# SNS COLLEGE OF TECHNOLOGY

**Coimbatore-35**
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# DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

## 23ECB202 – LINEAR INTEGERATED CIRCUITS

II YEAR/ III SEMESTER

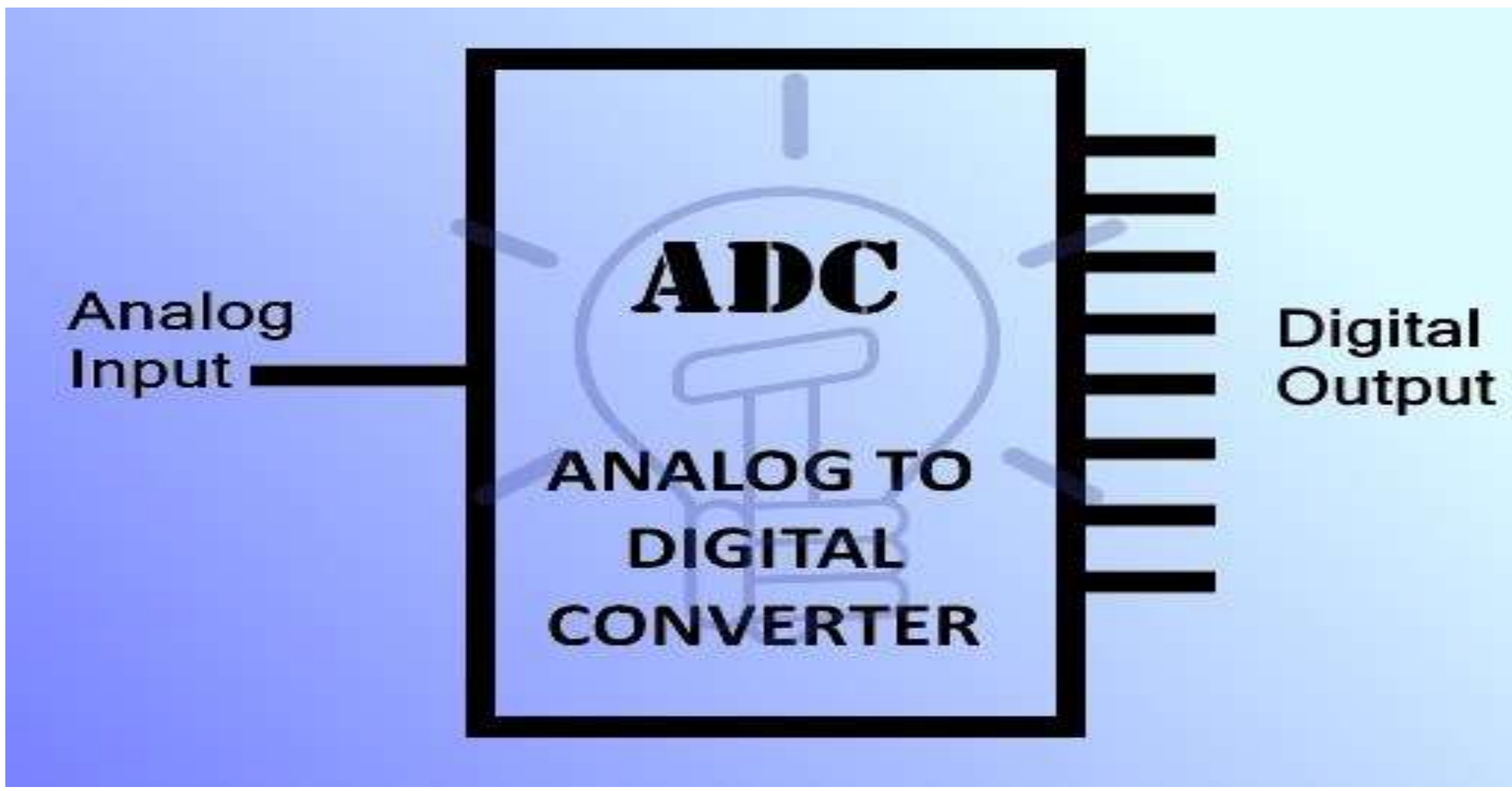


## UNIT 4 – ANALOG TO DIGITAL AND DIGITAL TO ANALOG CONVERTER

## TOPIC 4.2 – A/D Converters & Specifications

# Analog to Digital Converters

- ADC stands for analog to digital converter
- electronic device - converting an analog signal into a digital signal
- The analog input signal of ADC is continuous time & continuous amplitude signal
- The output of ADC is a discrete time and discrete amplitude digital signal

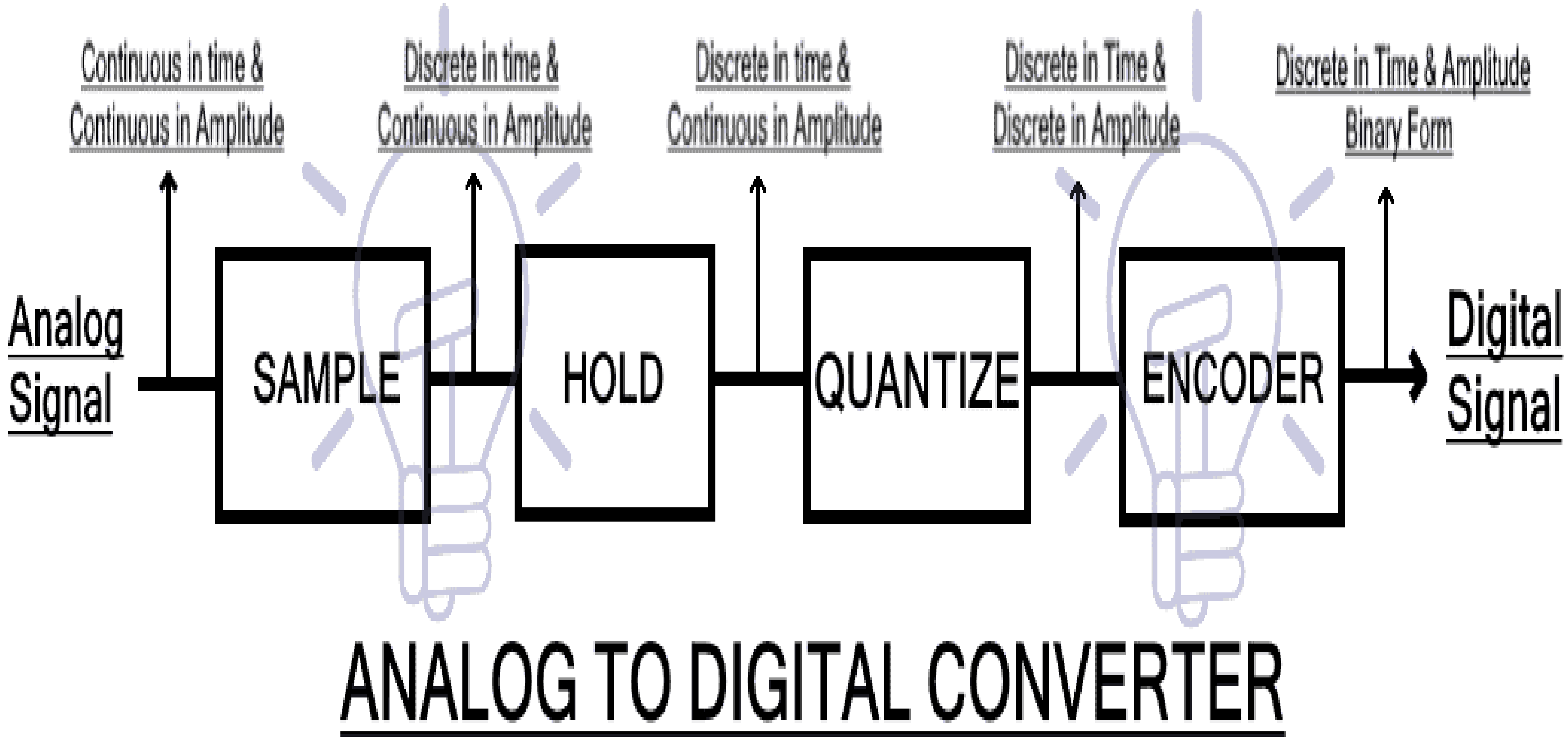


# Analog-to-Digital Converter

## Why ADC?

- In the real world, every real quantity such as voice, temperature, weight etc exists in the **analog state**
- it cannot be processed by any digital device such as a computer or a cell phone
- These analog quantities are converted into digital form so that a digital device can process it
- This conversion is done using **analog to digital converter**

# Analog-to-Digital Converter – Block Diagram



# Analog-to-Digital Converter – Block Diagram

- The analog signal is first applied to the '**sample**' block where it is sampled at a specific sampling frequency
- The sample amplitude value is maintained and held in the '**hold**' block
- It is an analog value
- The hold sample is quantized into discrete value by the '**quantize**' block
- Finally , the **encoder** converts the discrete amplitude into a binary number

# Analog-to-Digital Conversion – Steps

**Sample**

- sample the input analog signal at a specific time interval
- samples are taken in continuous amplitude & possess real value but they are discrete with respect to time
- sampling frequency plays important role in the conversion
- maintained at a specific rate
- sampling rate is set according to the requirement of the system.

# Analog-to-Digital Conversion – Steps

**Hold**

- It has no function
- only holds the sample amplitude until the next sample is taken
- The hold value remains unchanged till the next sample

**Quantize**

- This block is used for **quantization**
- It converts the analog or continuous amplitude into discrete amplitude
- The on hold continuous amplitude value in hold block goes through ‘**quantize’** block & becomes **discrete** in **amplitude**
- The signal is now in digital form as it has **discrete time** & **discrete amplitude**.

# Analog-to-Digital Conversion – Steps

**Encoder**

- The **encoder** block converts the digital signal into **binary form** i.e. into bits

- As we know that the digital devices operate on binary signals so it is necessary to convert the digital signal into the binary form using the Encoder

- This is the whole process of converting an Analog signal into digital form using an **Analog to Digital Converter**

- This whole conversion occurs in a microsecond

# Analog-to-Digital Conversion – Specifications

**Both D/A and A/D converters are available with wide range of specifications specified by manufacturer  like**

- Resolution
- Linearity
- Accuracy
- Monotonicity
- Settling time
- Stability

# Analog-to-Digital Conversion – Specifications

**Resolution**

- smallest change in voltage which may be produced at the output (or input) of the converter
- Eg. an 8-bit D/A converter has 28 -1=255 equal intervals
- Hence the smallest change in output voltage is (1/255) of the full scale output range
- Resolution can also be defined electrically, and expressed in volts
- The change in voltage required to guarantee a change in the output code level is called the least significant bit (LSB) voltage
- The resolution *Q* of the ADC is equal to the LSB voltage
- The voltage resolution of an ADC is equal to its overall voltage measurement range divided by the number of intervals

$$R = \frac{E_{\mathrm{FSR}}}{2^M - 1},$$

Where

$M$ is the ADC's resolution in bits

$E_{\mathrm{FSR}}$ is the full-scale voltage range (also called 'span')

# Analog-to-Digital Conversion – Specifications

$E_{\text{FSR}}$ is given by

$$E_{\text{FSR}} = V_{\text{RefHi}} - V_{\text{RefLow}}\,,$$

where

$V_{\text{RefHi}}$ and $V_{\text{RefLow}}$ are the upper and lower extremes, respectively, of the voltages that can be coded.

Normally, the number of voltage intervals is given by

$$N = 2^M - 1,$$

Where

$M$ is the ADC's resolution in bits ( one voltage interval is assigned in between two consecutive code levels)

# Analog-to-Digital Conversion – Specifications

The following table 1 shows the resolution for 6 to 16 bit DACs

| S.No. | Bits | Intervals | LSB size (% of full-scale) | LSB size (For a 10 V full-scale) |
|---|---|---|---|---|
| 1. | 6 | 63 | 1.588 | 158.8 mV |
| | | | | |
| 3. | 10 | 1023 | 0.0978 | 9.78 mV |
| 4. | 12 | 4095 | 0.0244 | 2.44 mV |
| 5. | 14 | 16383 | 0.0061 | 0.61 mV |
| 6. | 16 | 65535 | 0.0015 | 0.15 mV |

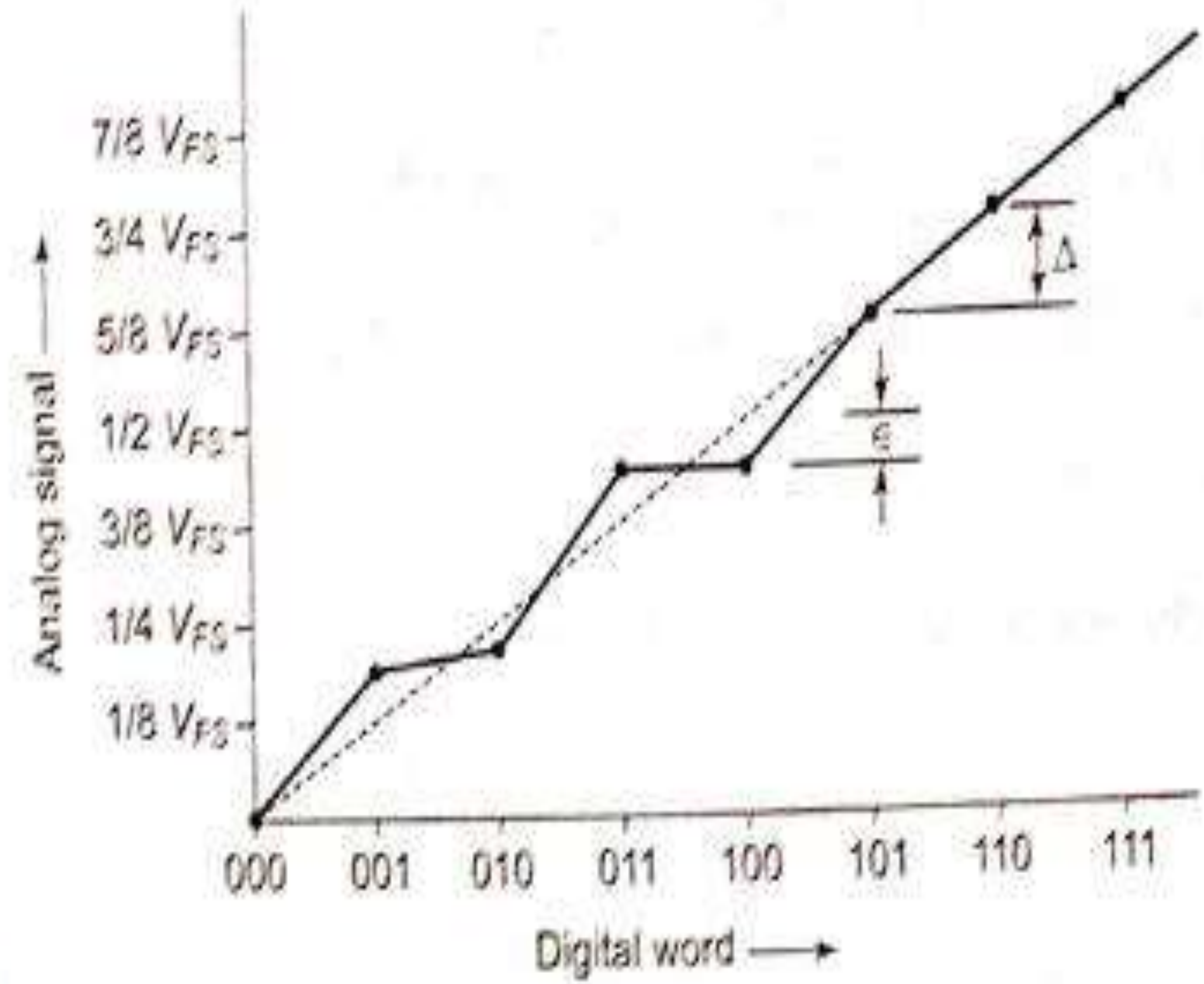
# Analog-to-Digital Conversion – Specifications

## Linearity

- The linearity of an A/D or D/A converter is an important measure of its accuracy
- In an ideal DAC ,equal increment in the digital input should produce equal increment in the analog output and the transfer curve should be linear
- In an actual DAC, output voltages do not fall on a straight line because of gain and offset errors as shown by the solid line curve
- The static performance of a DAC is determined by fitting a straight line through the measured output points

# Analog-to-Digital Conversion – Specifications

Linearity error of a 3-bit D/A converter



# Analog-to-Digital Conversion – Specifications

- The linearity error measures the deviation of the actual output from the fitted line and is given by ε/Δ
- The error is usually expressed as a fraction of LSB increment or percentage of full scale voltage
- A good converter exhibits a linearity error of less than ±(1/2)LSB

**Accuracy**

- Absolute accuracy is the maximum deviation between the actual converter output and the ideal converter output

- Relative accuracy is the maximum deviation after gain and offset errors have been removed

# Analog-to-Digital Conversion – Specifications

**Monotonicity**

- A monotonic DAC is the one whose analog output increases for an increase in digital input
- A monotonic characteristics is essential in control applications, otherwise oscillations can result
- If a DAC has to be monotonic, the error should be less than ±(1/2) LSB at each output level

**Settling time**

- Settling time represents the time it takes for the output to settle within a specified band ±(1/2) LSB of its final value, after the change in digital input
- It should be as small as possible
- Settling time ranges from 100 ns to 10 μs depending on word length and type of circuit used.

# Analog-to-Digital Conversion – Specifications

**Stability**

- The performance of converter changes with temperature, age and power supply variations

- So all the relevant parameters such as offset, gain, linearity error and monotonicity must be specified over the full temperature and power supply ranges

# THANK YOU