Real Time System

Third Level

Lecture Four

Analog to Digital Converters

RealTime Systems.
Dr. Osama Abbas Hussein

Goals
Up-on completing this lecture, the student should be able to:

1- Identify the concepts behind A/D conversion processes
2- Comprehend the concepts of resolution and accuracy.

Analog to Digital Converters:-

Analog to Digital Converters (ADC) are an electronic integrated circuit (IC) which transforms a signal from analog (continuous) to digital (discrete) form. Analog signals are directly measurable quantities. Digital signals only have two states. For digital computer, we refer to binary states, 0 and 1.

Why ADC is needed:-

ADC is needed for many reasons but the most important are: Microprocessors can only perform complex processing on digitized signals. When signals are in digital form they are less susceptible to the deleterious effects of additive noise. Also ADC Provides a link between the analog world of transducers and the digital world of signal processing and data handling.

Application of ADC:-

ADCs are used virtually everywhere where an analog signal has to be processed, stored, or transported in digital form. Some examples of ADC usage are digital volt meters, cell phone, thermocouples, and digital oscilloscope. Microcontrollers commonly used 8, 10, 12, or 16 bit ADCs.

Classification of ADC according to the technique:-

ADC can be classified into two general groups based on the conversion technique:-

The first technique involves comparing a given analog signal with the internally generated equivalent signal. This group includes successive-approximation, counter, and flash-type converters.

The second technique involves changing an analog signal into time and frequency and comparing these new parameters to known values. This group includes integrator converters and voltage to frequency converters.

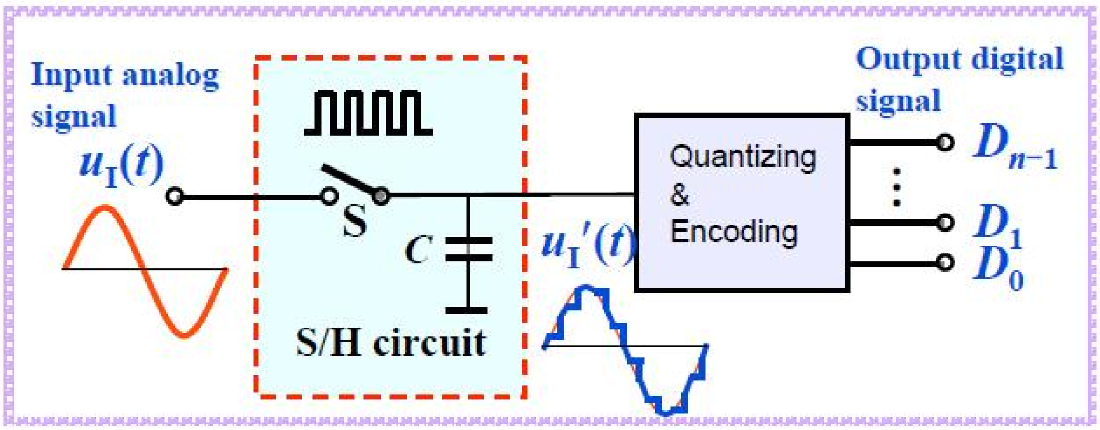
The tradeoff between two techniques is based on accuracy VS speed. The successive-approximation and flash-type converters are faster but generally less accurate than the integrator and voltage to frequency type converters. Furthermore, the flash-type is expensive and difficult to design for high accuracy.

The most commonly used ADC: The successive-approximation and the integrator. The successive-approximation is used in applications such as data loggers, and instrumentation, where conversion speed is important. The integrator types are used in applications such as digital meter, and monitoring system where the conversion accuracy is critical.

ADC process:-

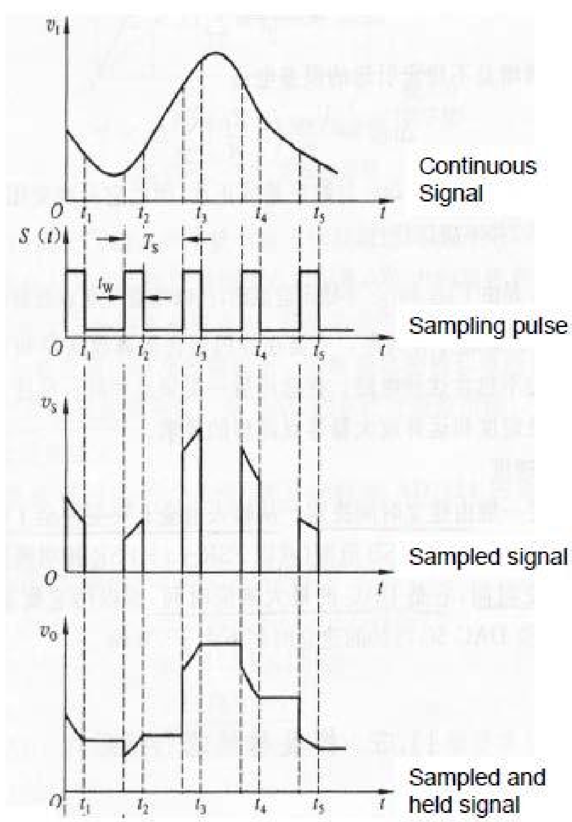
There are two steps process as shown in figure below:-

1. Sampling and Holding (S/H).
2. Quantizing and Encoding (Q/E).



Sampling and Holding:-

It is a process of taking a sufficient number of discrete values at point on a waveform that will define the shape of waveform. The more samples you take, the more accurately you will define the waveform. It converts analog signal into series of impulses, each representing amplitude of the signal at given point as shown in figure below.



Quantizing and Encoding:-

Quantizing - is the process of converting the sampled continuous signals into discrete-valued data (set of finite states).

Encoding - assigning a digital word or number to each state and matching it to the input signal.

The number of possible states that the converter can output is:

$N=2^n$

Where n is the number of bits in the ADC.

Example: if you have 0-10V signals. What is the Discrete Voltage Ranges and Output Binary Equivalent by using 3 bit A/D converter?

Solution:-

$N=2^n$

For a 3 bit A/D converter, $N=2^3=8$.

Analog quantization size:

Q = (Vmax – Vmin) / N = (10V – 0V) / 8 = 1.25V

Step 1: Quantizing:

Output States	**Discrete Voltage Ranges (V)**
0	**0.00-1.25**
1	**1.25-2.50**
2	**2.50-3.75**
3	**3.75-5.00**
4	**5.00-6.25**
5	**6.25-7.50**
6	**7.50-8.75**
7	**8.75-10.0**

Step 2: Encoding:

Here we assign the digital value (binary number) to each state for the computer to read.

Output States	Output Binary Equivalent
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Resolution:-

The smallest change in analog signal that will result in a change in the digital output.

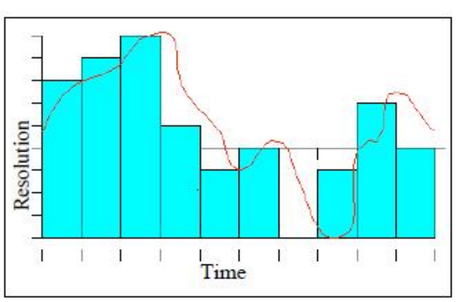
- Resolution (number of discrete values the converter can produce) = Analog Quantization size (Q)
- (Q) = Vrange / 2^n, where Vrange is the range of analog voltages which can be represented
- limited by signal-to-noise ratio (should be around 6dB)
- In our previous example: Q = 1.25V, this is a high resolution. A lower resolution would be if we used a 2-bit converter, then the resolution would be 10/2^2 = 2.50V.

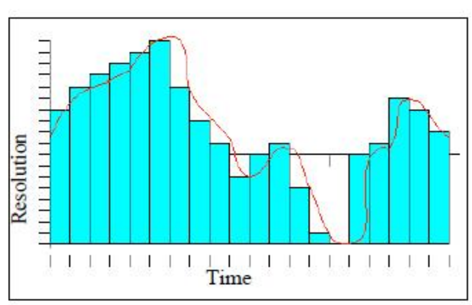
Accuracy of A/D Conversion:-

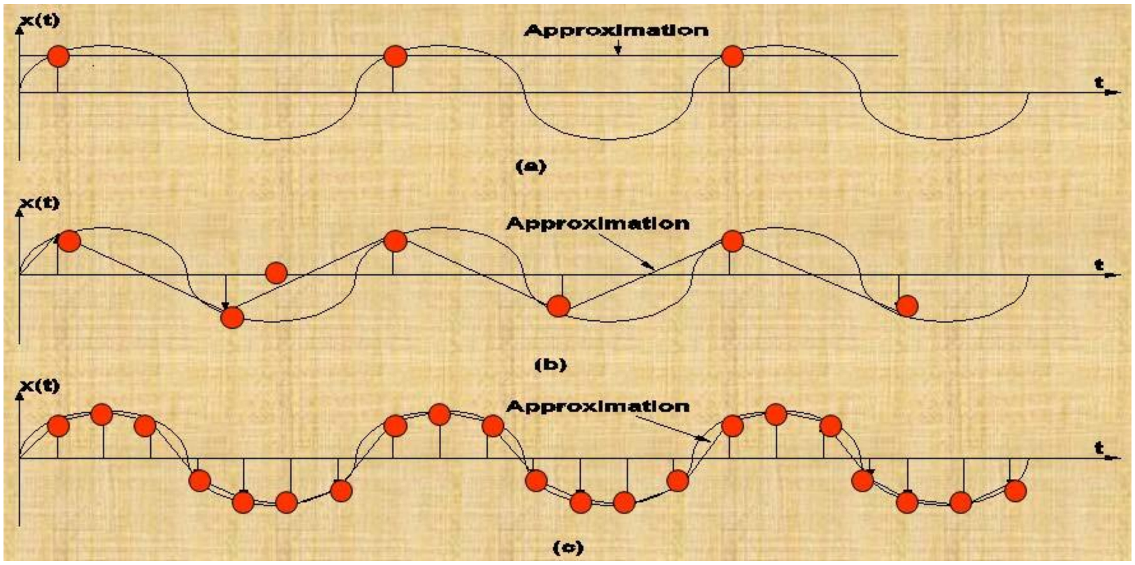
There are two ways to best improve accuracy of A/D conversion:

- Increasing the resolution which improves the accuracy in measuring the amplitude of the analog signal.
- Increasing the sampling rate which increases the maximum frequency that can be measured.

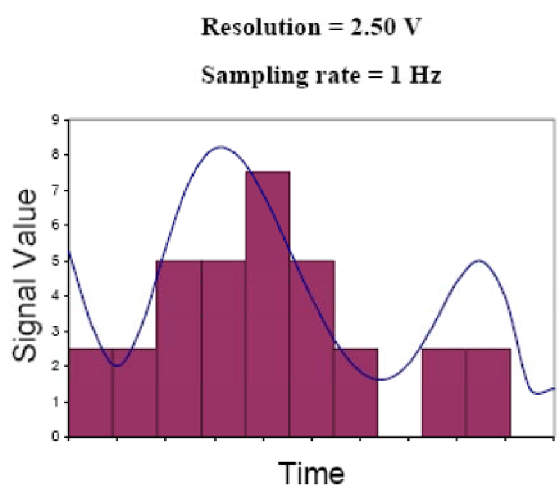
- Low Accuracy
- Improved

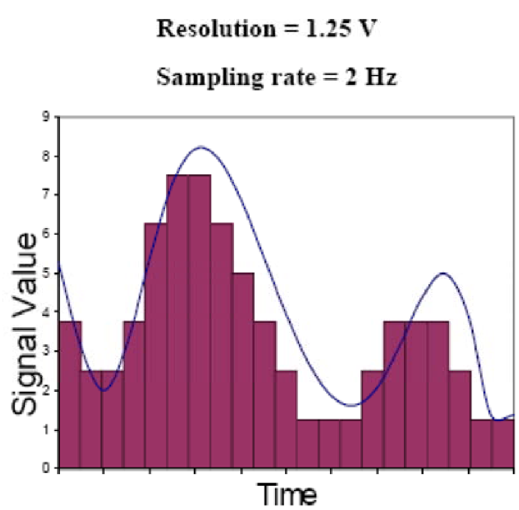






Overall Better Accuracy: Increasing both the sampling rate and the resolution you can obtain better accuracy in your AD signals.





Aliasing:-

Occurs when the input signal is changing much faster than the sample rate.

For example, a 2 kHz sine wave being sampled at 1.5 kHz would be reconstructed as a 500 Hz (the aliased signal) sine wave.

Nyquist Rule:

Use a sampling frequency at least twice as high as the maximum frequency in the signal to avoid aliasing.

Summary:
1- Analog signals can't be dealt with directly by the CPUs.
2- Sampling and Holding is the first process of the conversion process where discrete signals are produced.
3- Q&E is final and 2nd stage in the A/D conversion process where codes are assigned and digital output is produced.

Questions:
1- What are the A/D processes ?
2- Draw the sampling and hold-process
3- What is the relation between accuracy and resolution
4- For a 3 bits A/D converter with Vmin= 0 V and Vmax= 3.3 volts, find the code-word for Vin= 1.5 volts.