Electronic Prototyping

Analog to Digital Converter

Lesson 4

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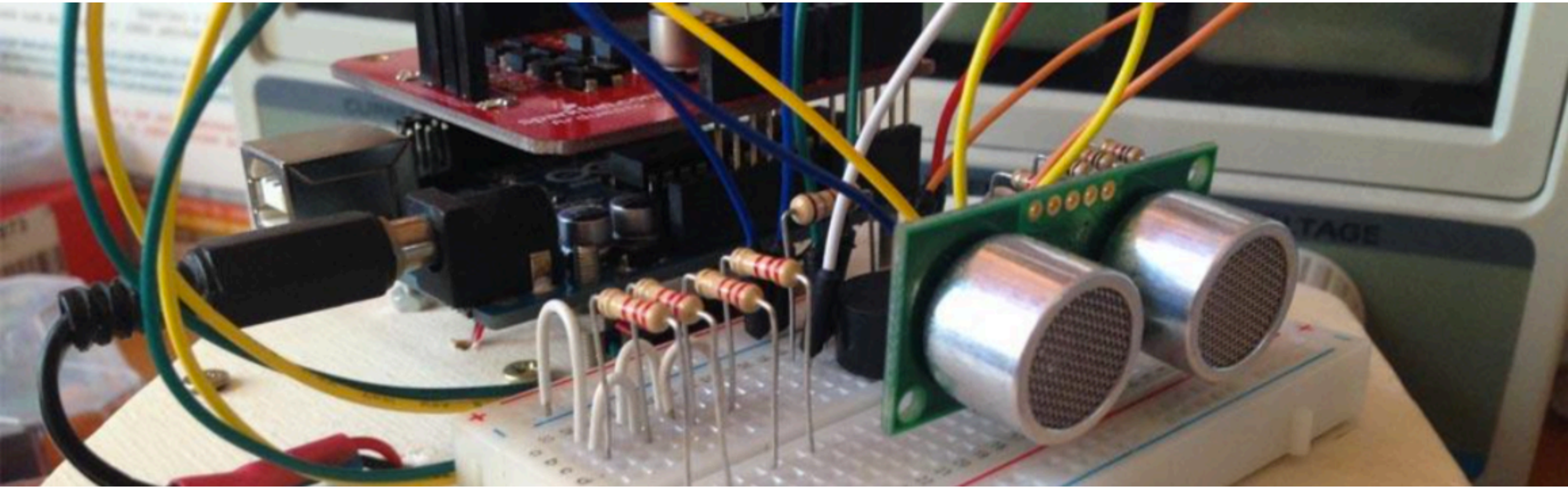


Example of A/D Applications

- **Microphones**
  - Take your voice varying pressure in the air and convert them into varying electrical signals
- **Strain gages**
  - Determines the amount of strain (change in dimensions) when a stress is applied
- **Thermocouple**
  - Temperature measuring device converts thermal energy to electrical energy

What is an ADC?

An ADC (Analog-to-Digital-Converter) is a circuit which gets an analog voltage signal and provides (to software) a variable proportional to the input signal.

An ADC is characterised by:

- The **range** (in volts) of the input signal (typical [0,5V] or [0, 3.3V]).
- The **resolution** (in **bits**) of the converter

Example

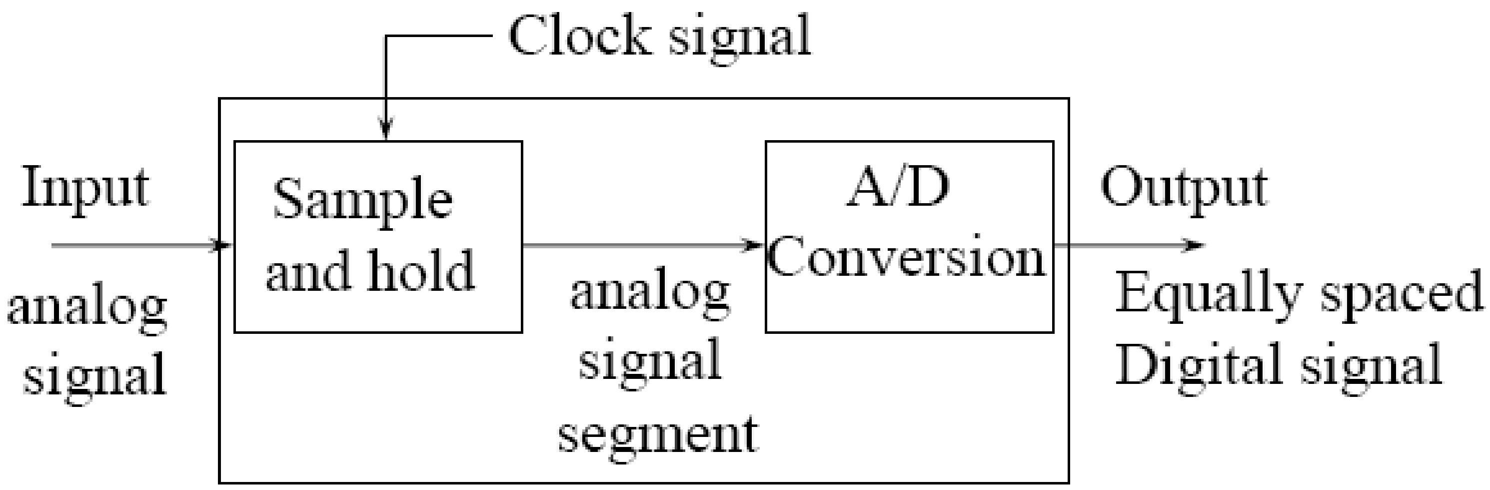
- **Range** = [0,5V]
- **Resolution** = 12 bits

Results in range [0, 2^{12}- 1] = [0, 4095]

0V → 0 2.5V → 2048 5V → 4095

Just what does an A/D converter do?

- **Converts analog signal into binary words**



Analog → Digital Conversion 2 Step process:

- **Quantizing**
  - Breaking down analog value is a set of finite states
- **Encoding**
  - Assigning a digital word or number to each state and matching it to the input signal

Step 1: Quantizing (1/2)

Example

You have 0-10V signals. Separate them into a set of discrete states with 1.25V increments.

(How did we get 1.25V?

See next slide…)

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 1: Quantizing (2/2)

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

$$N=2^n$$

where n is the number of bits in the AD converter

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

Analog quantization size:

$$Q=(V_{max}-V_{min})/N = (10V - 0V)/8 = 1.25V$$

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

Accuracy of A/D Conversion

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

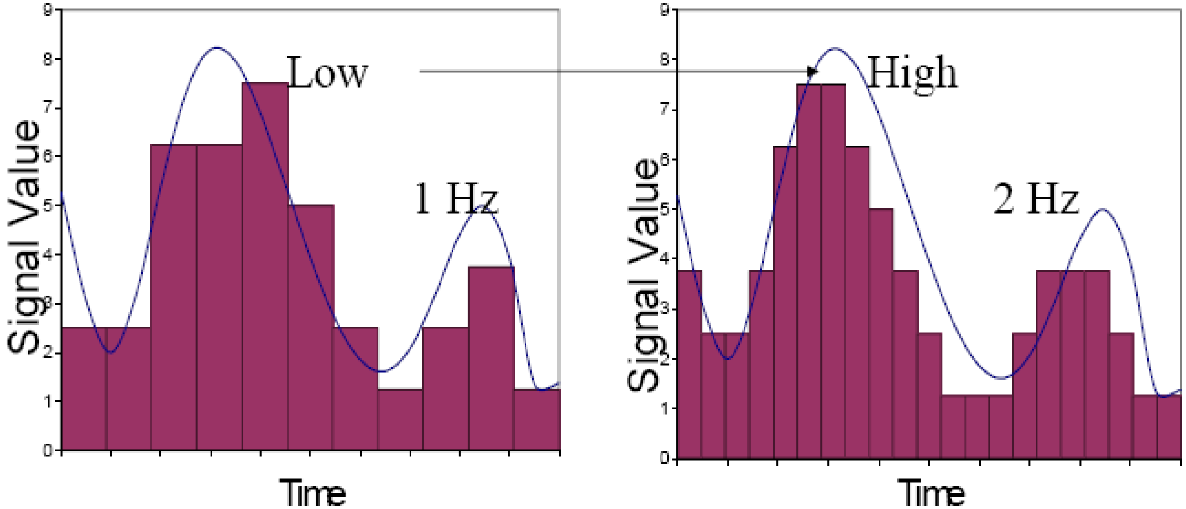
- increasing the resolution which improves the accuracy in measuring the amplitude of the analog signal.

- increasing the sampling rate which increases the maximum frequency that can be measured.

Resolution

- **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 $10/2^2 = 2.50$V.

Sampling rate



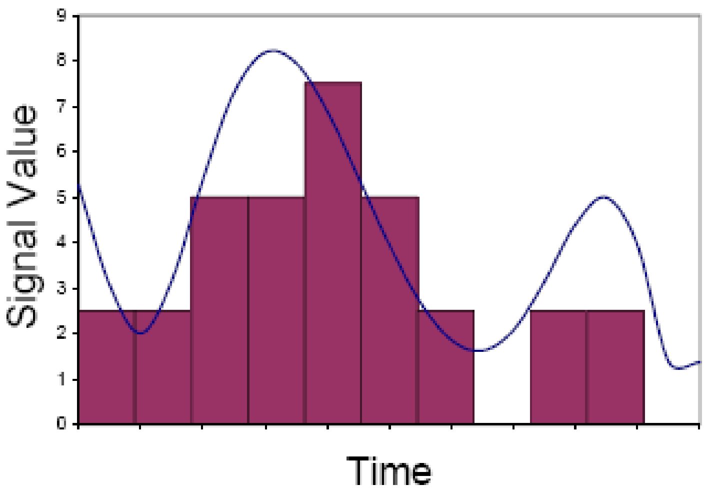
Frequency at which ADC evaluates analog signal. As we see in the second picture, evaluating the signal more often more accurately depicts the ADC signal.

Overall Better Accuracy

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

Resolution = 2.50 V

Sampling rate = 1 Hz



Resolution = 1.25 V

Sampling rate = 2 Hz