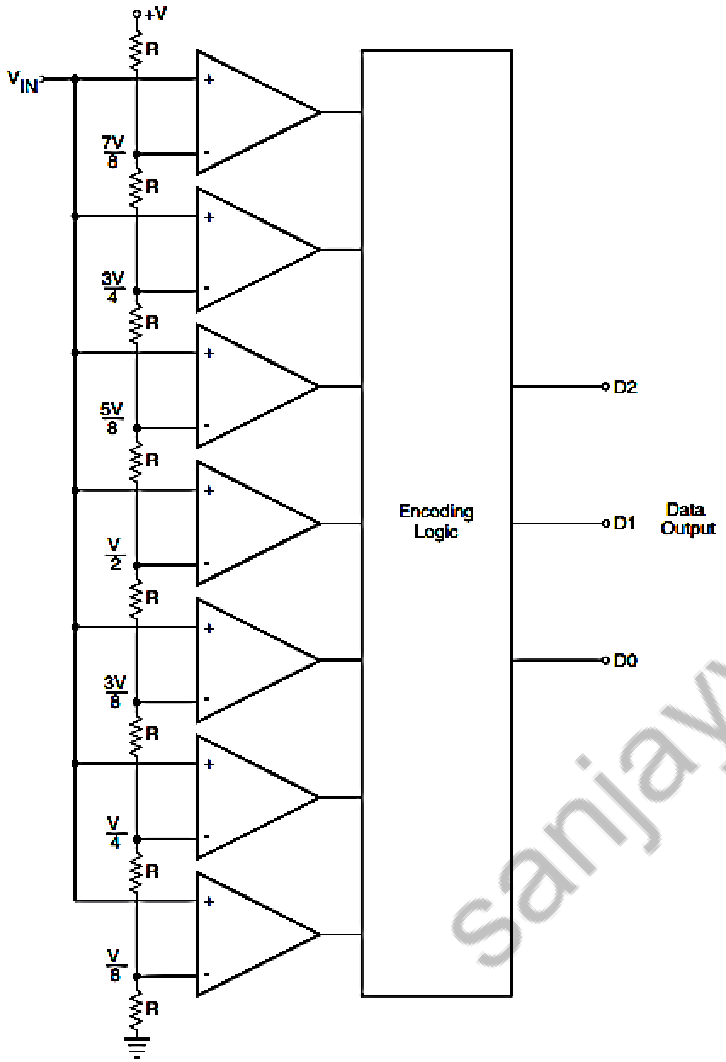
Digital Design : 2021-22
Lecture 26 : ADC and DAC

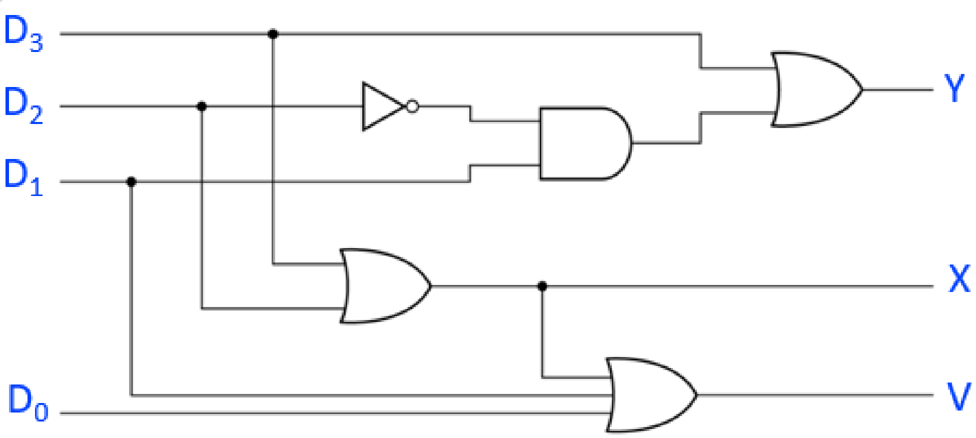
By Dr. Sanjay Vidhyadharan

Analogue-to-Digital Converters

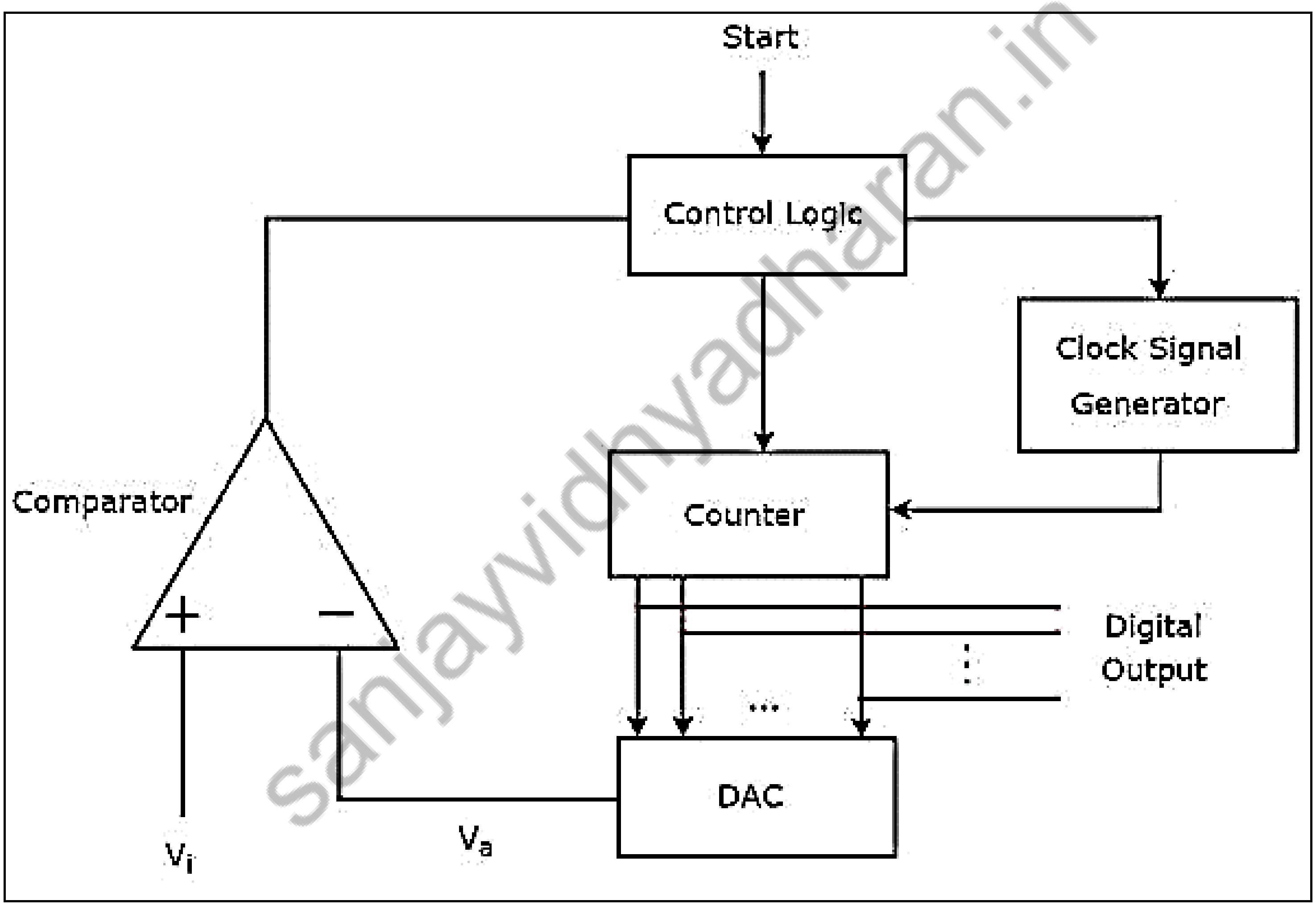


D_0	D_1	D_2	D_3
1	0	0	0
X	1	0	0
X	X	1	0
X	X	X	1

X	Y
0	0
0	1
1	0
1	1

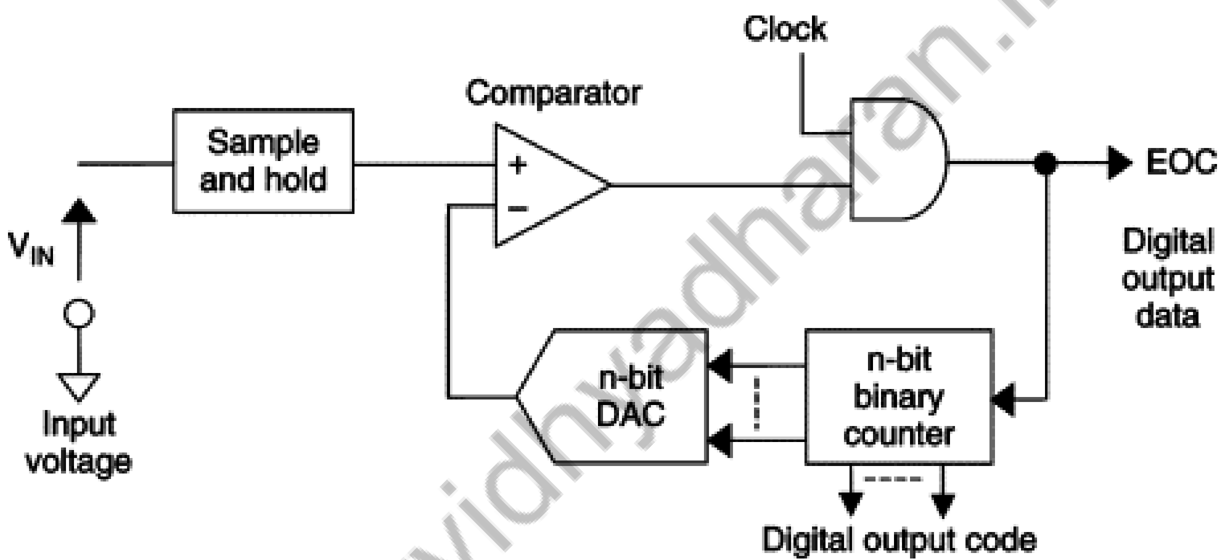


Analogue-to-Digital Converters



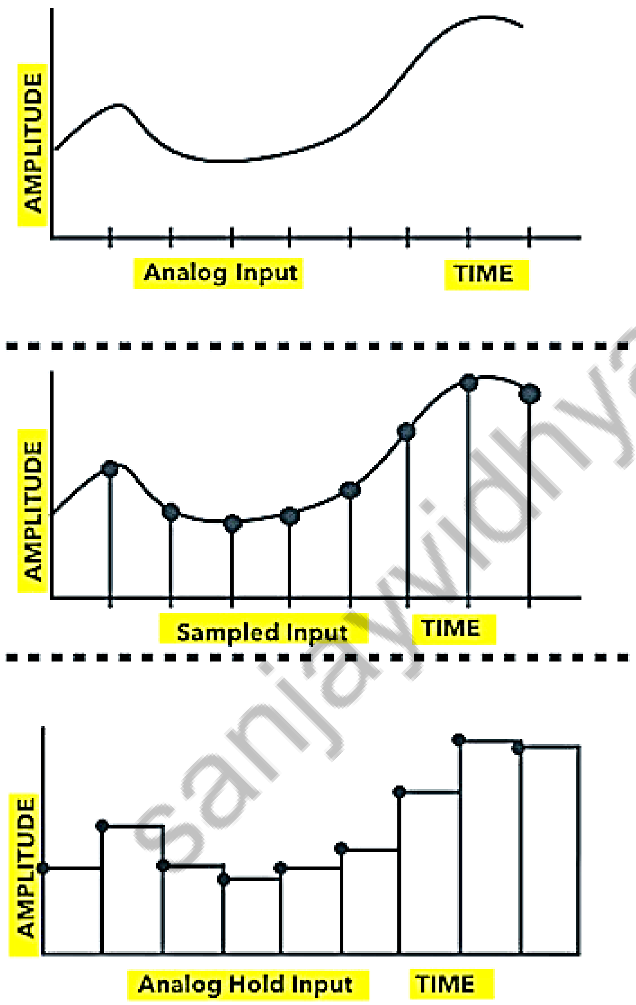
Analogue-to-Digital Converters

Sample and Hold



Analogue-to-Digital Converters

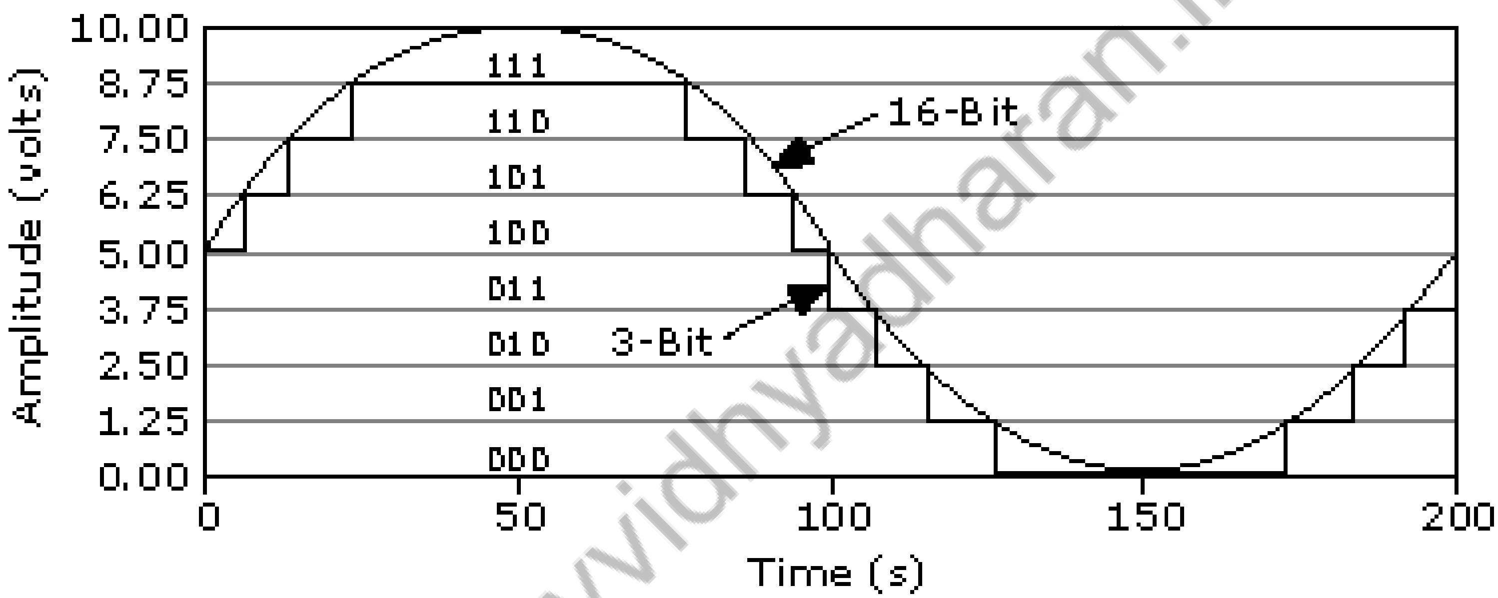
Sample and Hold



Nyquist criterion requires that the **sampling frequency be at least twice the highest frequency contained in the signal**, or information about the signal will be lost.

Analogue-to-Digital Converters

Resolution



$$\text{ADC Voltage Resolution} = \frac{(V_H - V_L)}{2^n}$$

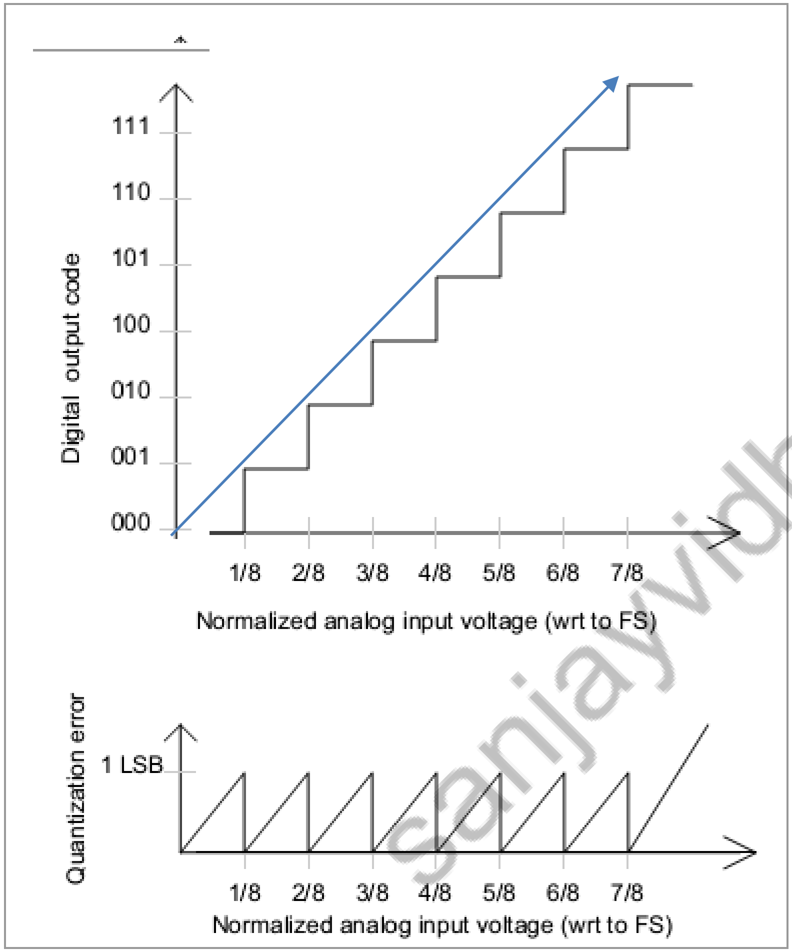
where n is the number of bits of resolution of the ADC

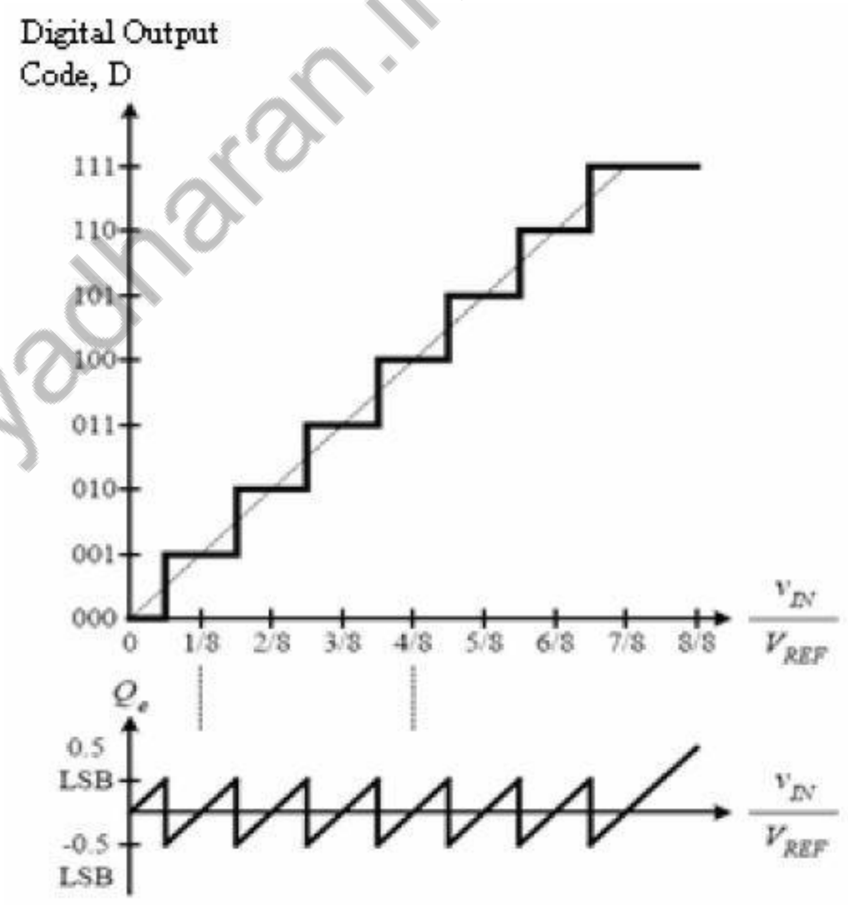
$$For\ n = 3\ \ Resolution = \frac{10-0}{2^3} = 1.25$$

$$For\ n = 16\ \ Resolution = \frac{10-0}{2^{16}} = 0.00015$$

Analogue-to-Digital Converters

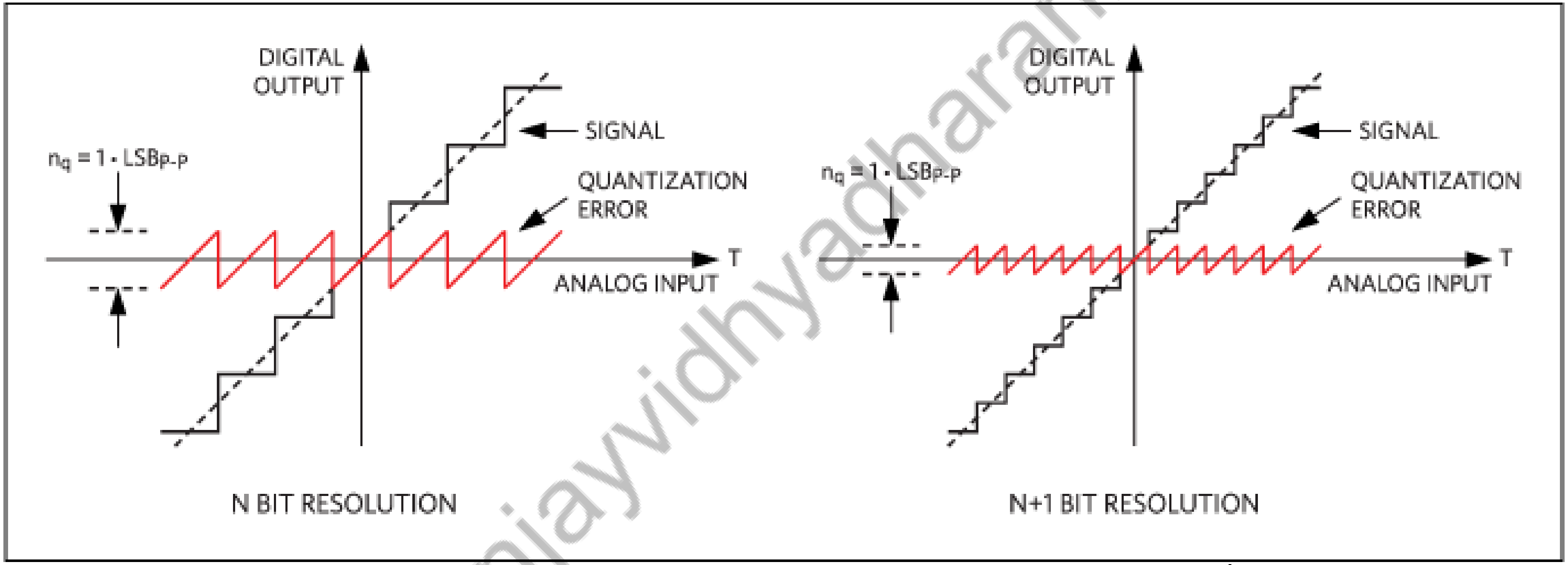
Quantisation Error





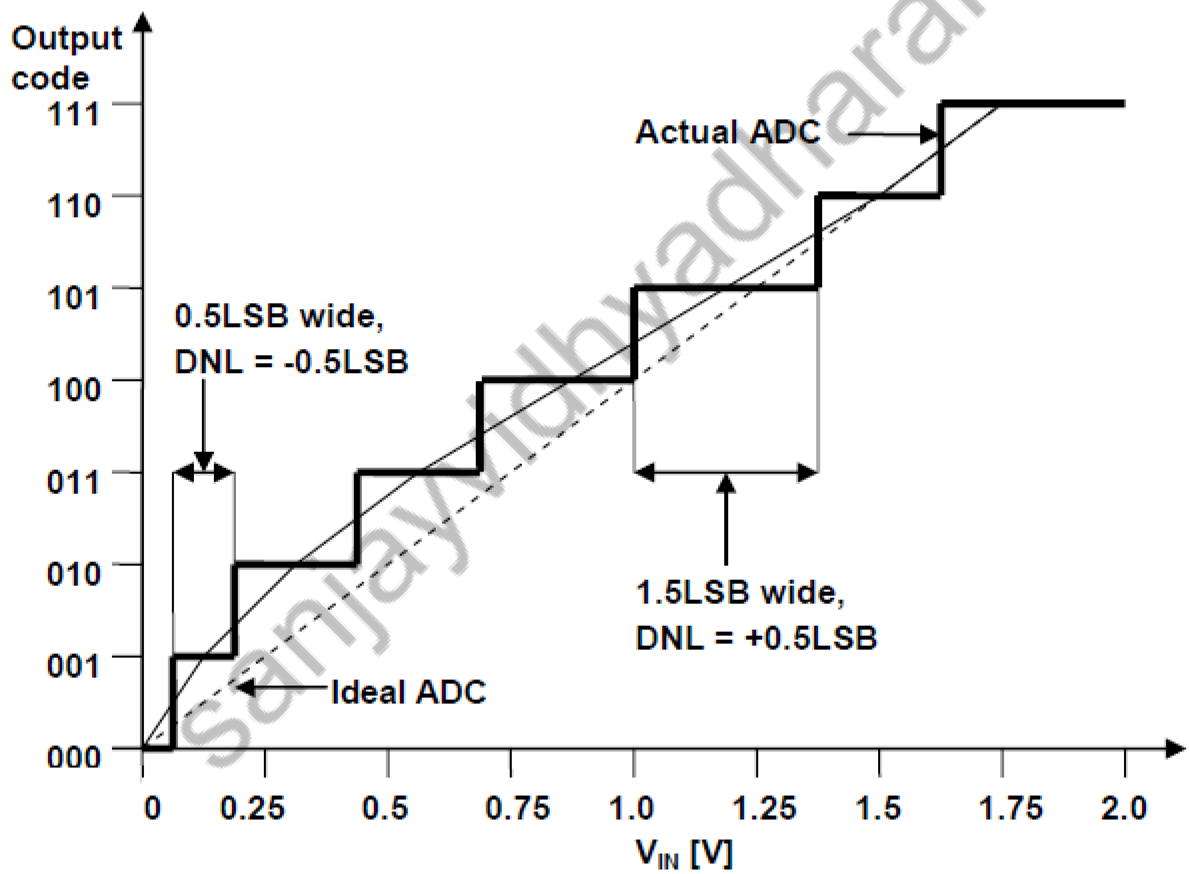
Analogue-to-Digital Converters

Quantisation Error



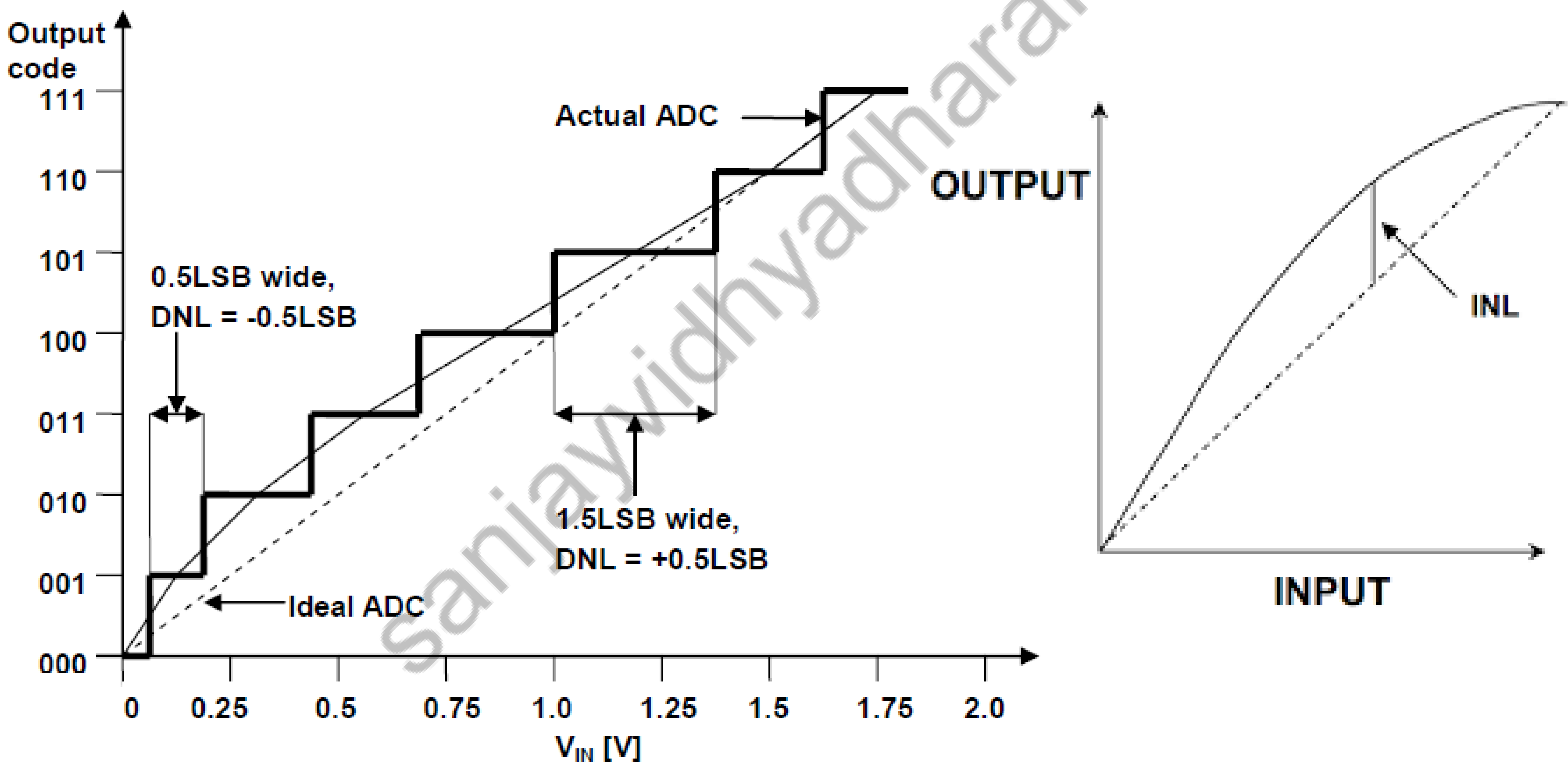
Analogue-to-Digital Converters

Differential Non-Linearity (DNL)



Analogue-to-Digital Converters

Integral Non-Linearity

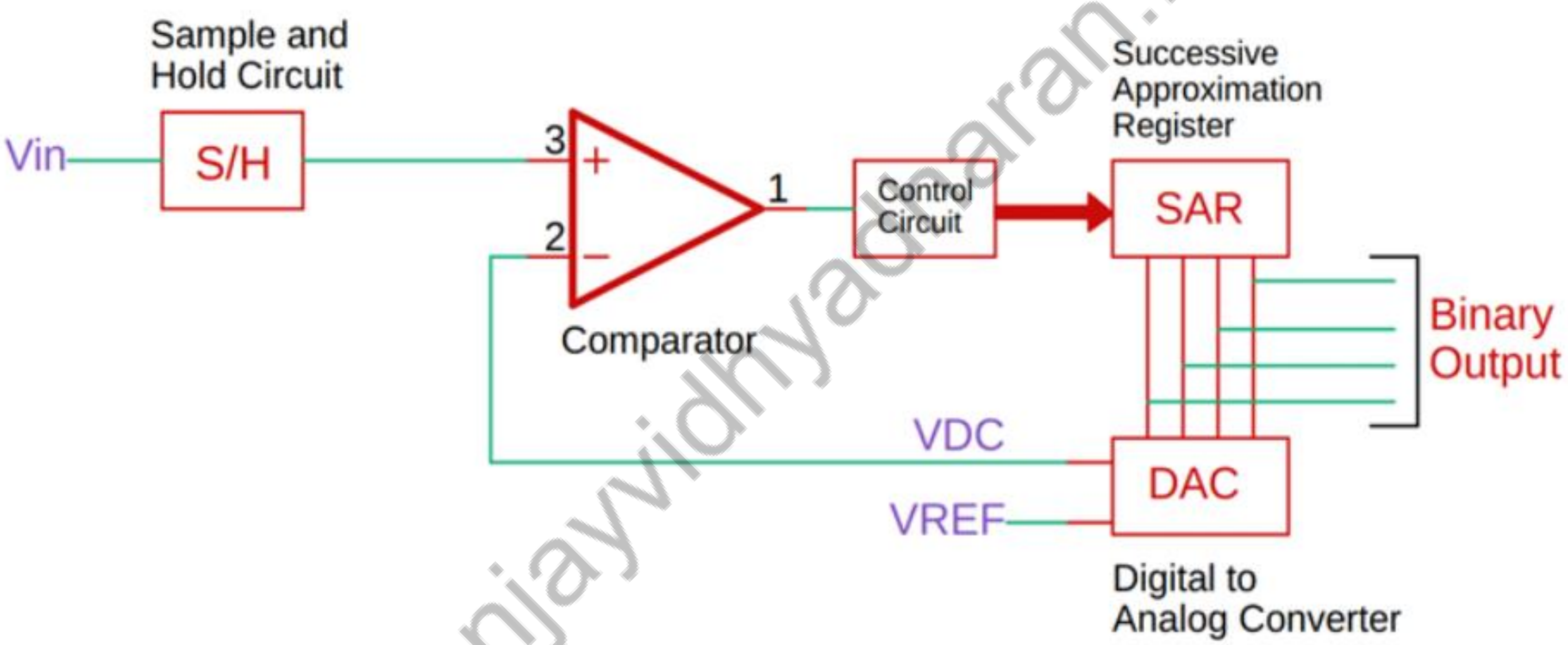


Analogue-to-Digital Converters

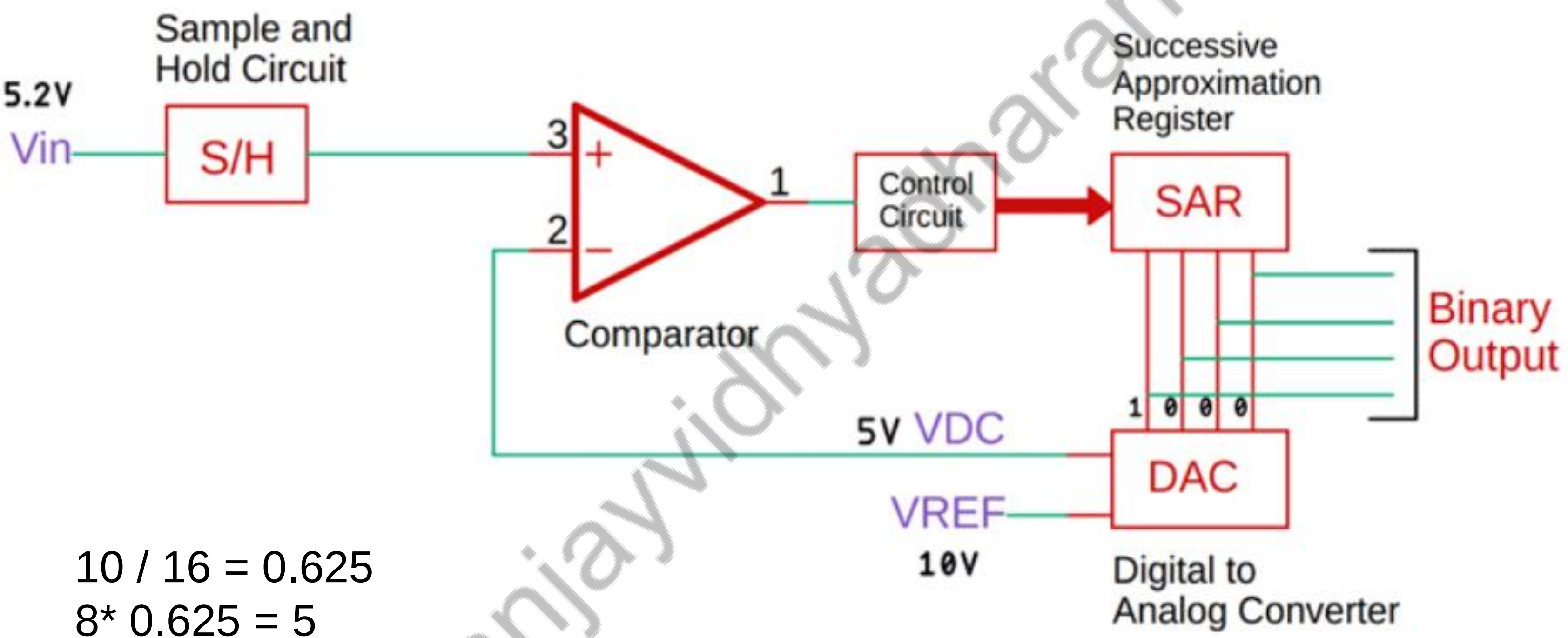
Accuracy

The accuracy specification describes the maximum sum of all errors, both from analogue sources (mainly the comparator and the ladder resistors) and from the digital sources (quantization error) of the A/D converter. These errors mainly include the gain error, the offset error and the quantization error. The accuracy describes the actual analogue input and full-scale weighted equivalent of the output code corresponding to the actual analogue input.

Successive Approximation ADC



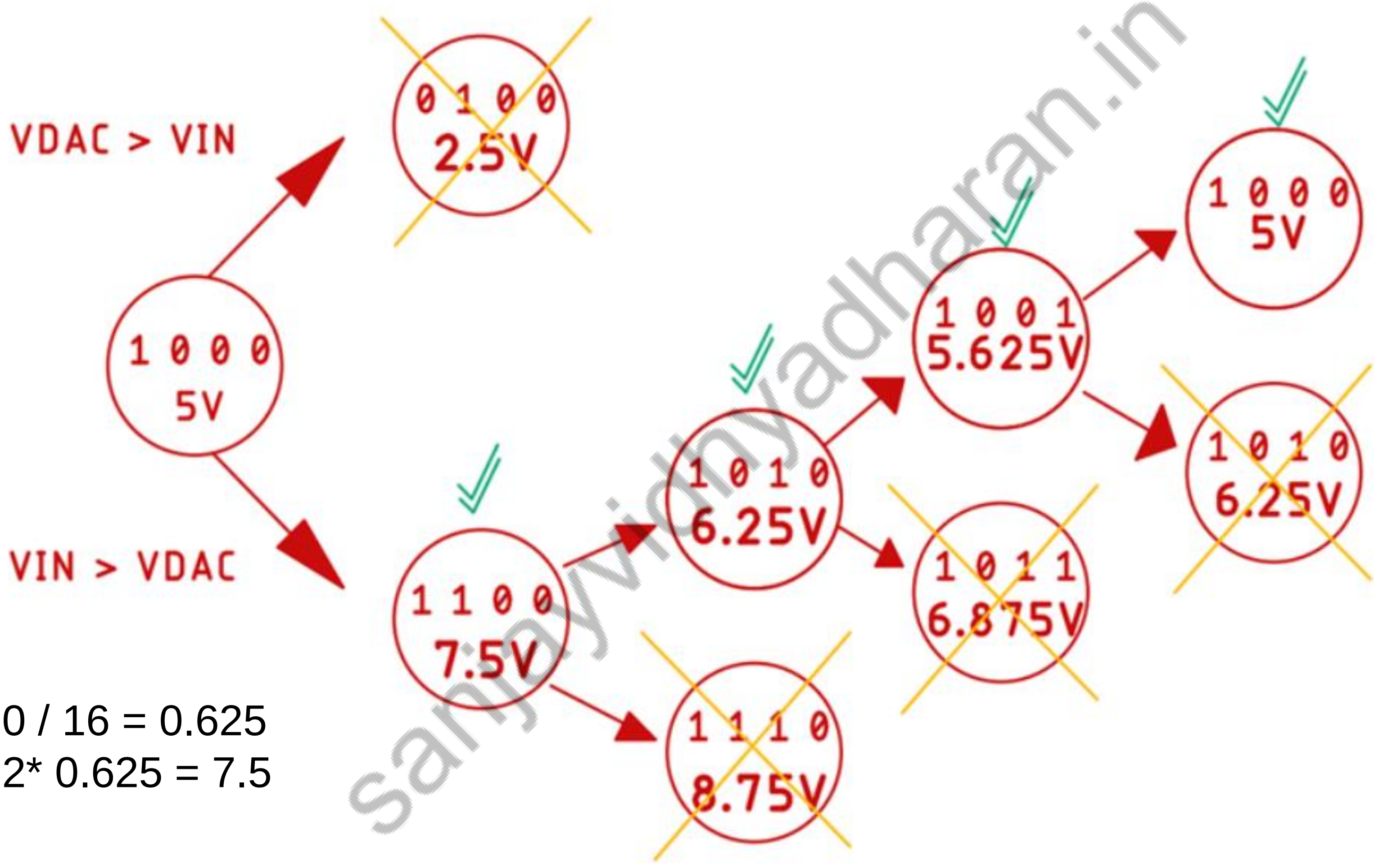
Successive Approximation ADC



10 / 16 = 0.625

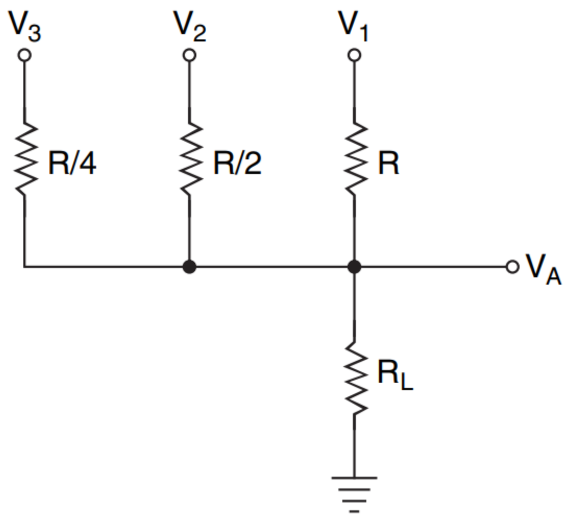
8* 0.625 = 5

Successive Approximation ADC



10 / 16 = 0.625
12* 0.625 = 7.5

Digital-to-Analogue Converters



R_L is much larger than R

$$\frac{R}{4} || \frac{R}{2} = \frac{\frac{R}{4} * \frac{R}{2}}{\frac{R}{4} + \frac{R}{2}} = \frac{R}{6}$$

$$\frac{R}{1} || \frac{R}{4} = \frac{\frac{R}{1} * \frac{R}{4}}{\frac{R}{4} + \frac{R}{1}} = \frac{R}{5}$$

$$\frac{R}{1} || \frac{R}{2} = \frac{\frac{R}{1} * \frac{R}{2}}{\frac{R}{1} + \frac{R}{2}} = \frac{R}{3}$$

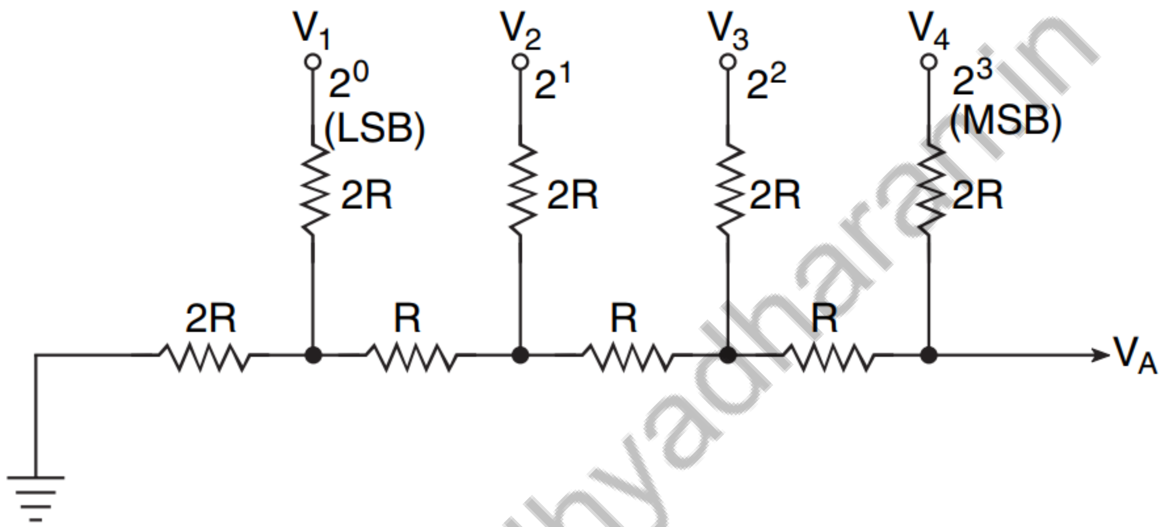
$$V_{A(V1)} = \frac{V_1 \frac{R}{6}}{\frac{R}{6} + R} = \frac{V_1}{7}$$

$$V_{A(V2)} = \frac{V_2 \frac{R}{5}}{\frac{R}{5} + \frac{R}{2}} = \frac{2V_2}{7}$$

$$V_{A(V3)} = \frac{V_3 \frac{R}{3}}{\frac{R}{3} + \frac{R}{4}} = \frac{4V_3}{7}$$

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

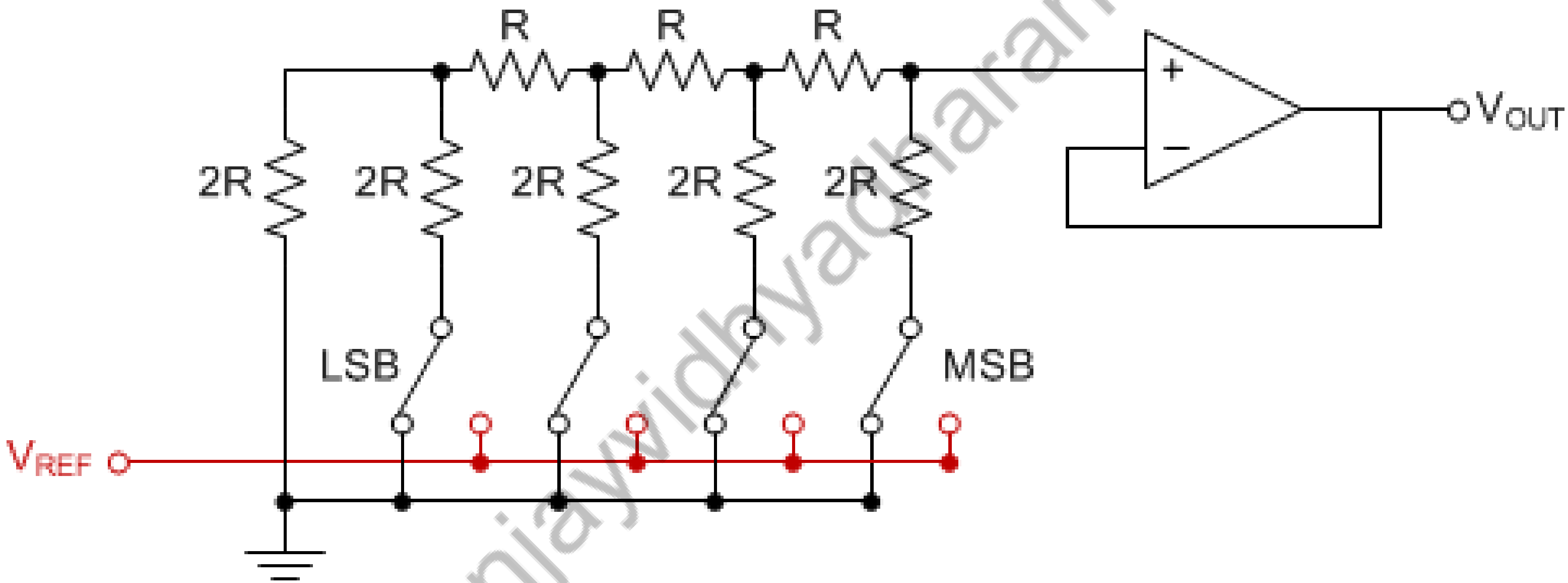
Digital-to-Analogue Converters



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

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

Digital-to-Analogue Converters



Digital-to-Analogue Converters

Resolution

The ***resolution*** of a D/A converter is the number of states (2^n into which the full-scale range is divided or resolved.

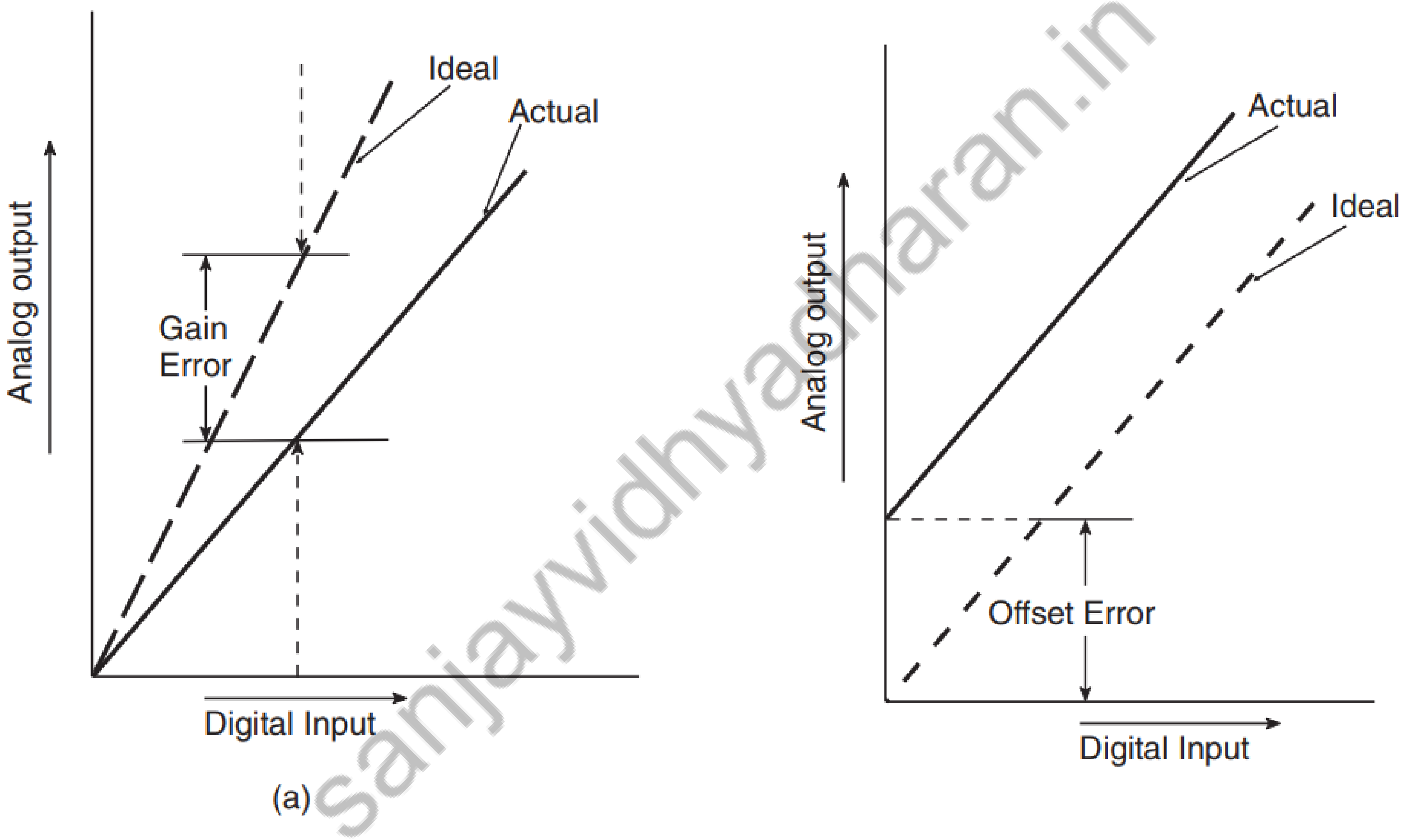
An eight-bit D/A converter has 255 resolvable levels and percentage resolution of (1/255) × 100 = 0.39 %

A 12-bit D/A converter would have a percentage resolution of (1/4095) × 100 = 0.0244 %.

In general, for an n-bit D/A converter, the percentage resolution is given by ($1/2^n - 1$) × 100.

The resolution in millivolts for the two cases for a full-scale output of 5 V is approximately 20 mV (for an eight-bit converter) and 1.2 mV (for a 12-bit converter)

Digital-to-Analogue Converters



Digital-to-Analogue Converters

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.

Sources of error include the *gain error* (or full-scale error), the *offset error* (or zero-scale error), *nonlinearity errors* and a drift of all these factors.

Digital-to-Analogue Converters

Conversion Speed or Settling Time

The *conversion speed* of a D/A converter is expressed in terms of its settling time. The *settling time* is the time period that has elapsed for the analogue output to reach its final value within a specified error band after a digital input code change has been effected.

General-purpose D/A converters have a settling time of several microseconds, while some of the high-speed D/A converters have a settling time of a few nanoseconds. The settling time specification for D/A converter type number AD 9768 from Analog Devices USA, for instance, is 5 ns.

Thank you