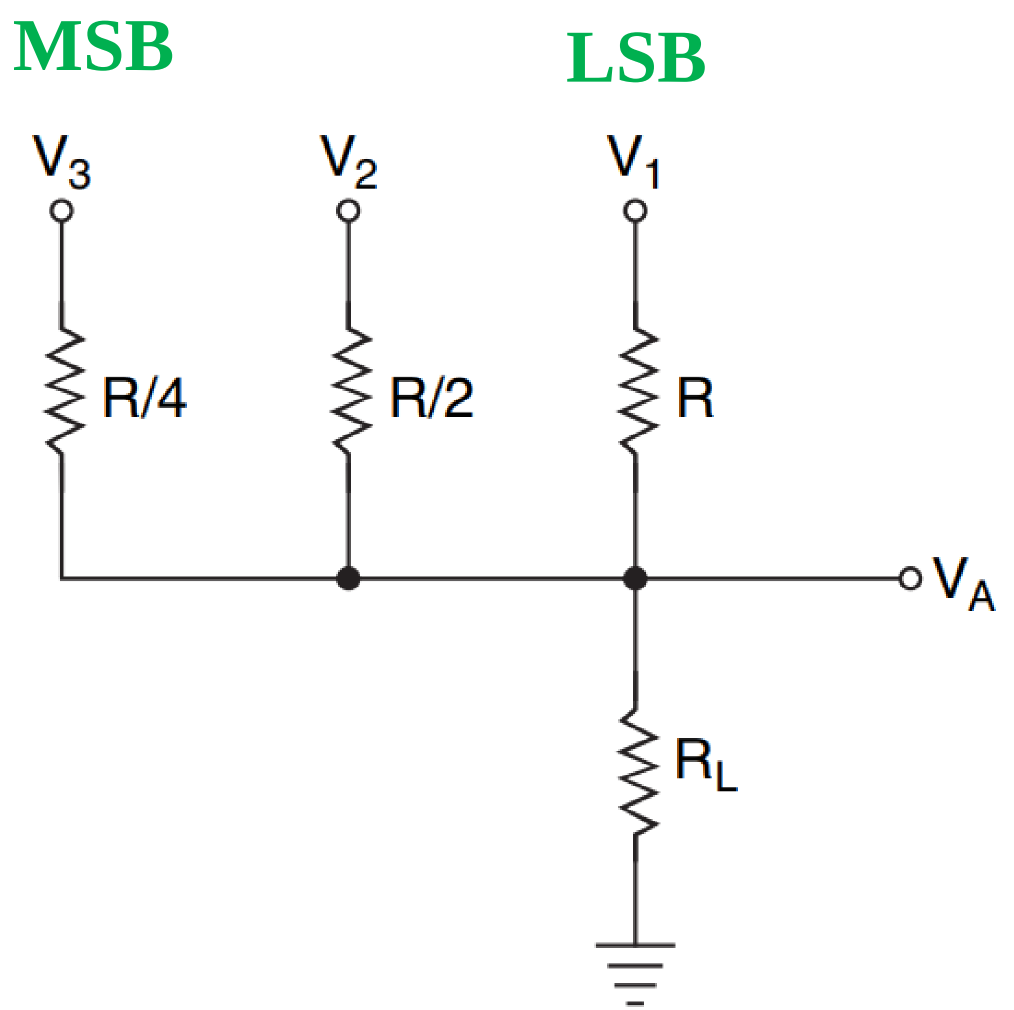
Analog Output Signal
0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011
Digital Input Signal

Types of DACs

- Two Types:

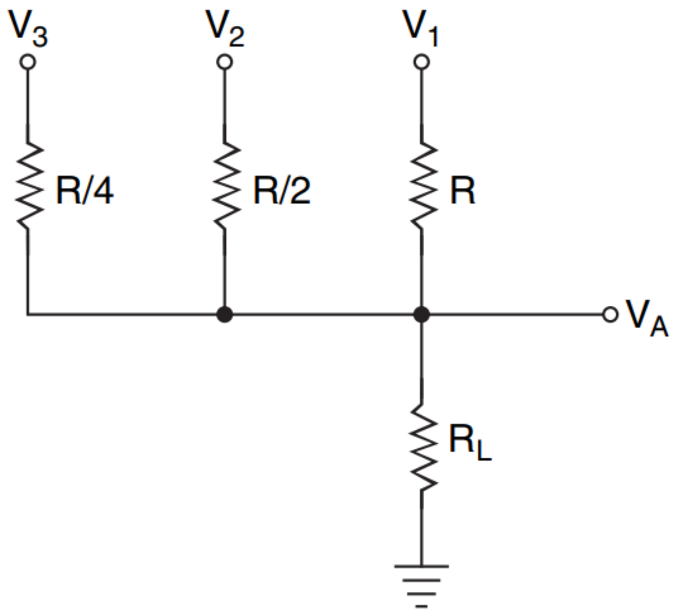
  - Resistive Divider Network (Binary Weighted Resistor)
  - R-2R Ladder

Simple Resistive Divider Network for D/A Conversion

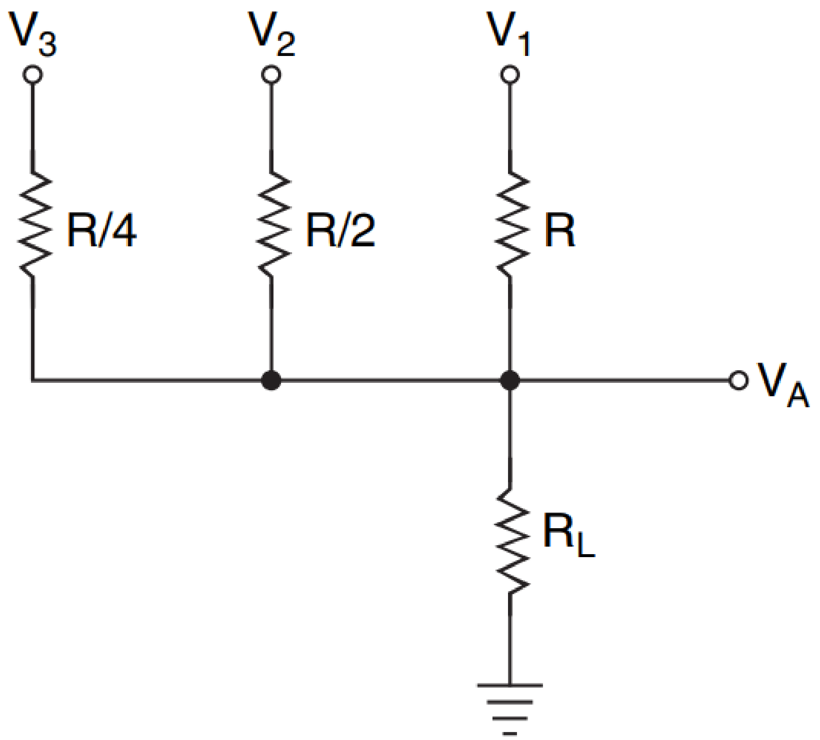


Simple Resistive Divider Network for D/A Conversion

- Simple resistive networks can be used to convert a digital input into an equivalent analogue output.
- Normally, RL (load resistor) is much larger than R



$$\frac{(V_A - V_3)}{R/4} + \frac{(V_A - V_2)}{R/2} + \frac{(V_A - V_1)}{R} + \frac{V_A}{R_L} = 0$$



$$V_A = \frac{[V_1/R] + [V_2/(R/2)] + [V_3/(R/4)]}{[1/R] + [1/(R/2)] + [1/(R/4)]}$$

$$= \frac{[V_1/R] + [2V_2/R] + [4V_3/R]}{[1/R] + [2/R] + [4/R]}$$

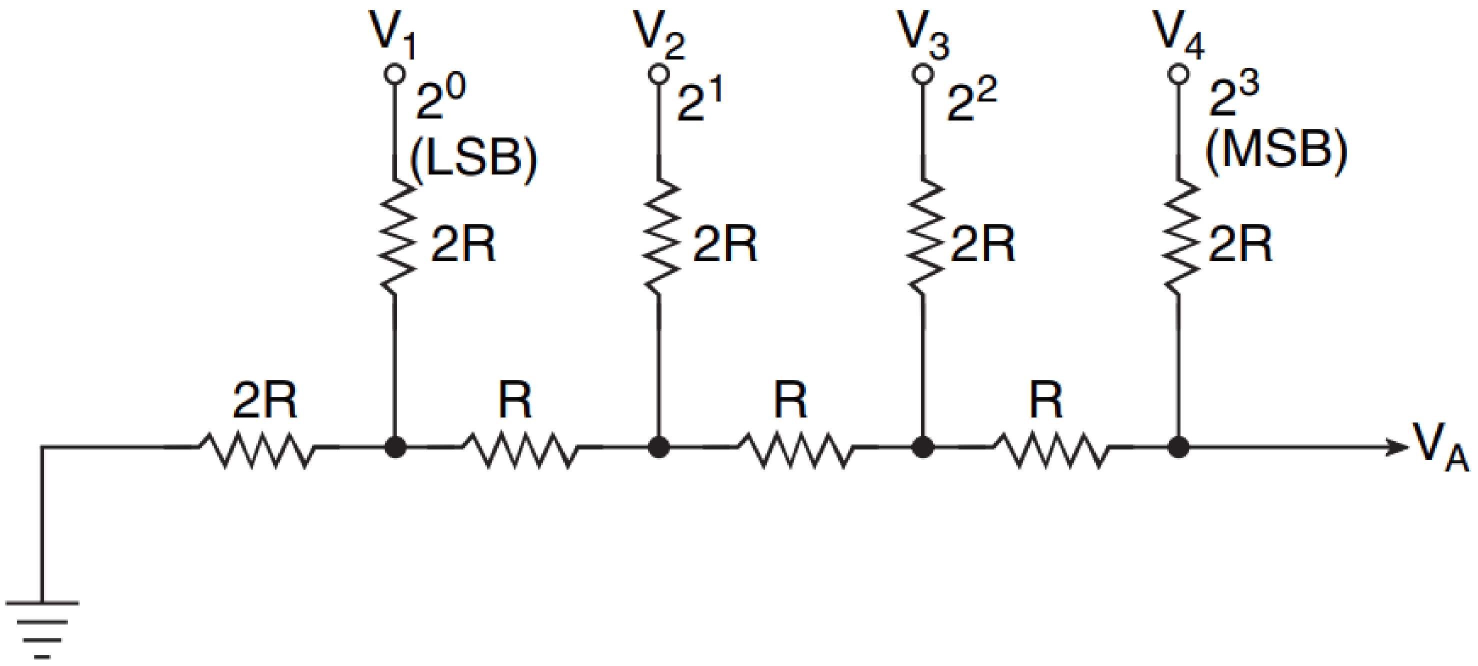
$$= \frac{V_1 + 2V_2 + 4V_3}{7}$$

$$V_A = \frac{V_1 \times 2^0 + V_2 \times 2^1 + V_3 \times 2^2}{2^3 - 1}$$

Resistive Divider Network

- **Advantages**
  - Simple Construction/Analysis
  - Fast Conversion
- **Disadvantages**
  - Requires large range of resistors (2000:1 for 12-bit DAC) with necessary high precision for low resistors
  - Requires low switch resistances in transistors
  - Can be expensive. Therefore, usually limited to 8-bit resolution.

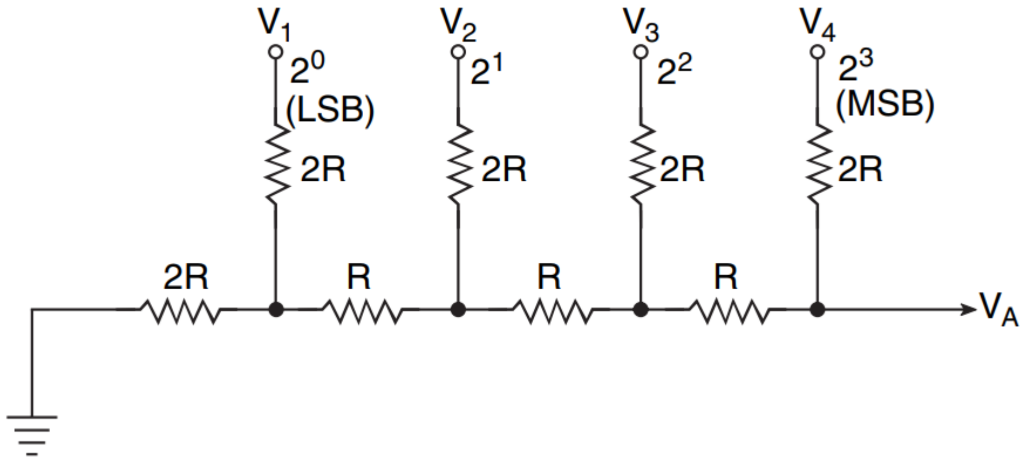
Binary Ladder Network for D/A Conversion



Binary Ladder Network for D/A Conversion

- The ladder is made up of only two different values of resistor.

- It can be proved with the help of simple mathematics that the analogue output voltage VA



$$V_A = \frac{V_1 \times 2^0 + V_2 \times 2^1 + V_3 \times 2^2 + V_4 \times 2^3}{2^4}$$

R-2R Ladder

- **Advantages**
  - Only two resistor values (R and 2R)
  - Does not require high precision resistors

- **Disadvantage**
  - Lower conversion speed than binary weighted DAC

Specifications of DACs

- **Resolution**
- **Speed**
- **Linearity**
- **Settling Time**

Resolution

- Smallest analog increment corresponding to 1 LSB change
- An N-bit resolution can resolve 2^N distinct analog levels
- Common DAC has a 8-16 bit resolution

$$\text{Resolution} = V_{LSB} = \frac{V_{ref}}{2^N}$$

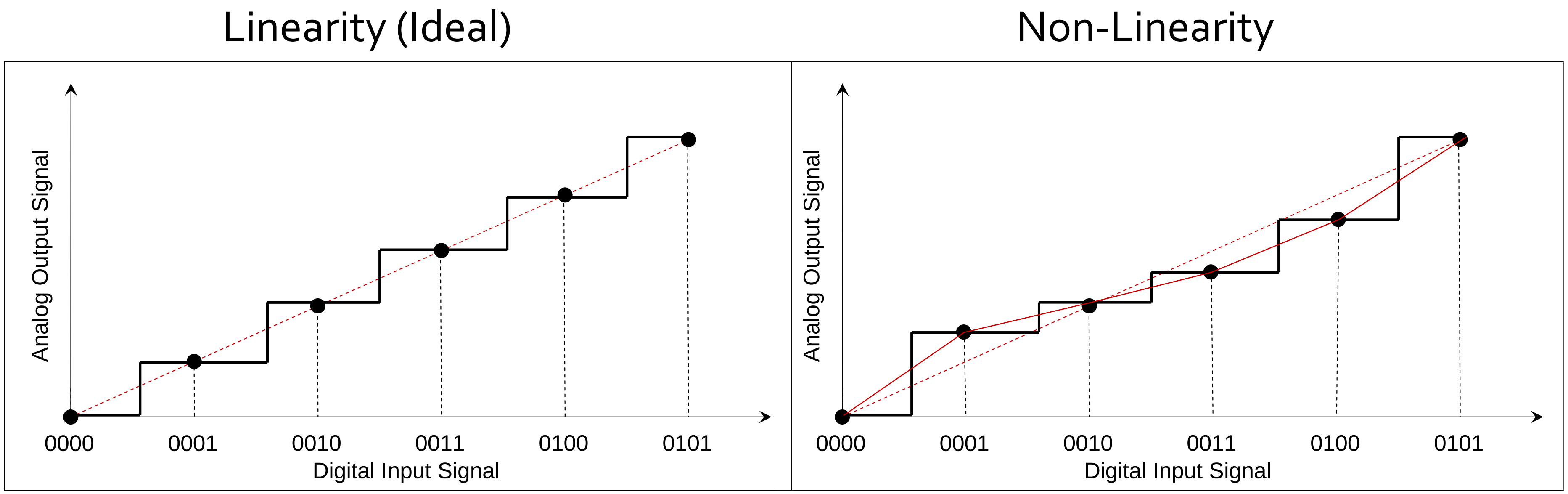
$$\text{where } N = \textit{number of bits}$$

Speed

- Rate of conversion of a single digital input to its analog equivalent
- Conversion rate depends on
  - clock speed of input signal
  - settling time of converter
- When the input changes rapidly, the DAC conversion speed must be high.

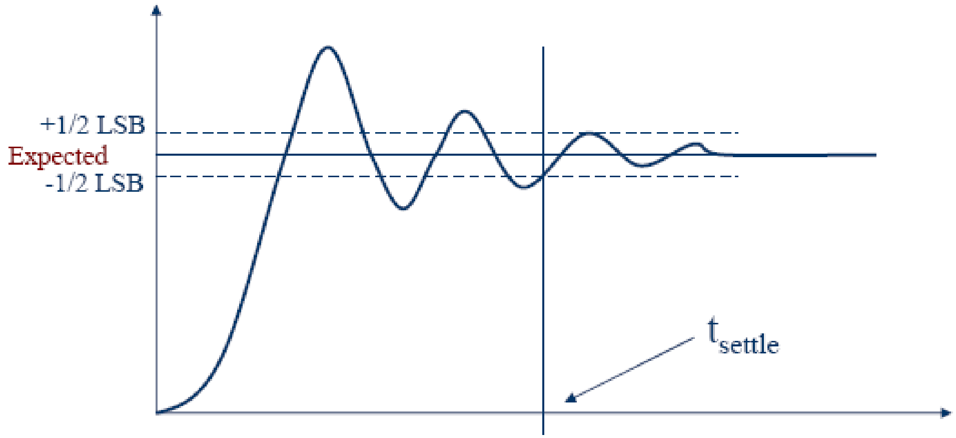
Linearity

- Ideally, a DAC should produce a linear relationship between the digital input and analog output



Settling Time

- Time required for the output signal to settle within +/- ½ LSB of its final value after a given change in input scale
- Ideally, an instantaneous change in analog voltage would occur when a new binary word enters into DAC



Accuracy

The accuracy of a D/A converter is the difference between the actual analogue output and the ideal expected output when a given digital input is applied.