Department of Physics
Periyar Arts College, Cuddalore

III B.Sc . PHYSICS

Elective - Digital Electronics

6-8-2020   10 AM- 11AM

UNIT 5

Introduction to D/A and A/D Converters

Binary Weighted Resistor DAC

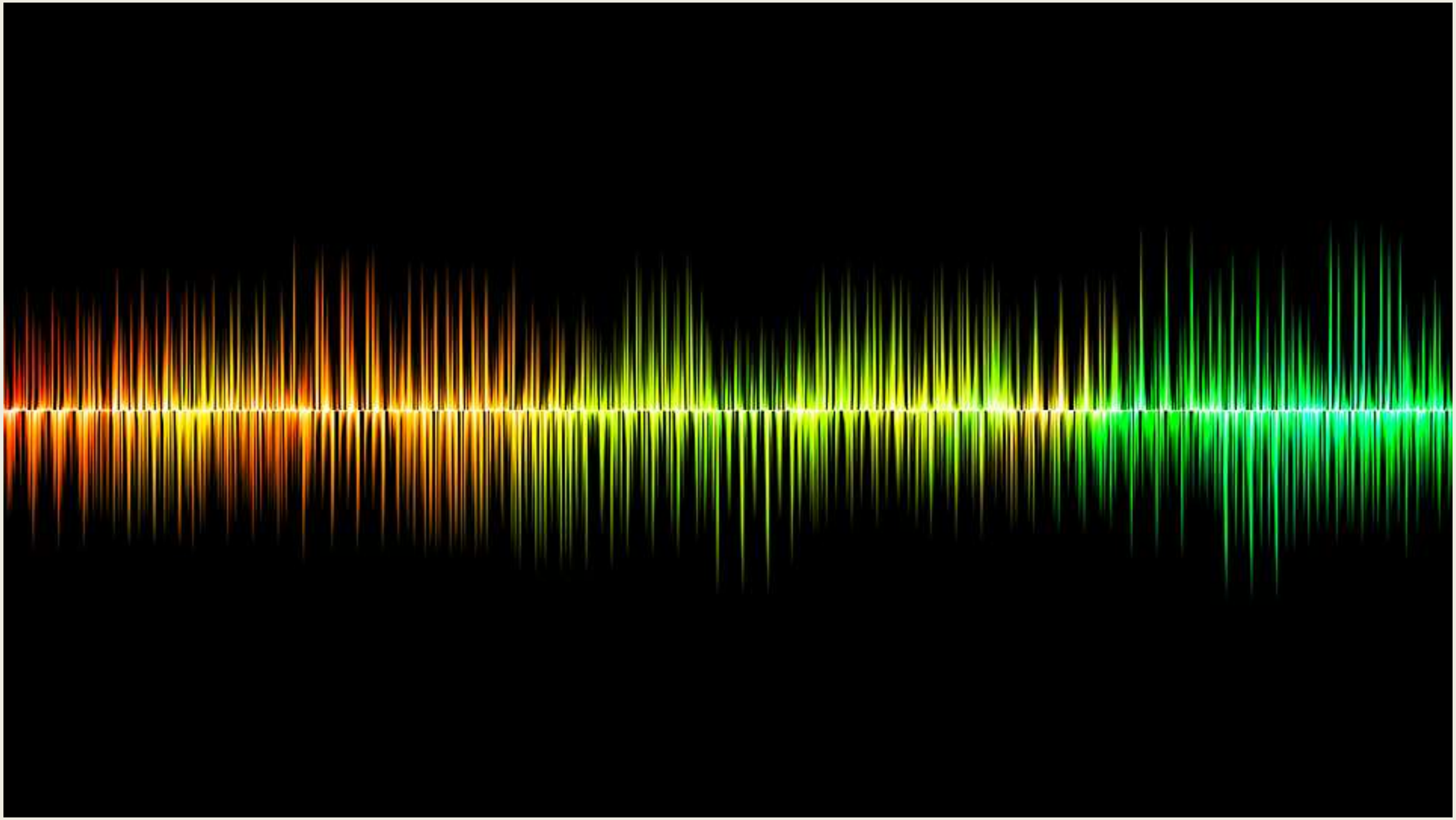
Slides prepared by JA

ANALOG SIGNALS

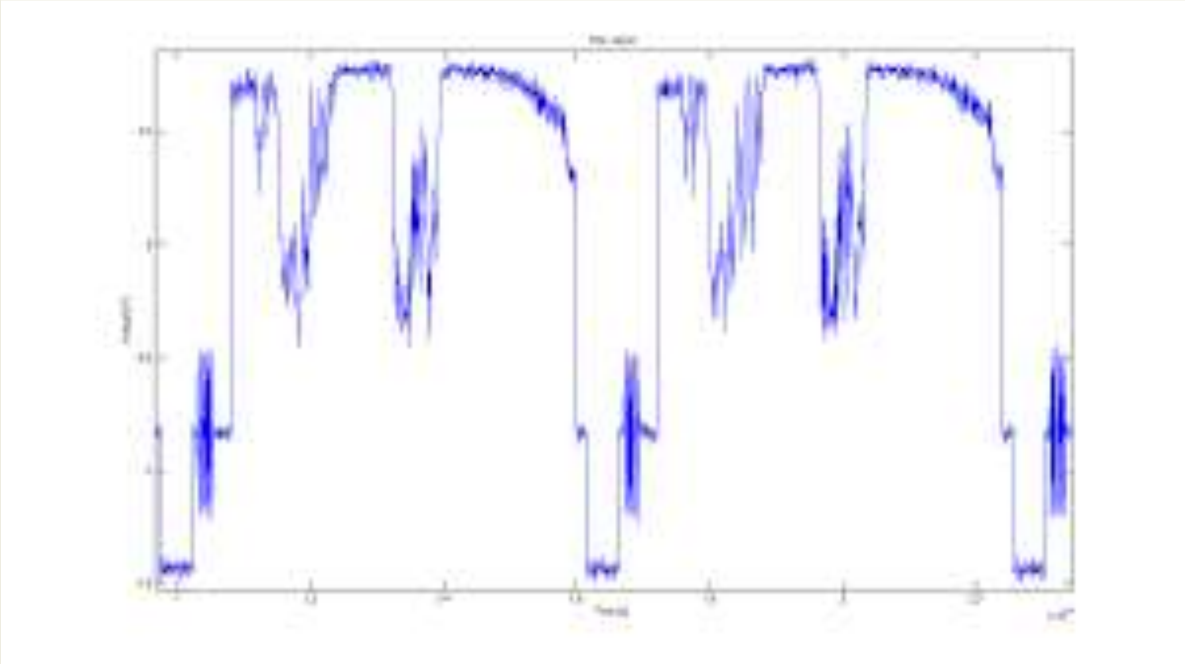
(Continuously Changing with time)

- Pressure Variations
- Light Intensity Variations
- Sound Signal
- Video Signal
- ECG Signals
- Temperature Variations
- Any Physical Quantity from transducers
- The real world deals with only Analog signals

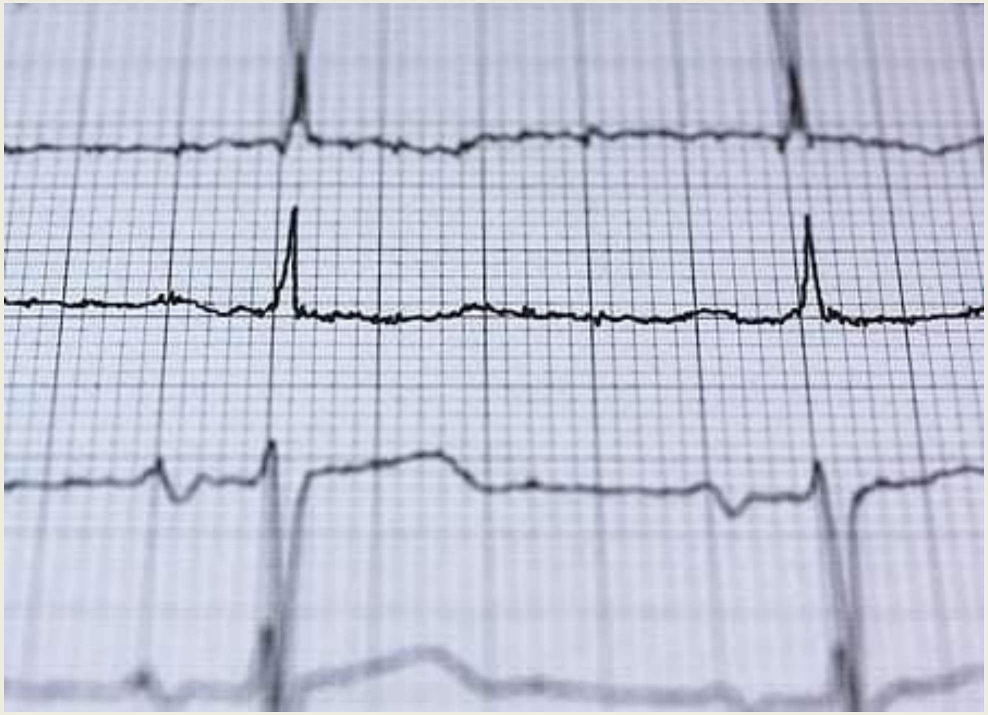
Voice Signal from Microphone (Analog Signal)



Composite Video Signal (TV) (Analog Signal)

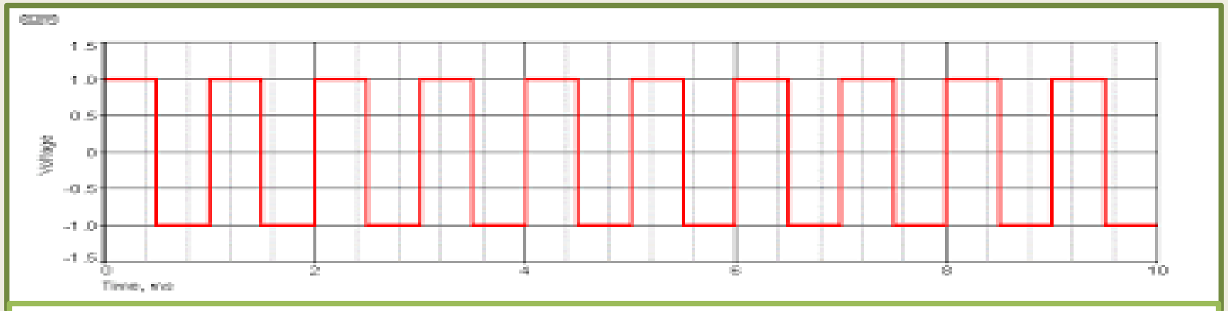


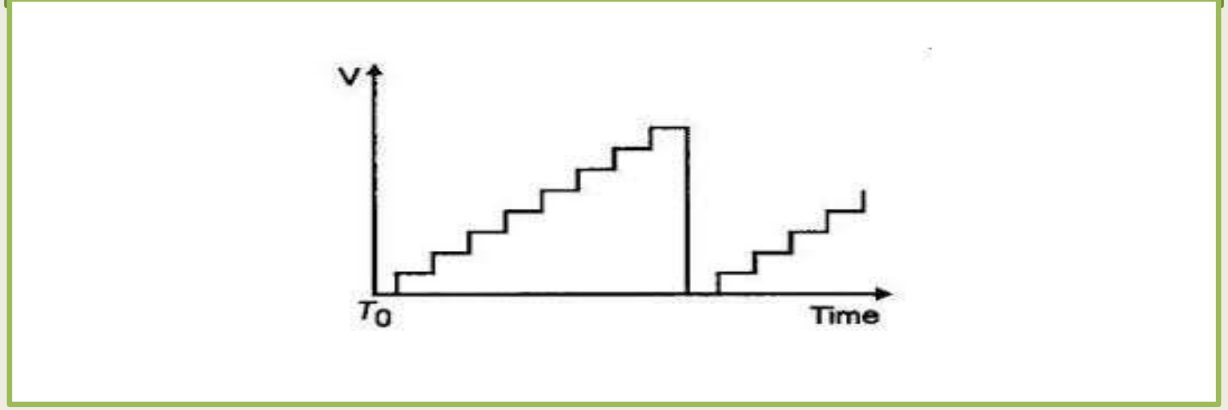
ECG Signal (Analog signal)
Electro Cardio Graph
Human Heart beat pulses



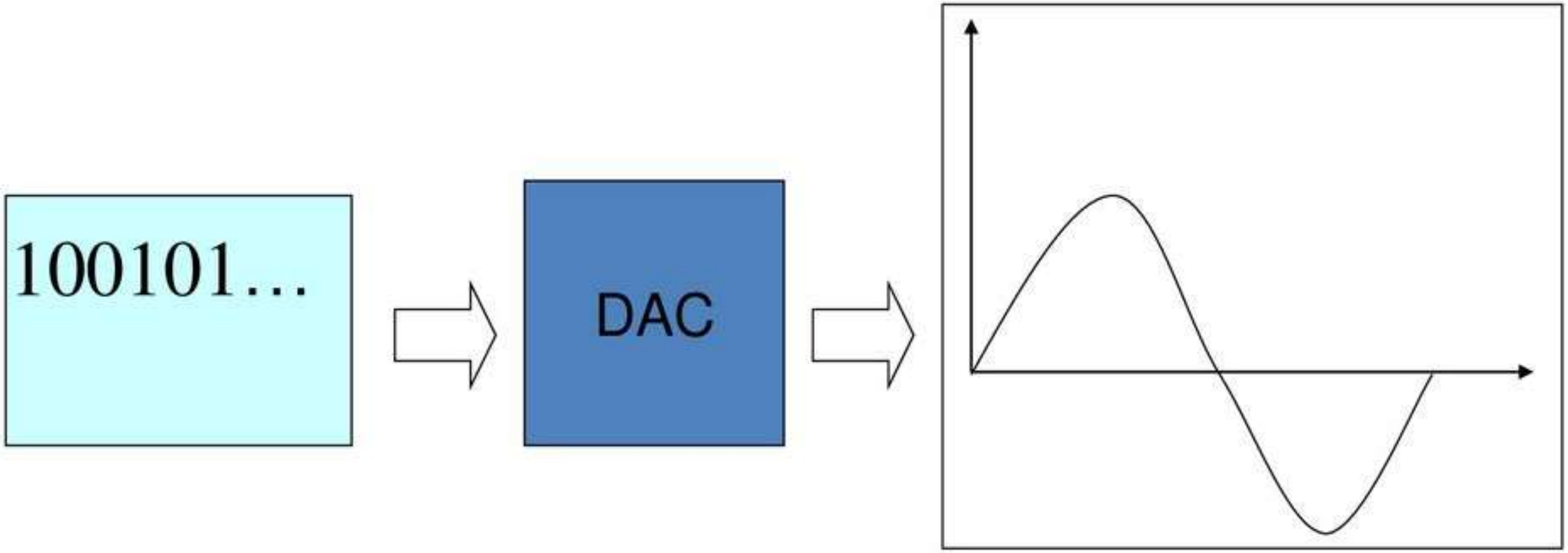
DIGITAL SIGNALS (Discrete signals, 0 or 1)

Computer Data (Square, Rectangular pulses, Clock Pulses, Staircase waveforms)

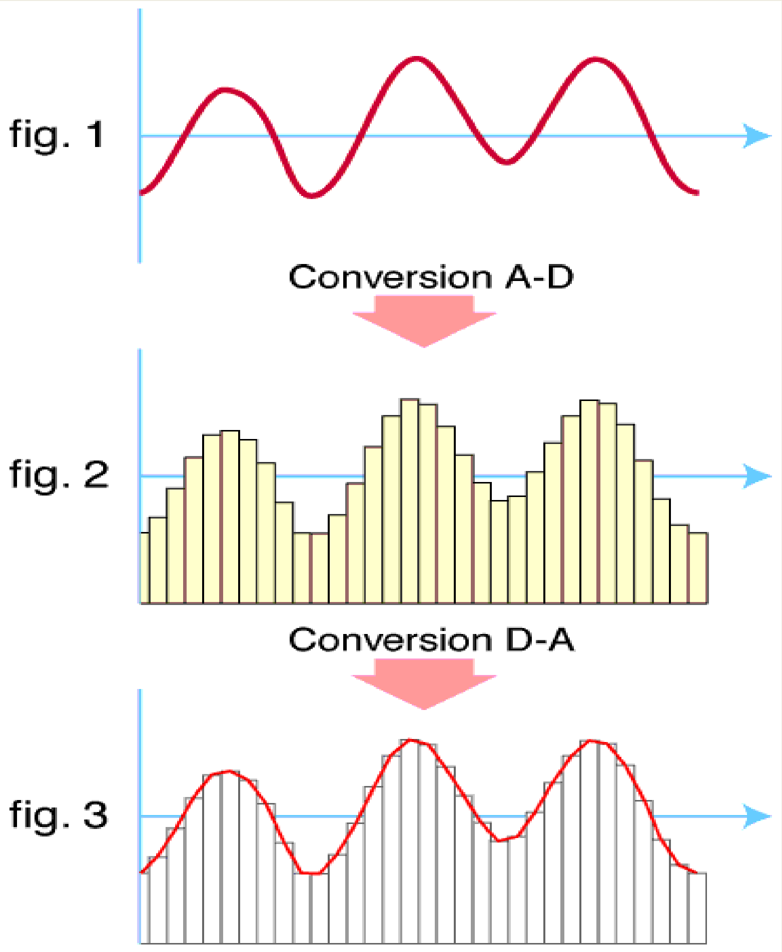




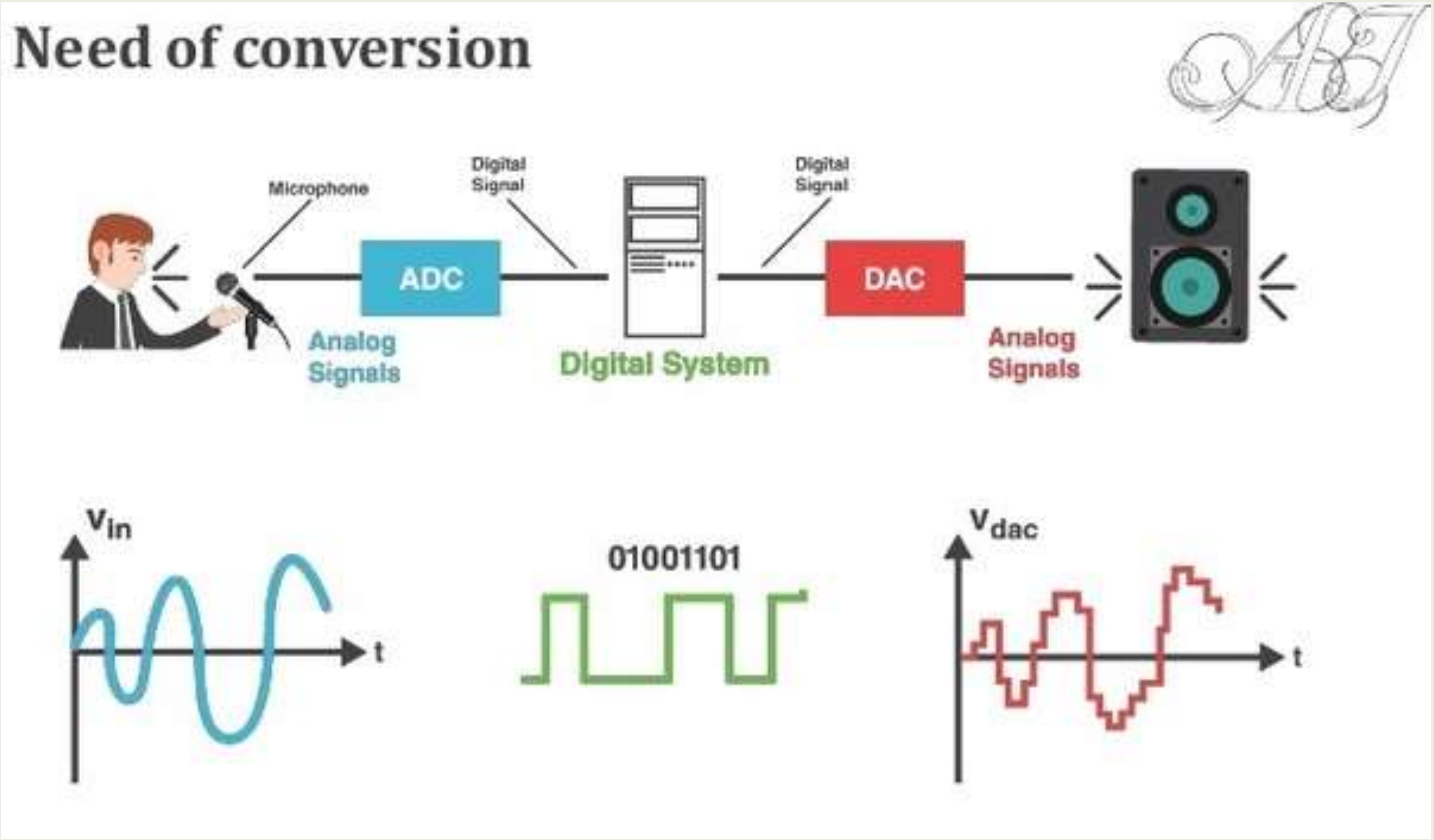
- A digital to analog converter (DAC) converts a digital signal to an analog voltage or current output.



CONVERSION A/D and D/A



NEED FOR CONVERSION



Binary Weighted Resistor DAC (4 bits)

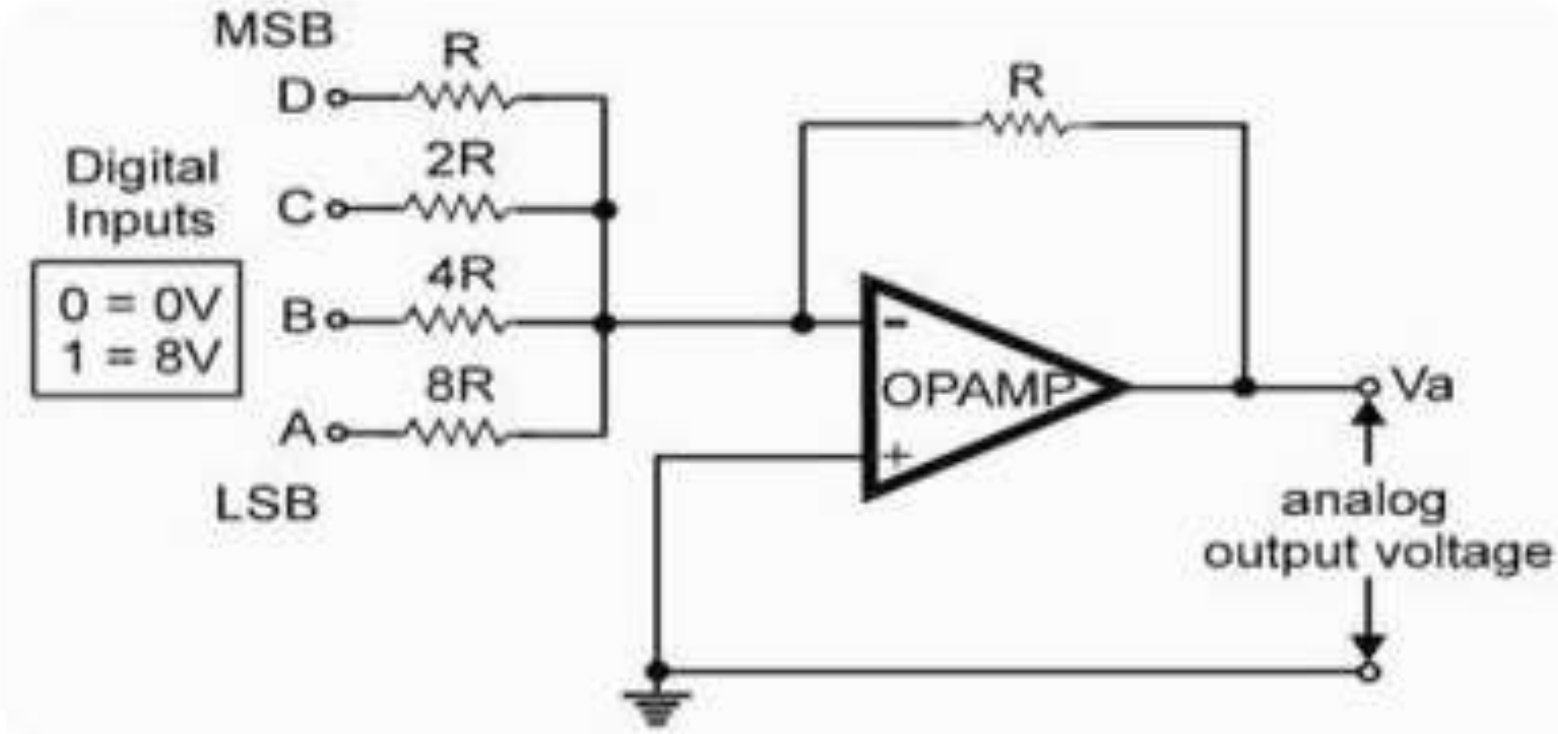


Figure: Weighted resistors D/A converter

WORKING of 4 Bit DAC

Currents flowing through Input Resistances, **R**, **2R**, **4R**, **8R**, as the inverting input of op-amp acts as **Virtual ground,**

1) $I_D = \frac{V_{ref}}{R}$

2) $I_C = \frac{V_{ref}}{2R}$

3) $I_B = \frac{V_{ref}}{4R}$

4) $I_A = \frac{V_{ref}}{8R}$

Total current flowing through the feedback resistor R,

$$I = I_D + I_C + I_B + I_A$$

Output voltage, $V_o = - I R$

Therefore, $V_o = - (I_D + I_C + I_B + I_A) R$

Since the circuit is summing amplifier, its output is given by the following equation

$$V_0 = -R\left(\frac{D}{R} + \frac{C}{2R} + \frac{B}{4R} + \frac{A}{8R}\right)V_{ref}$$

Here V_{ref} = 8 Volts

D, C, B, A are digital inputs, either 0 or 1

Output Voltage Calculations

- D is the MSB,

Most Significant Bit

- A is the LSB,

Least Significant Bit

Case i

When input DCBA = 0000, and

V_{ref} = 8 Volts

then

$$V_0 = -R\left(\frac{0}{R}+\frac{0}{2R}+\frac{0}{4R}+\frac{0}{8R}\right)8$$

$$V_0 = 0 \text{ Volts}$$

Output Voltage Calculations

Case ii

When digital input of the circuit DCBA = 0001,

$$V_0 = -R\left(\frac{0}{R}+\frac{0}{2R}+\frac{0}{4R}+\frac{1}{8R}\right) 8$$

$$V_0 = -R\left(\frac{8}{8R}\right) = -1\ V$$

Case iii

When digital input of the circuit DCBA = 0010

$$V_0 = -R\left(\frac{0}{R}+\frac{0}{2R}+\frac{1}{4R}+\frac{0}{8R}\right) 8$$

$$V_0 = -R\left(\frac{8}{4R}\right) = -2 \text{ Volts}$$

And so on….

In this way, when digital input DCBA changes from 0000 to 1111 (in BCD style), output voltage (Vo) changes proportionally.

V_{ref} = 8 volts

D	C	B	A	V_O (volts)
0	0	0	0	0
0	0	0	1	-1
0	0	1	0	-2
0	0	1	1	-3
0	1	0	0	-4
0	1	0	1	-5
0	1	1	0	-6
0	1	1	1	-7
1	0	0	0	-8
1	0	0	1	-9
1	0	1	0	-10
1	0	1	1	-11
1	1	0	0	-12
1	1	0	1	-13
1	1	1	0	-14
1	1	1	1	-15

DAC Output Waveform

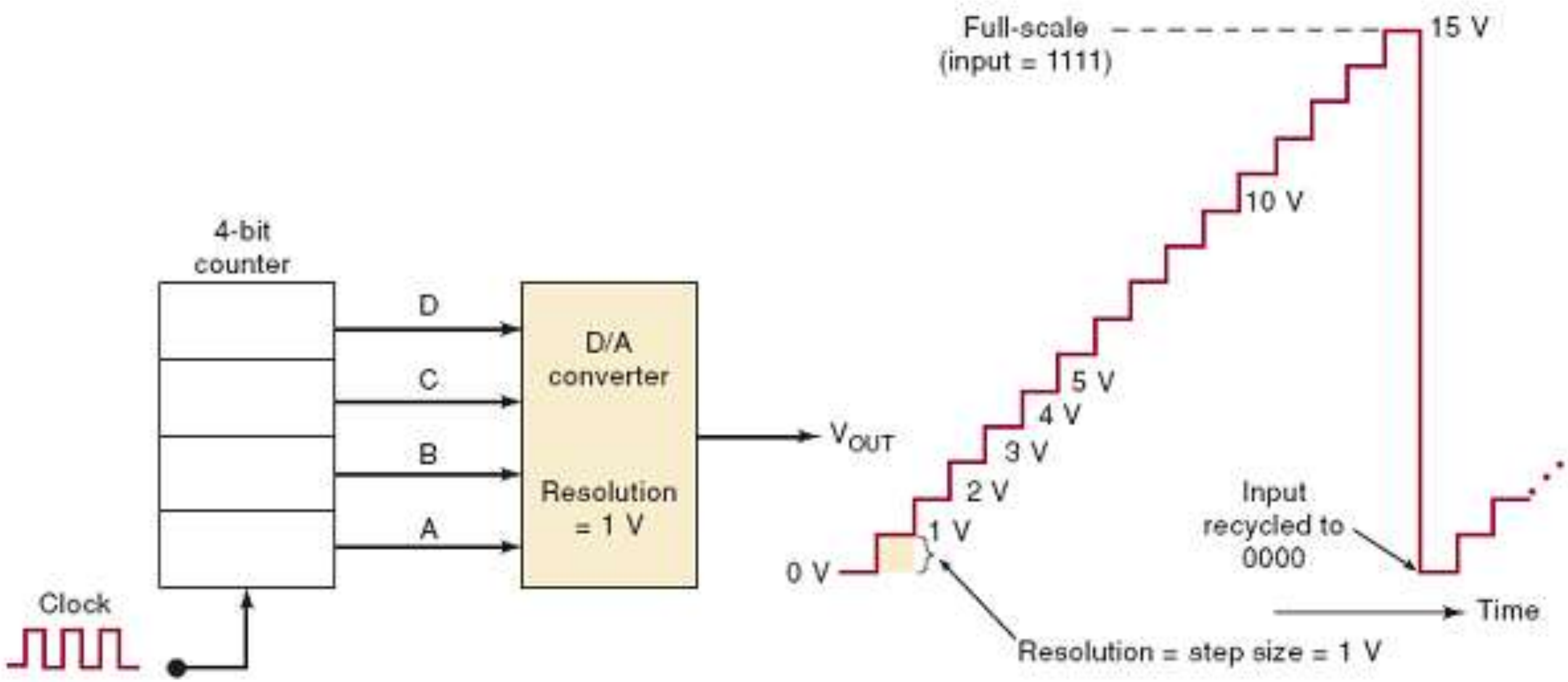
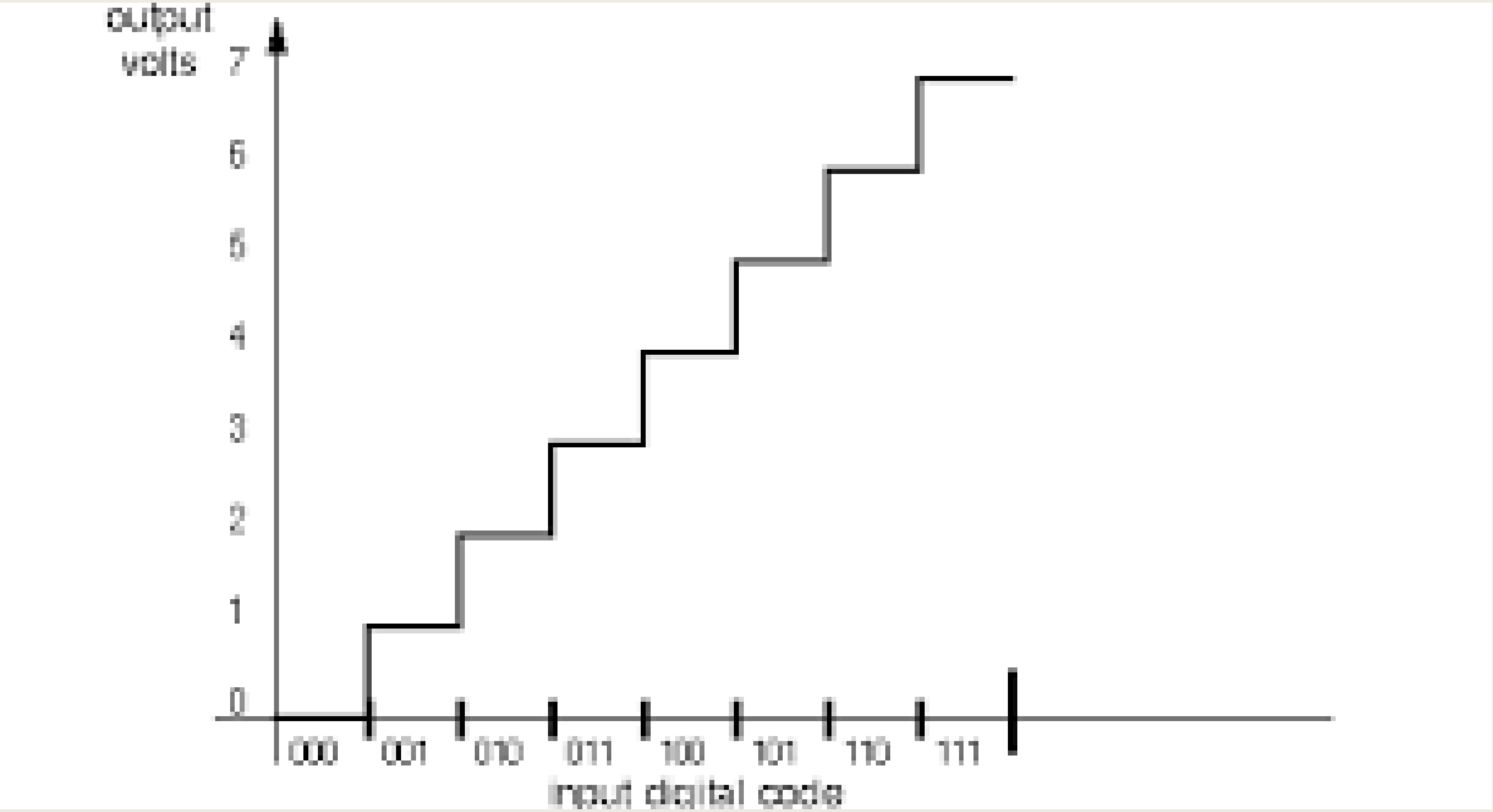


FIGURE 11-3 Output waveforms of a DAC as inputs are provided by a binary counter.

DAC Graph
Digital input in x - axis, Anlog Output in y - axis



RESOLUTION

- Defined as the smallest change that can occur in the analog output when digital input changes
- resolution for DAC is in bits number

  examples

  10-bit DAC have 10 bits resolution.
  10-bit DAC has a resolution smaller than 8-bits DAC
- Resolution can be expressed in two cases, either the voltage or Ampere and also percentages.
- Resolution is usually referred to the step size since it was a total change in Vout when the digital input changes from one step to the next step.
- Its value is equal to the LSB wheighted

Resolution Percentages (%)

Formula

$$\% \text{ Resolution} = \frac{\text{Step Size}}{\text{Full Scale}} \times 100\%$$

$$\text{Full Scale} = \text{Number Of Step} \times \text{Step Size}$$

$$\text{Step Size} = \frac{\text{Full Scale}}{\text{Number Of Step}}$$

$$\% \text{ Resolusi} = \frac{1}{\text{Number Of Step}} \times 100\%$$

$$= \frac{1}{2^n - 1} \times 100\%$$

Formula

Resolution = Step Size = Input bit for LSB

Vout (analog output)= K x Digital Input

$$K = \frac{\text{Total Voltage/Current}}{\text{Number Of Step}} \quad \text{Or} \quad \frac{\text{Analog Output}}{\text{Digital Input}}$$

* K = the factor of proportionality and is a fixed value for a DAC

Digital Input = Number of Step

Number of Step = $2^n - 1$

Where;

n = Number of input bits

ACCURACY

- Manufacturer of digital to analog converter has a several ways to define accuracy. Two of them are often referred to Linearity Error and Full-scale error

<u>Full Scale Error</u>

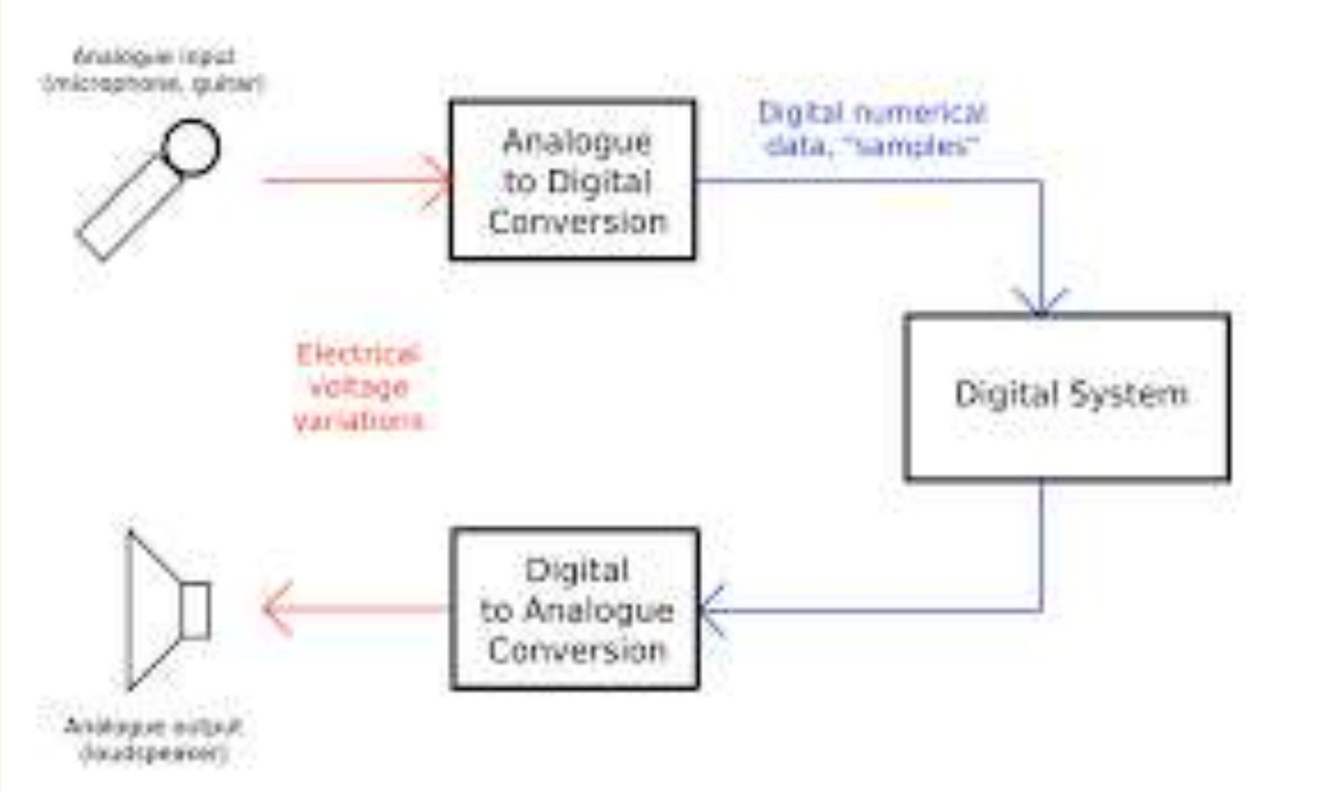
- The maximum deviation from the ideal DAC output value.

- Examples

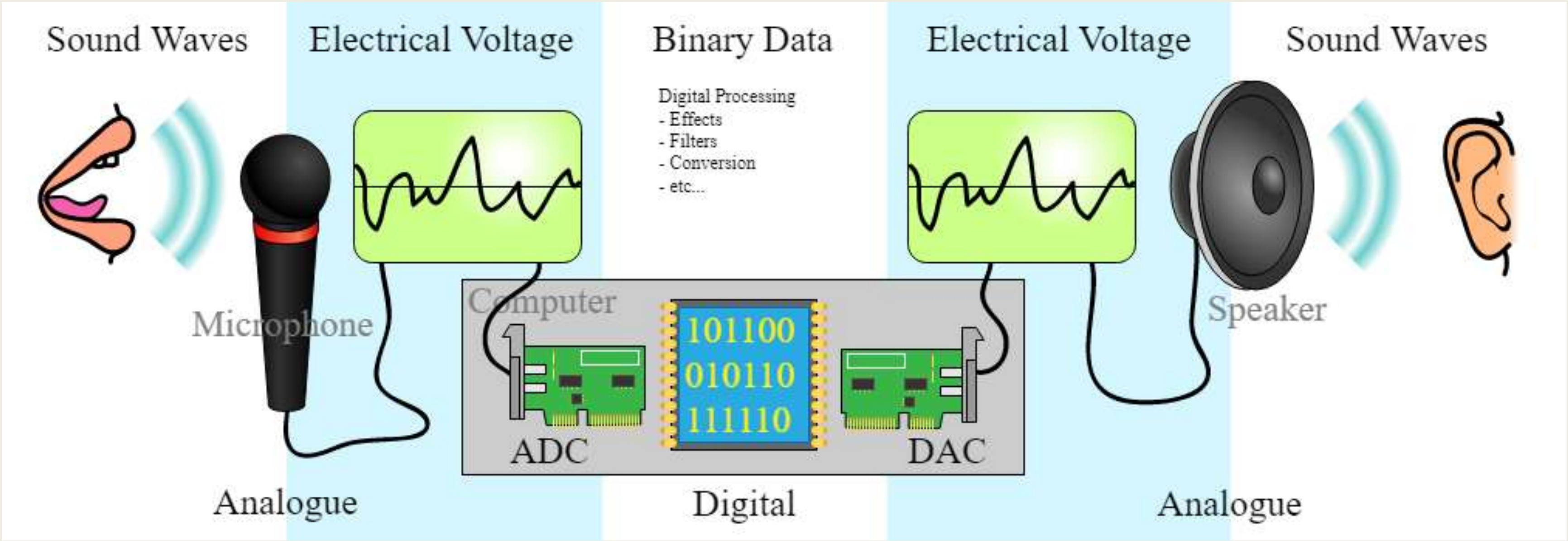
  4-bit DAC has $\pm$0.01%FS accuracy and DAC full-scale is15V. So $\pm$0.01% x 15 = $\pm$1.5mV.

  This means that the DAC output will be different from the ideal value 1.5mV

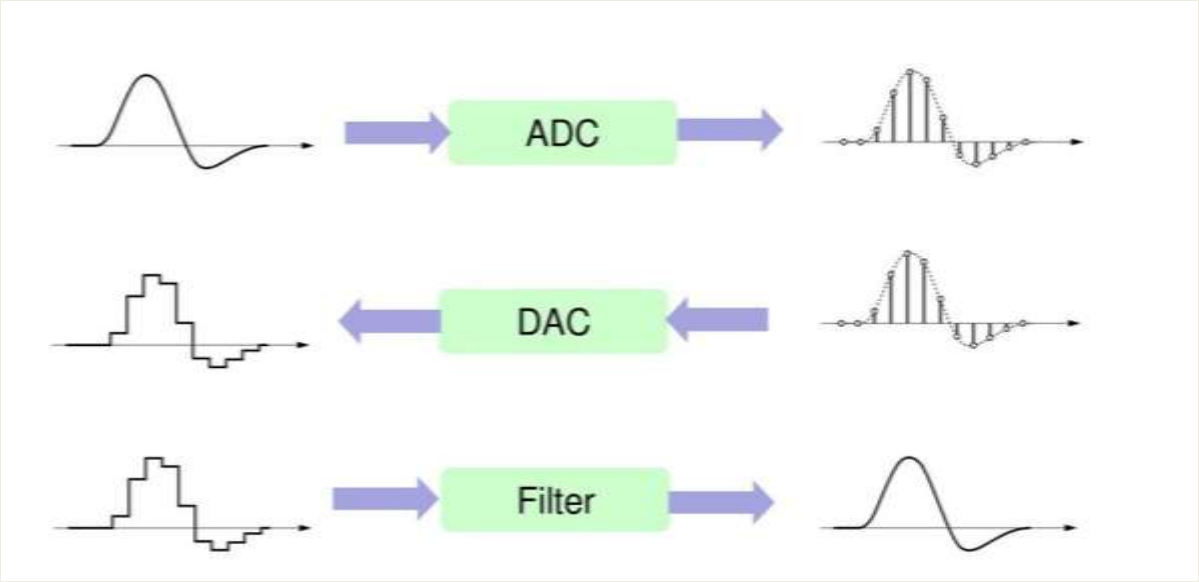
BLOCK DIAGARAM



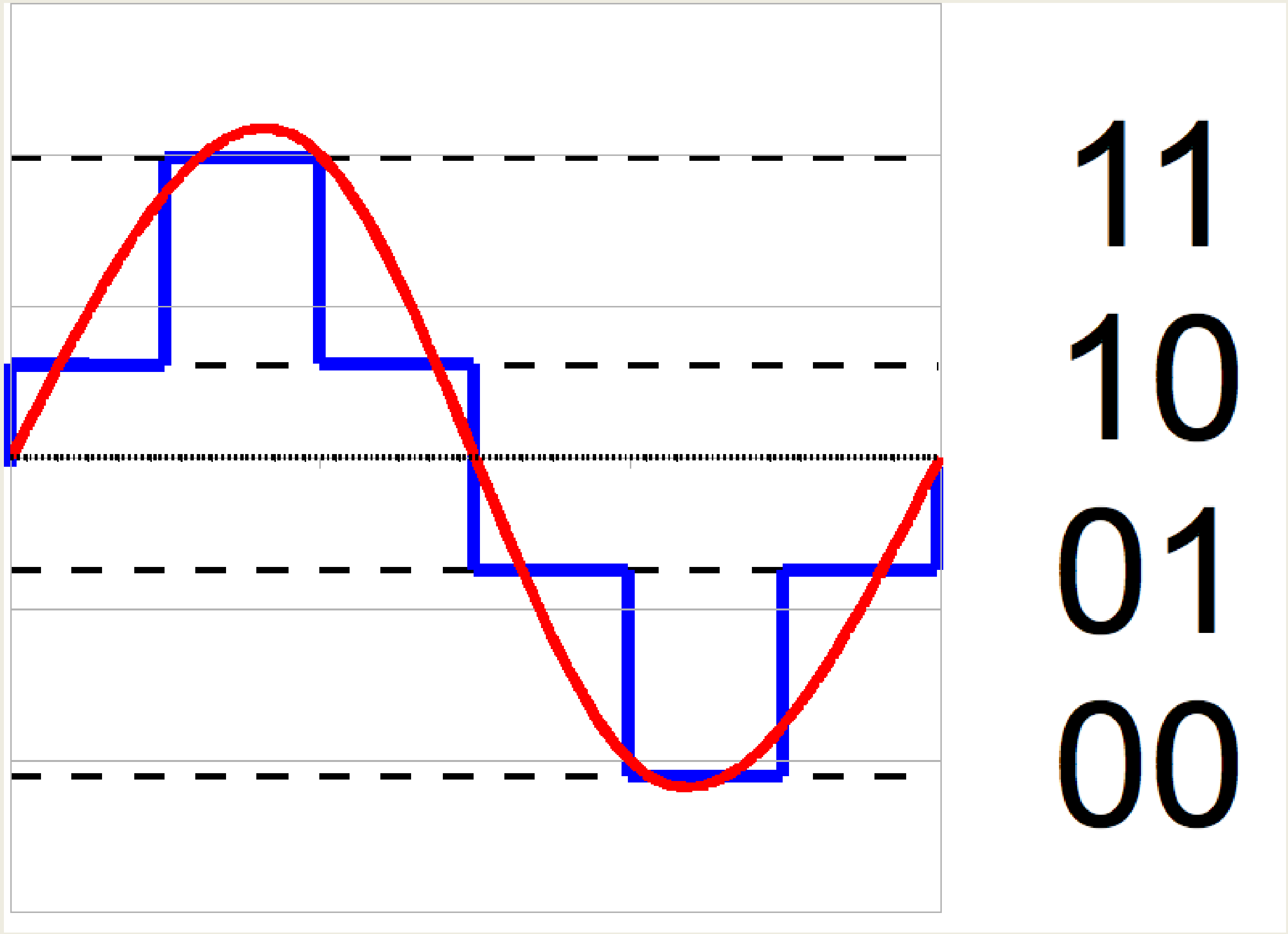
ANALOG TO DIGITAL AND DIGITAL TO ANALOG OF SOUND SIGNAL



SIGNAL CONVERSION



BIT RESOLUTION



QUESTION TIME

Students can ask questions/ clarifications now

HAVE A NICE DAY !!!