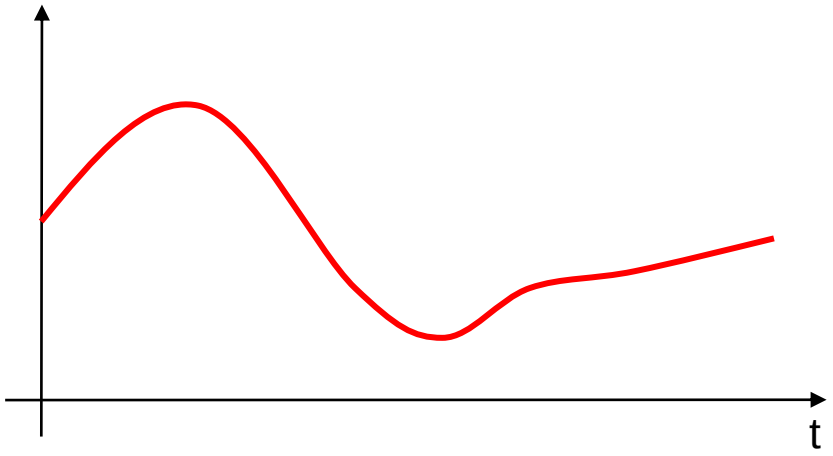
Signal Conversion and Processing

ENGG 6150: Bio-Instrumentation

Signal Types

Analog Signals

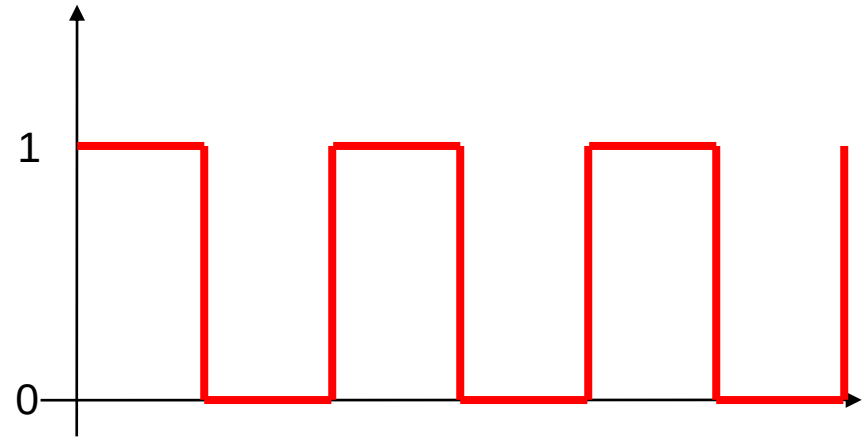
- Analog signal is a continuous wave that keeps on changing over a time period.
- It is described by the amplitude, period or frequency, and phase.
- It has no fixed range
- It is more prone to distortion.



Signal Types

Digital Signals

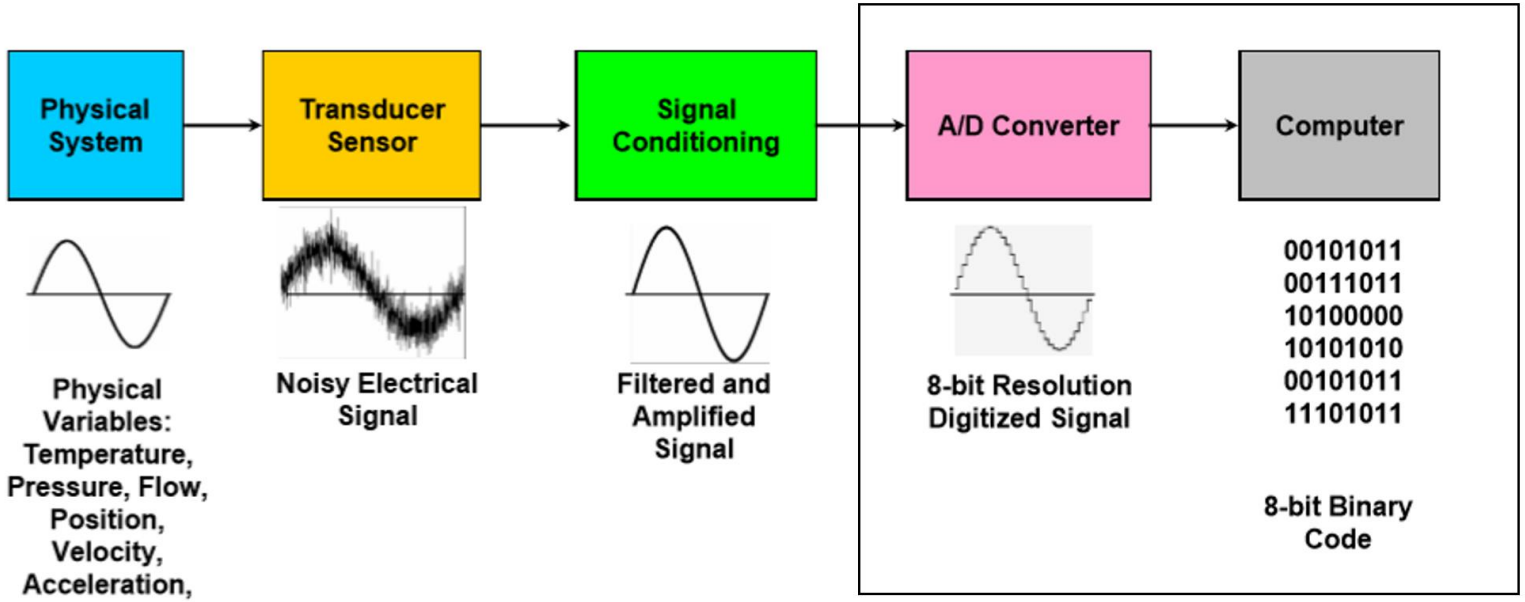
- A digital signal is a discrete wave that carries information in binary form.
- It is described by bit rate and bit intervals.
- It has a finite numbers i.e. 0 and 1.
- It is less prone to distortion



What is Data Acquisition?

Data acquisition systems

- It is an information system that collects, stores and distributes information.
- It is used in commercial instrumentation to capture electrical signals in order to be processed in a computer device.

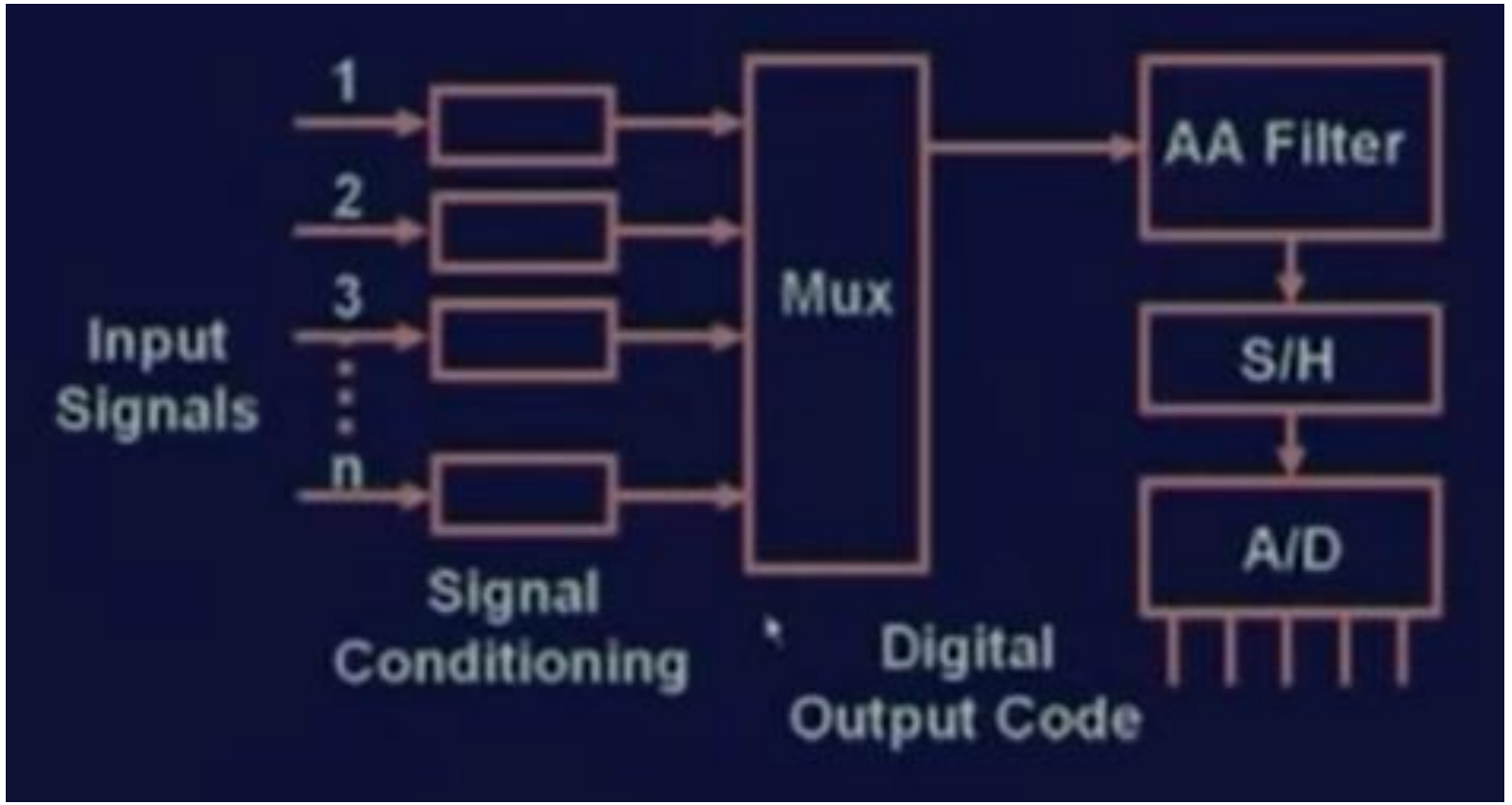


Specifications for DAQ

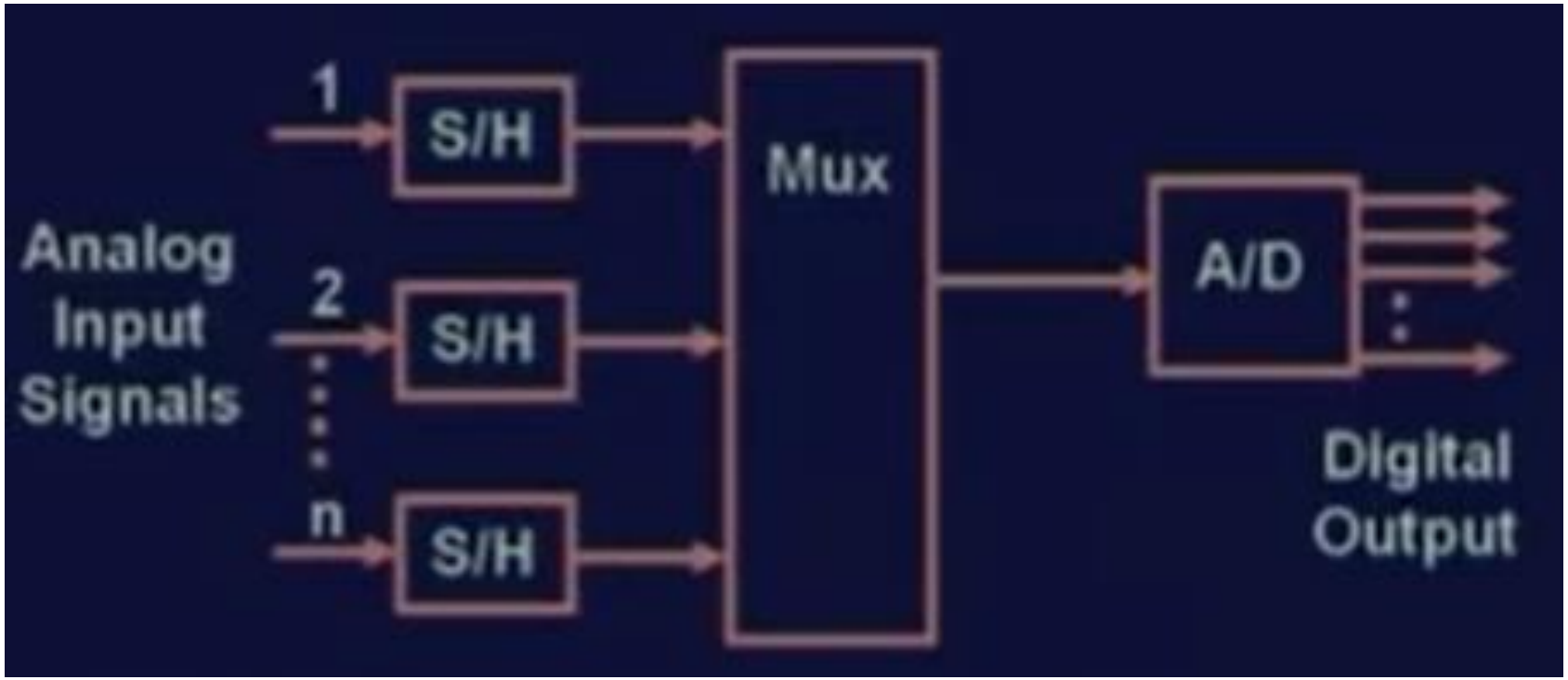
- The most significant criteria when selecting DAQ cards are:
  - Number of input channels
  - Single-ended or differential input signals
  - Sampling rate (in samples per second)
  - Resolution (usually measured in bits of resolution)
  - Input range (specified in full-scale volts)
  - Analog output
  - Digital input and outputs

	Analog Input					Analog Output		DIO	Counters	Connectivity*
	Max Num Ch.	Simul-taneous	Sample Rate	Resolution	Absolute Accuracy	Num Ch.	Update Rate	No. Channels	No. Channels	
USB-6366	8	yes	2 MS/s	16 bits	2.69 mV	2	3.33 MS/s	24	4	ST,MT,BNC
USB-6363	16	no	2 MS/s	16 bits	1.66 mV	4	2.86 MS/s	48	4	ST,MT,BNC

Block Diagram of Data Acquisition System



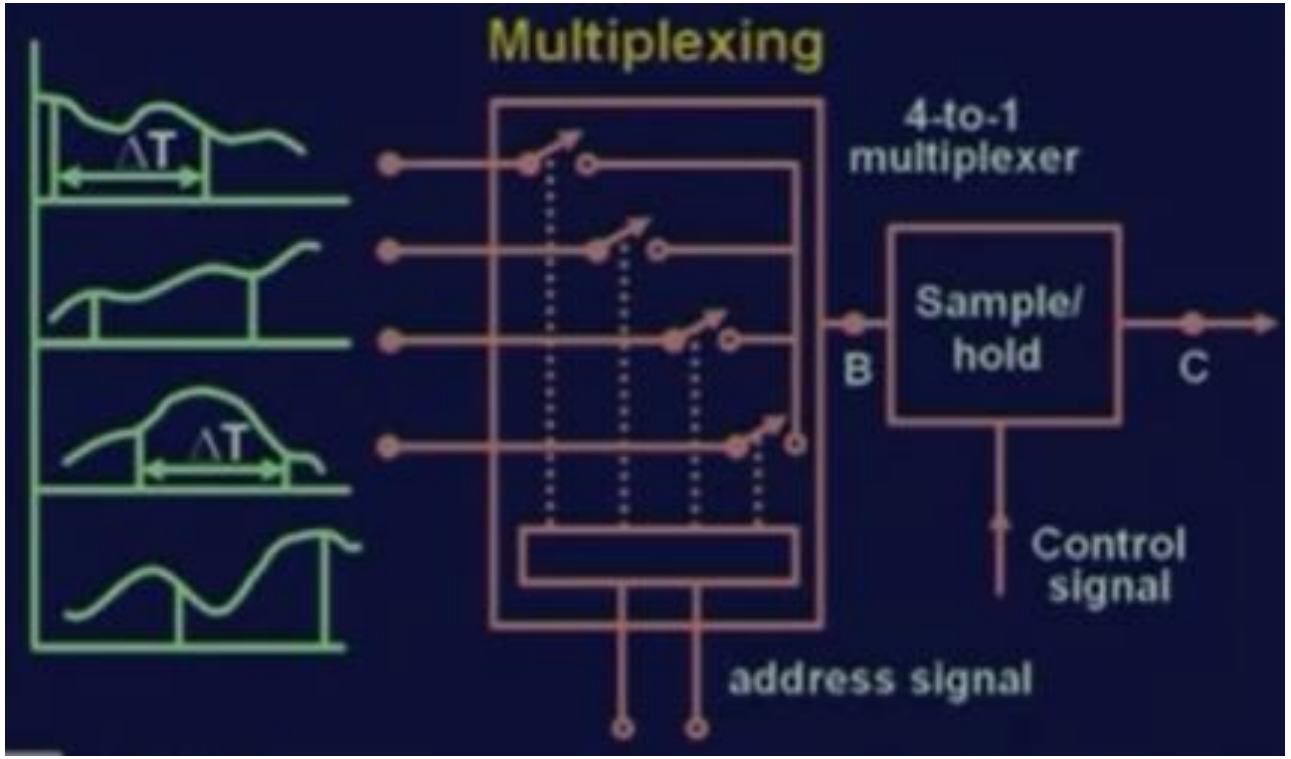
Block Diagram of Data Acquisition System



In this configuration, we have simultaneous sample and hold of the signals, so there is no time shift in the sampling and hence synchronized data.

Multiplexer

- Accepts multiple analog inputs and provide a single output signal according to the requirements



Multiplexer

Effective rate of each individual channel is inversely proportional to the number of channels sampled.

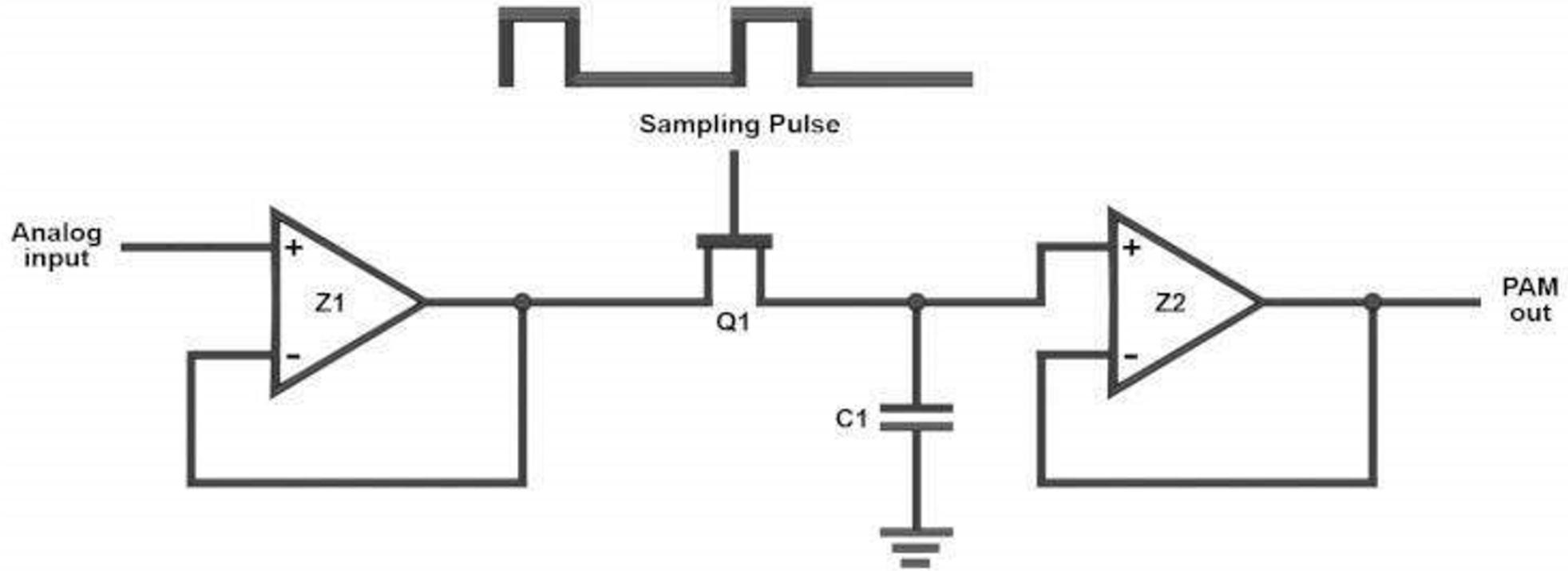
Example:

- 100 KHz maximum.
- 16 channels.

100 KHz/16 = 6.25 KHz per channel.

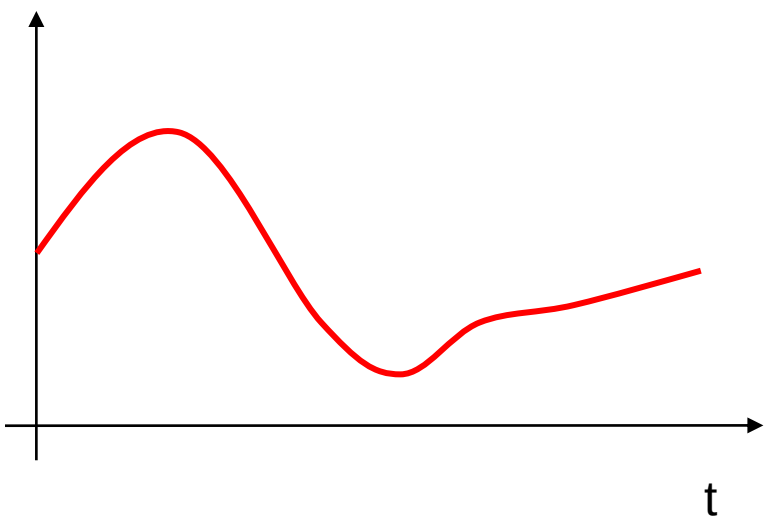
Sample and Hold

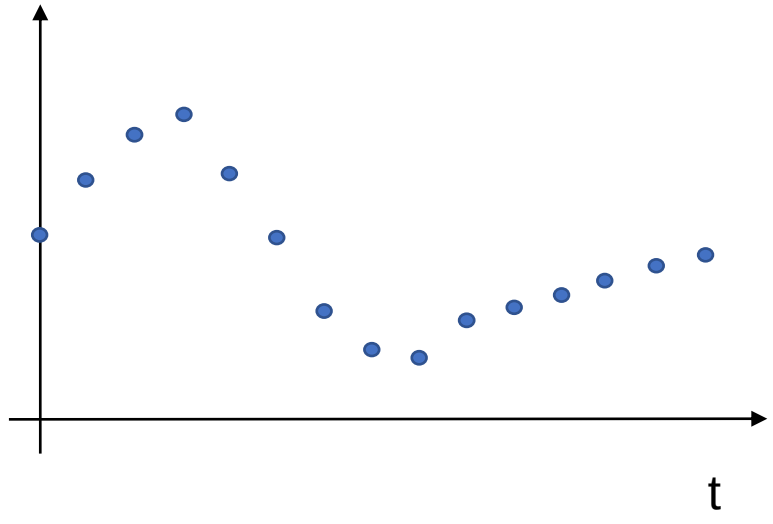
Sample and hold circuit



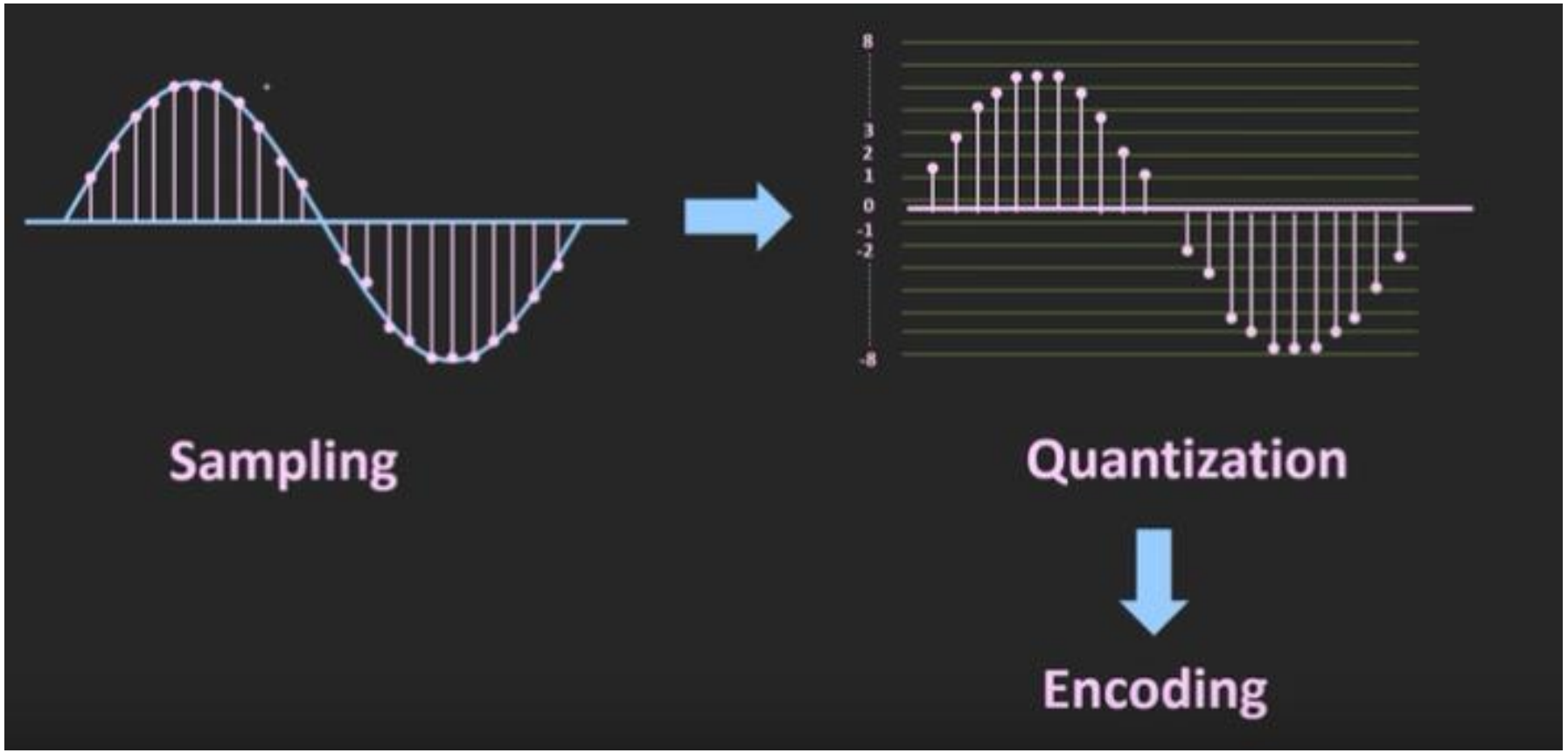
A/D Conversion

- Analog-to-Digital converter is an electronic integrated circuit which converts a signal from analog (**continuous**) to digital (**discrete**) form
- This circuit provides an interface link between the analog world of transducers and the digital world of signal processing and data handling



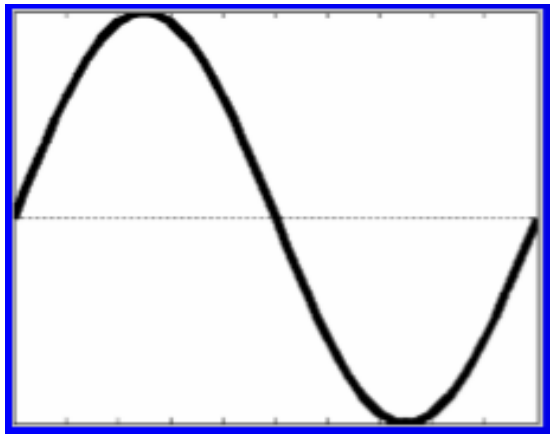


A/D Conversion

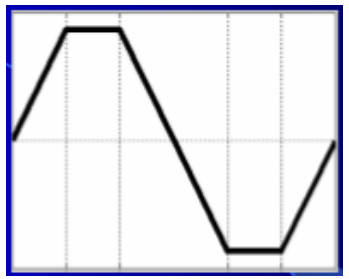


Sampling Rate

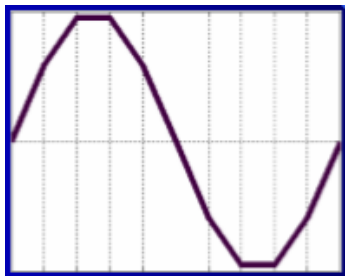
- One of the most critical factors when selecting an A/D board is sampling rate (speed).
- The sampling rate is a measure of how rapidly the A/D board can scan the input channel and identify the discrete value of the signal.



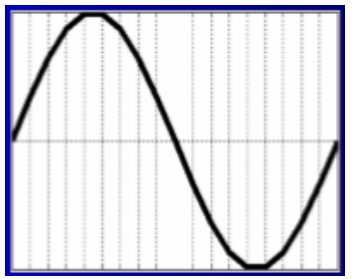
Analog input



4 samples per cycle



8 samples per cycle



16 samples per cycle

Aliasing

- If the sampling rate is too slow, then a completely different waveform of a lower frequency is constructed from the data acquired. This effect is called aliasing.

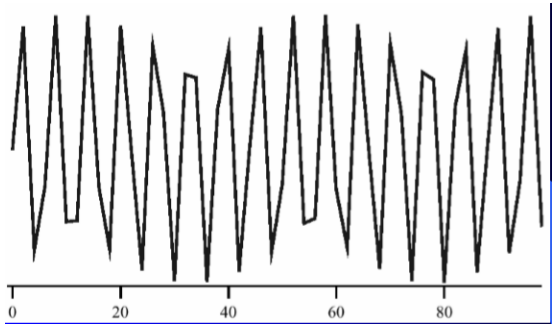
- Aliasing has the effect of increasing the variance in the recorded signal, i.e. it adds noise to the signal by missing the peaks.

- So, if the signal has the same peak all the time (like sinusoidal signals) the board will catch the rising and falling part of the signal but may miss the peak giving the impression that the peak is changing.

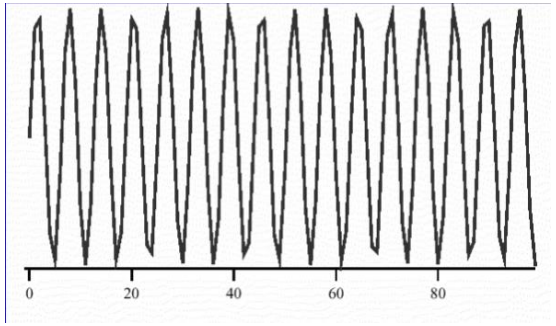
Aliasing

- To avoid aliasing, it is necessary to have a sampling rate at least twice the highest expected input frequency (theoretically) but should be 5-10 times (practically).

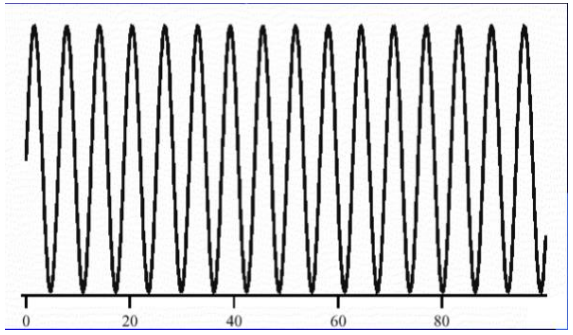
Analog Signal of 160Hz (6.25 ms between peaks)



Sampled at T=2 ms or f=500 Hz



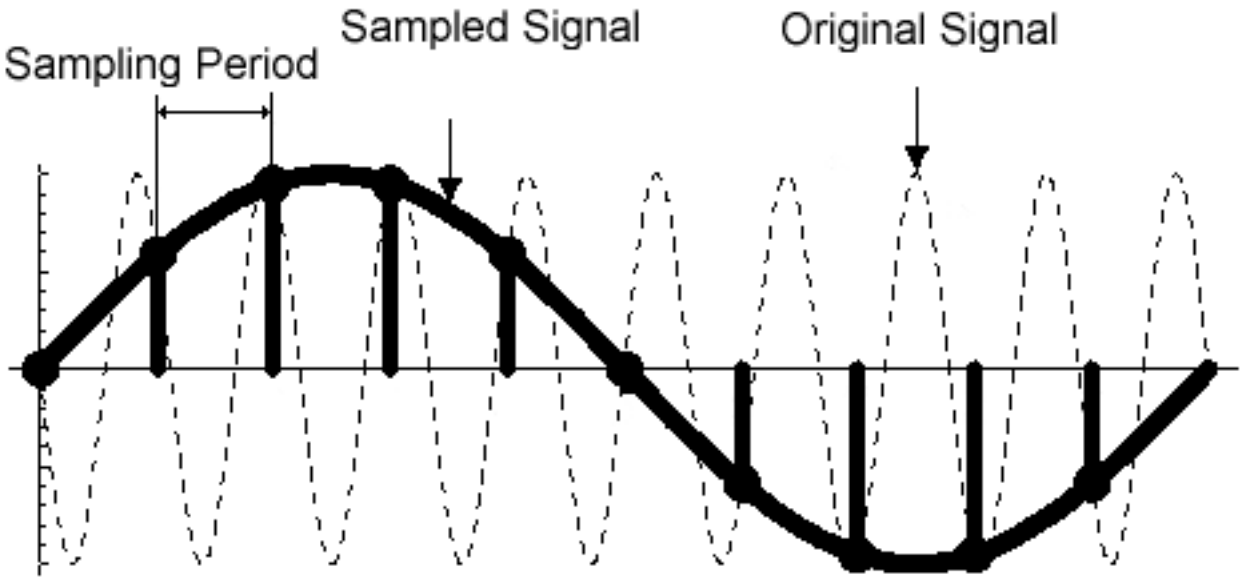
Sampled at T=1 ms or f=1KHz



Sampled at T=0.1 ms, or f=10KHz

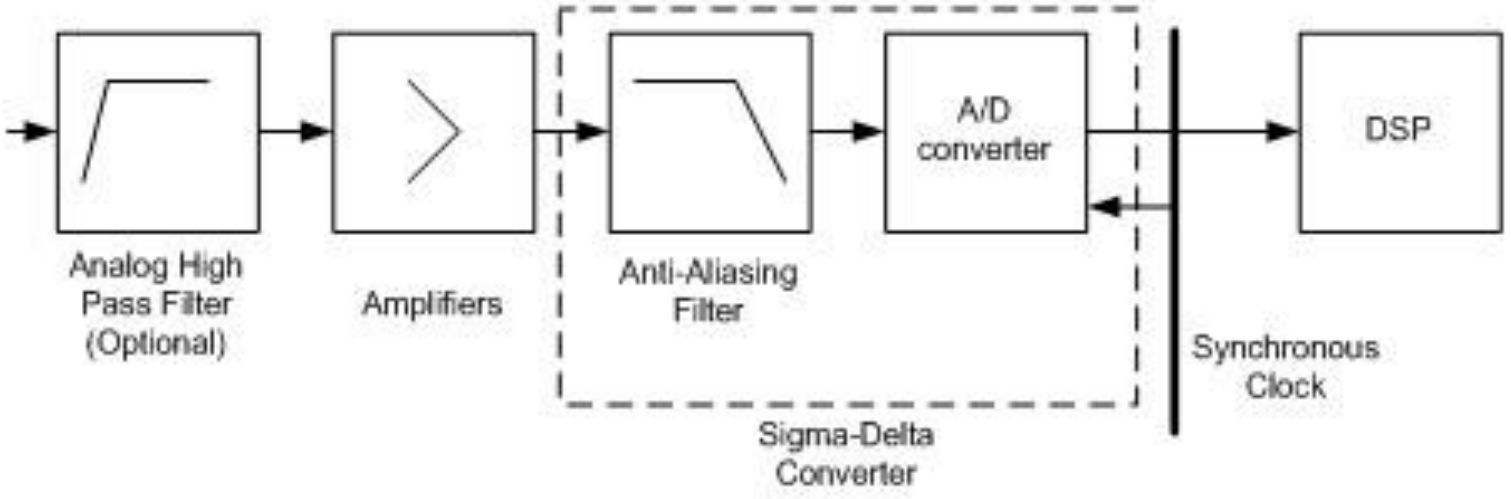
Aliasing

- If you completely under sample the signal you will get a signal with totally different frequency.



Aliasing

- When we sample the signal, in many times we do not know the full frequency information about the acquired signal.
- To avoid aliasing, we apply anti aliasing filter to ensure that the sampled signal has frequencies only 1/10th of the sampling frequency.
- Other higher frequencies will not pass and hence will not create low frequency error.



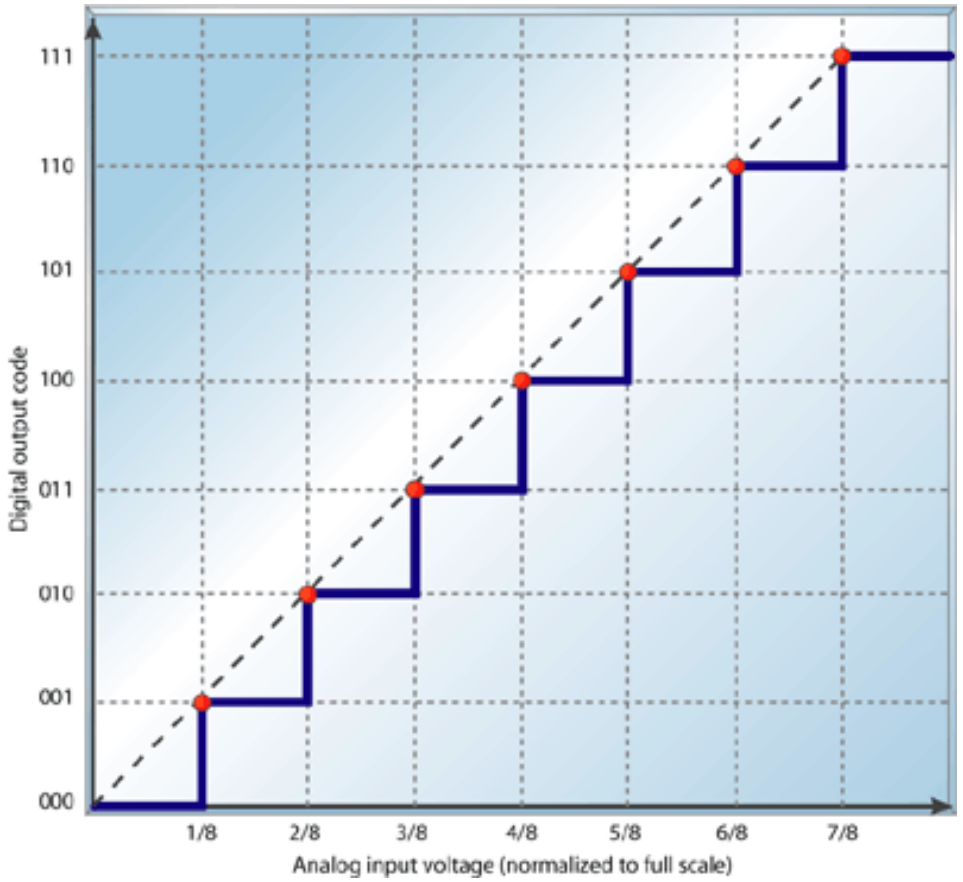
Resolution and Range

- The range is the minimum and maximum voltage levels that the A/D converter can quantize.
- The division of the full scale range of voltage to the total number of states, which is 2^N, available in the A/D defines the resolution of the A/D converter. Where *N* is the total number of bits dedicated in the A/D for the digital data.

$$\text{Resolution} = \frac{\text{Full Scale Range (FSR)}}{2^{(\text{No. of bits})}} = \frac{\text{Vmax - Vmin}}{2^{(\text{No. of bits})}}$$

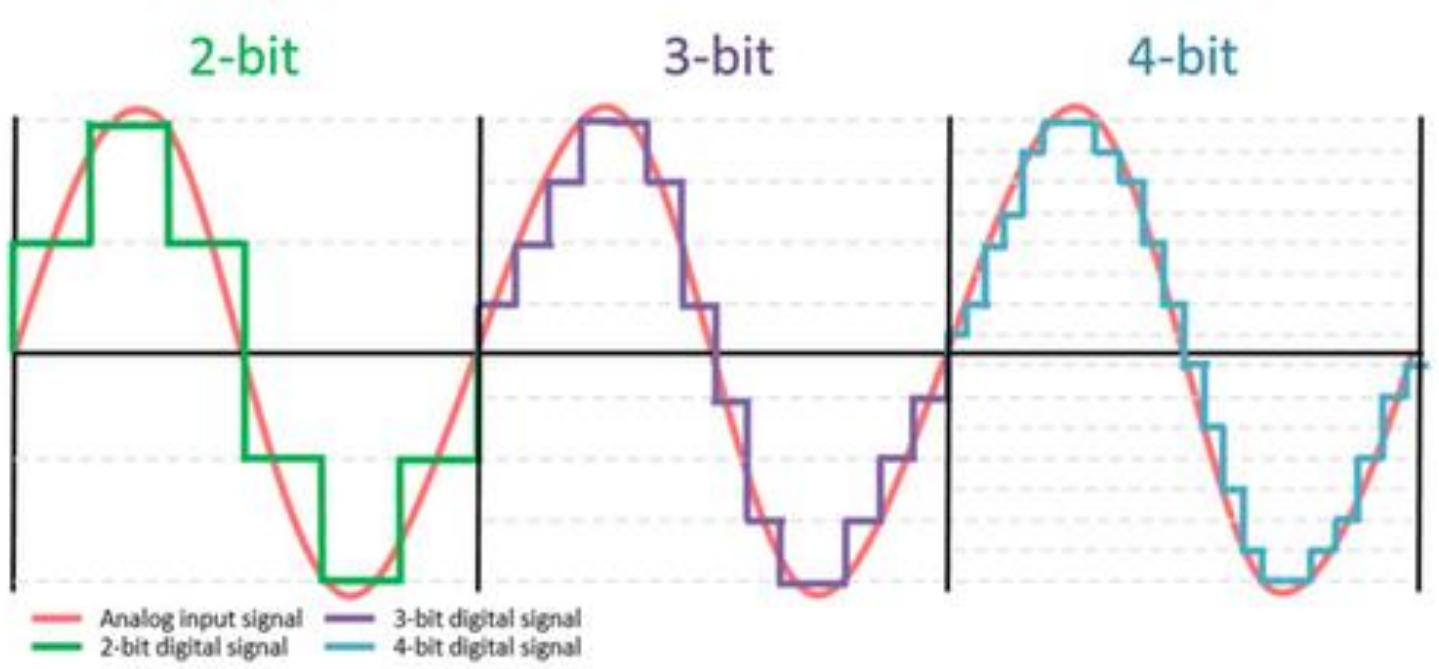
Resolution and Range

- If the A/D has 3-bit resolution, 1V as full range, then the input signal can be measured in steps of $1/2^3 = 0.125V$.



Resolution and Range

- The following diagram shows the effect of resolution on the constructed signal:



Resolution and Range

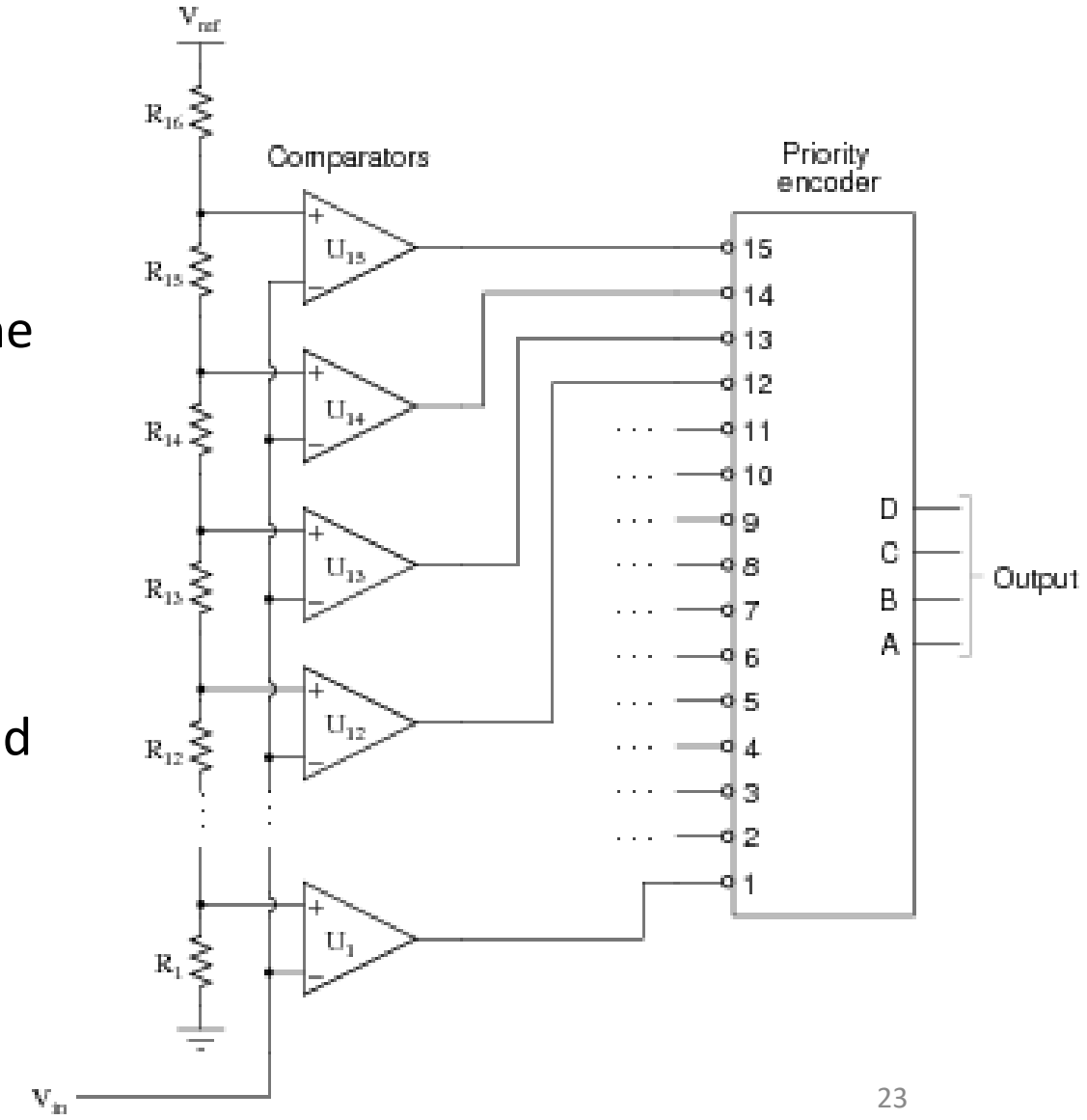
- Commonly used values are:
  - 8 bits = 2^8, 256 values
  - 12 bits = 2^{12}, 4,096 values
  - 16 bits = 2^{16}, 65,536 values
- So, A/D has 8-bit resolution, then the input signal can be measured in step of:

  $10/2^8 = 10/256 = 0.039V = 39mV$
- So, this A/D board is only capable of detecting input changes greater than 0.039V.
- A 12 bit board would be more sensitive to changes in the input voltage source since its minimum resolution would be:

  $10/4096 = 2.44mV$

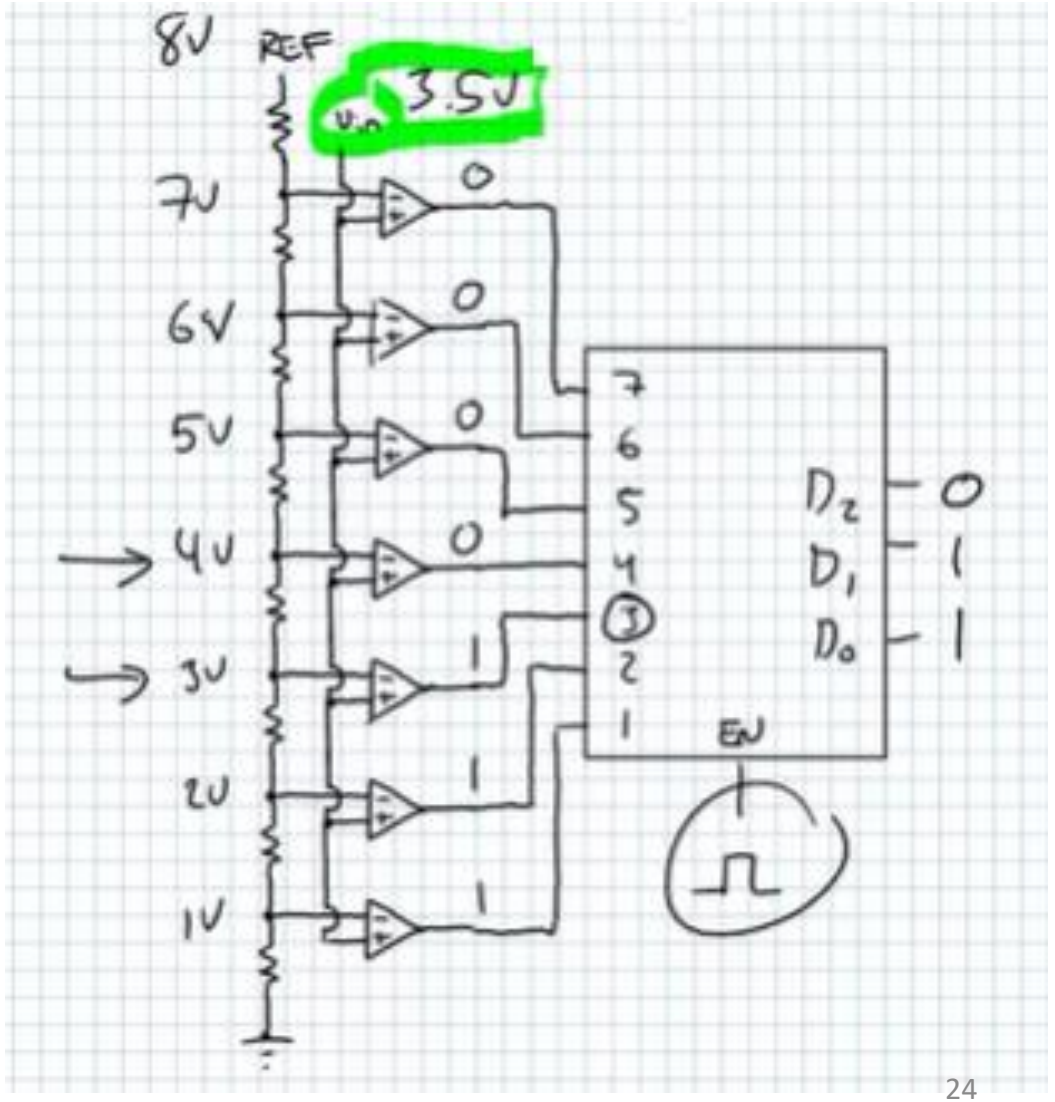
Flash A/D Conversion

- The basic components of flash A/D are:
  - ❑ Voltage divider network (2^N resistors)
  - ❑ Comparators (2^N – 1 comparators)
  - ❑ Priority encoder
- The voltage divider has identical resistors, so the voltage at each resistor will be the same.
- In this example, if Vref = 8 V, then the voltage across each R will be 1 V because we have 8 resistors.
- Also, the voltage to ground for the top resistor will be 8V, then 7V to the resistor beneath it and so on.



Flash A/D Conversion

- The positive terminal from each comparator will receive Vin and the negative terminal will receive a voltage from voltage divider.
- So, if the input is 3.5 V, this will be the output of the A/D



Analog Outputs

- Analog outputs are generated using a procedure which is the inverse of that used to read analog inputs.
- An analog output is typically required for any application involving a variable control device such as a servo motor.
- The outputs may be configured as voltages (0-10V, 0-5V, ±10V, ±5V) or as a 4-20mA current sources.

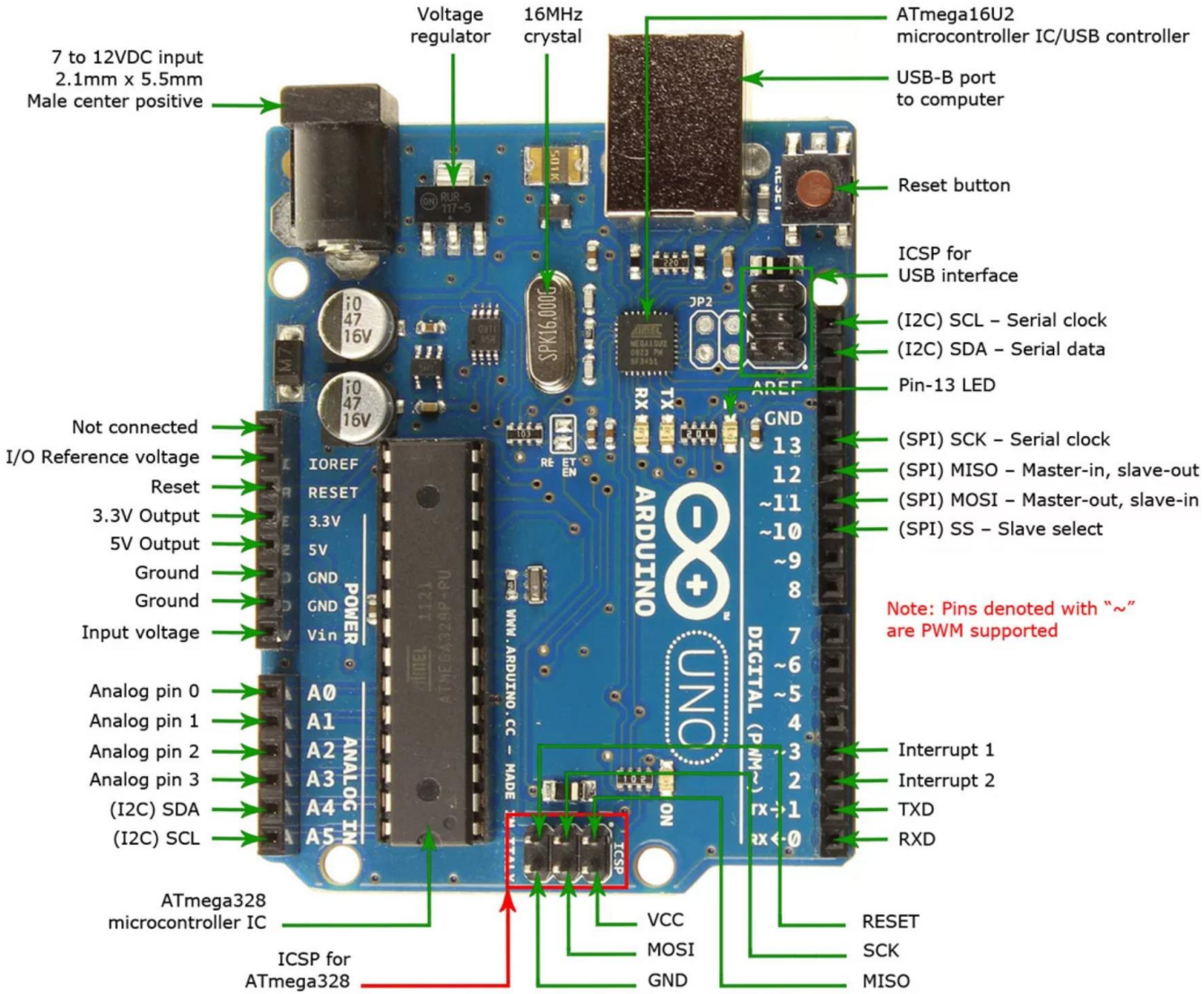
Digital Inputs and Outputs

- Most analog input/output boards also incorporate general-purpose digital input/output channels.
- These channels are useful for many system functions like to sense and control high-power AC/DC voltages through solid state relays.

Data Acquisition Software

- It can be the most critical factor in obtaining reliable, high performance operation.
- Controls the hardware and the system is processing the obtained data.
- Different alternatives:
  - Programmable software: like BASIC, FORTRAN, C++, C…
  - Data acquisition software packages: like LABVIEW

Arduino UNO Pinout Diagram



https://www.youtube.com/watch?v=nL34zDTPkcs

Installing Arduino's Software

Download and Install the Arduino Software (IDE)

Before plugging the USB cable to your computer, you need to first install the Arduino IDE.

Go to the Download page on the adruino.cc:

https://www.arduino.cc/en/Main/Software

Now find the steps suitable for your operating system to install the IDE:

Windows

Linux

Mac OS X

- https://www.arduino.cc/en/Main/Software