Microcontrollers 1

ADC – analog to digital conversion

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Kom verder. Saxion.

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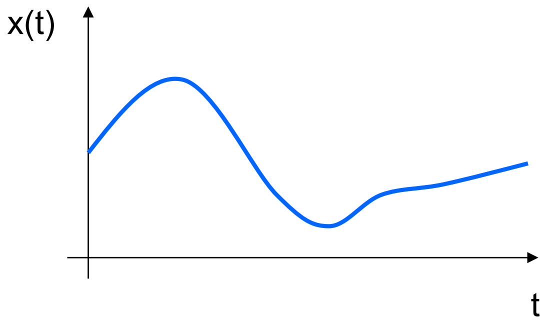
Content

- ADC principles
- Flash ADC
- Succesive Approximation ADC
- Atmega ADC

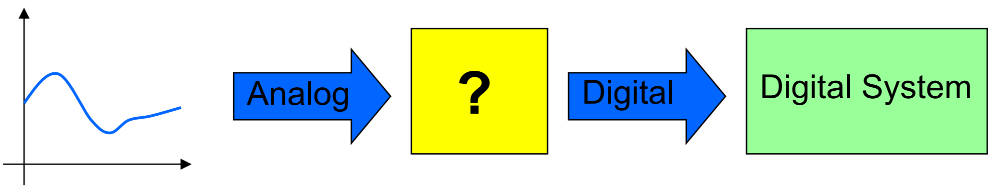
Definition

- Most signals we want to process are analog
- i.e.: they are continuous and can take an inifinity of values



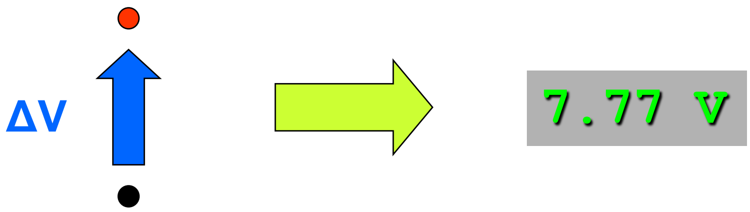
Definition

- Digital systems require discrete digital data
- ADC converts an analog information into a digital information

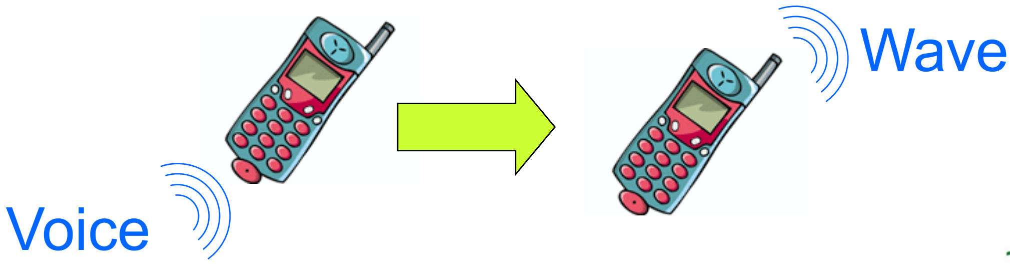


Examples of use

- **Voltmeter**



- **Cell phone (microphone)**



Conversion process

3 steps:

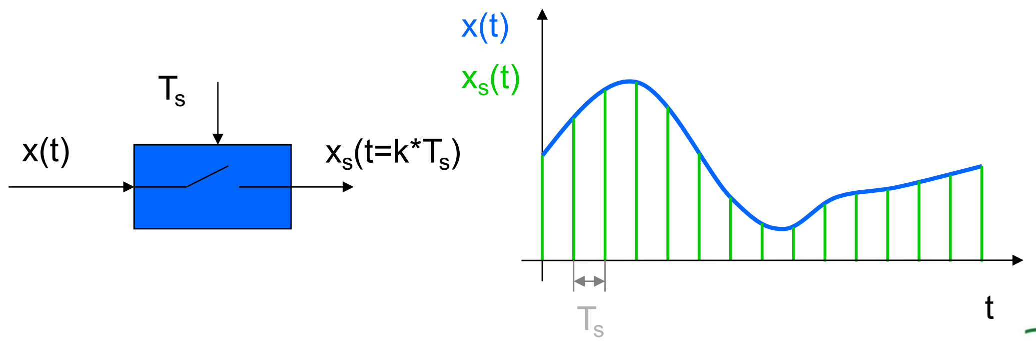
- Sampling
- Quantification
- Coding

These operations are all performed in a same element:

the A to D Converter

Conversion process: Sampling

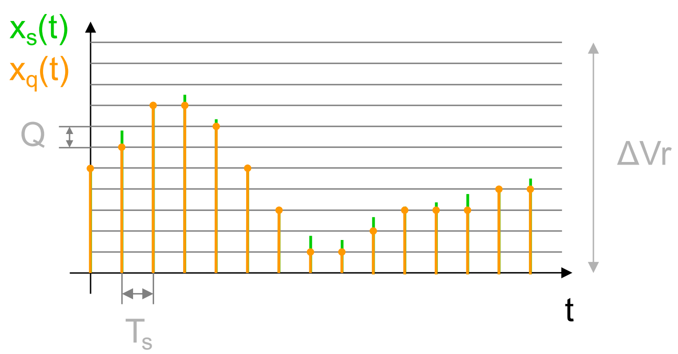
- Digital system works with discrete states
- The signal is only defined at determined times
- The sampling times are proportional to the sampling period (T_s)



Conversion process: Quantification

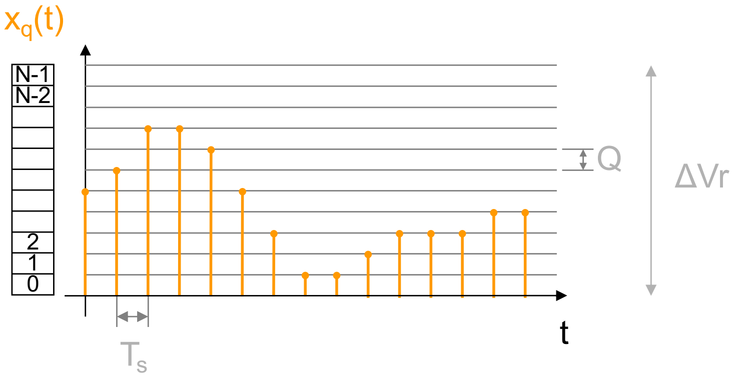
The signal can only take determined values
Belonging to a range of conversion (**ΔV_r**)

- Based on number of bit combinations that the converter can output
- Number of possible states: $N=2^n$ with n = number of bits
- Resolution: **$Q= \Delta V_r/N$**



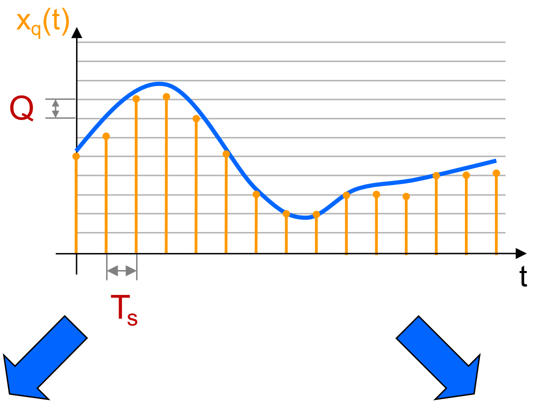
Conversion process: Coding

- Assigning a unique digital word to each sample
- Matching the digital word to the input signal

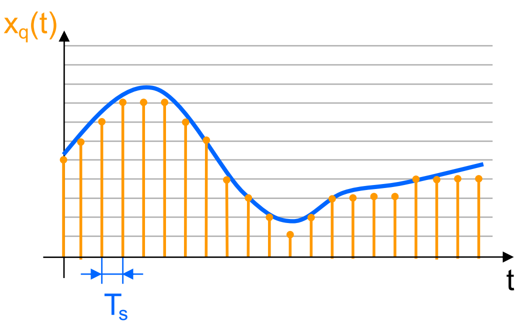


Accuracy

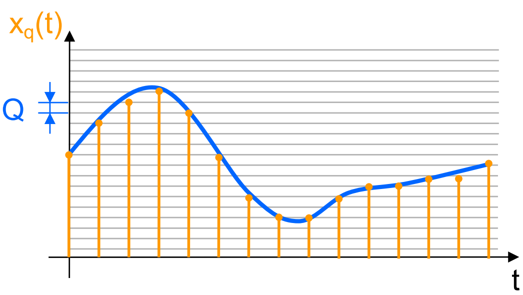
The accuracy of an ADC can be improved by:



Higher Sampling rate (T_s)



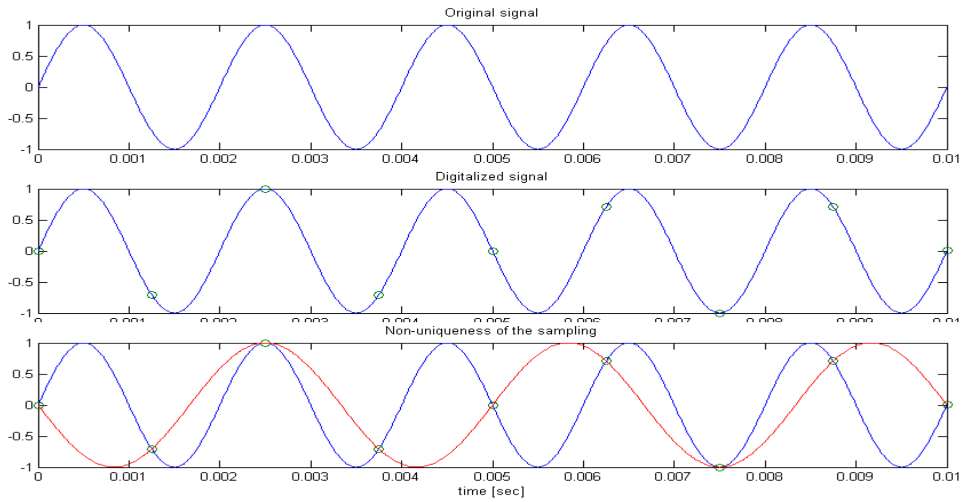
Higher Resolution (Q)



Sampling rate

- **Nyquist-Shannon theorem**: Minimum sampling rate should be at least twice the highest data frequency of the analog signal

$f_s > 2 * f_{max}$



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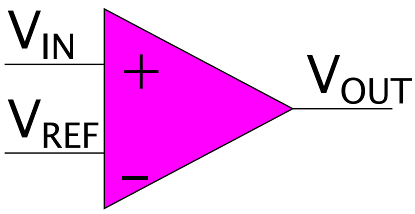
How to measure a sample ?

ADC – comparator

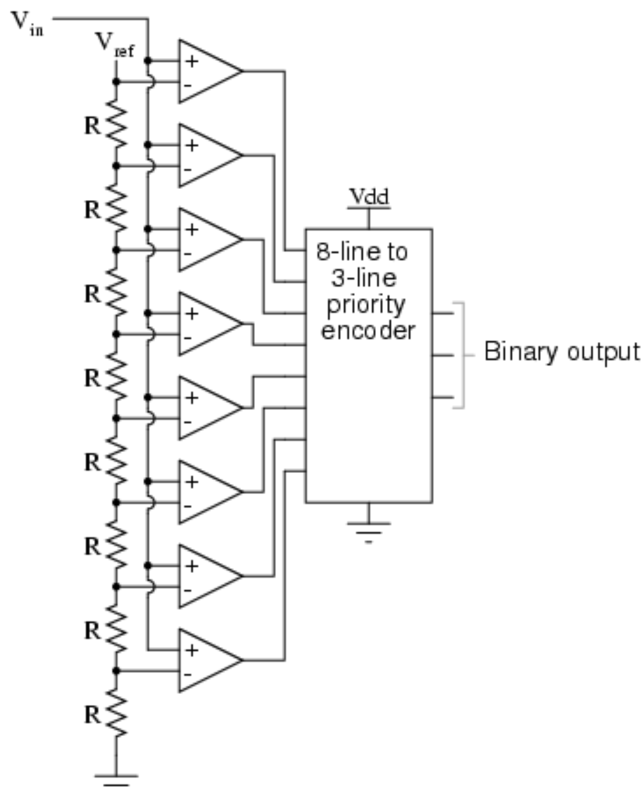
Comparator is one use of an Op-Amp
It can “measure” a voltage difference



If	Output
$V_{IN} > V_{REF}$	High
$V_{IN} < V_{REF}$	Low

Flash ADC

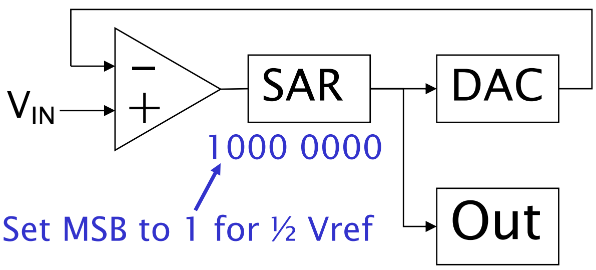
- “parallel A/D”
- Uses a series of comparators
- Each comparator compares V_{in} to a different reference voltage, starting with V_{ref} = 1/2 lsb
- Usually 2^n or $2^n – 1$ comparators

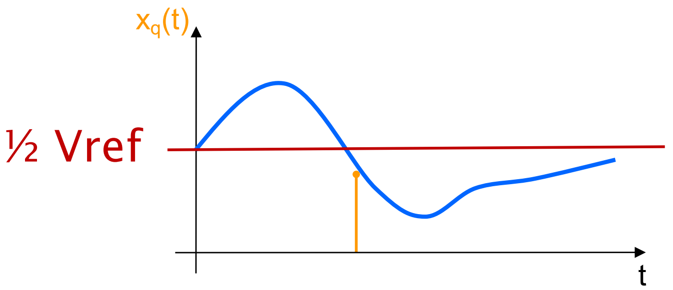


Flash ADC

Advantages	Disadvantages
• Very fast	• Needs many parts (255 comparators for 8-bit ADC) • Lower resolution • Expensive • Large power consumption

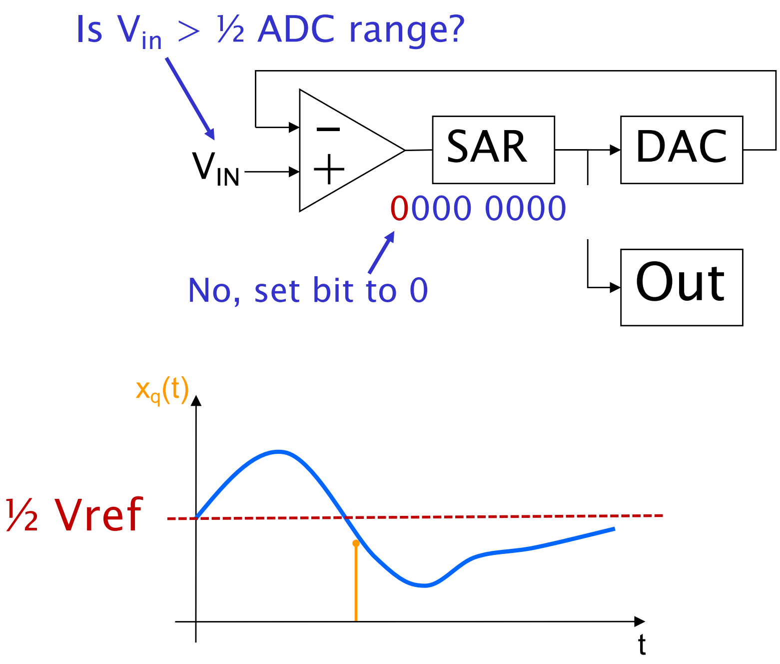
Successive Approximation ADC





1. Set MSB
2. Convert MSB to analog using DAC
3. Compare guess to actual input
4. Set bit accordingly
5. Test next bit

Successive Approximation ADC



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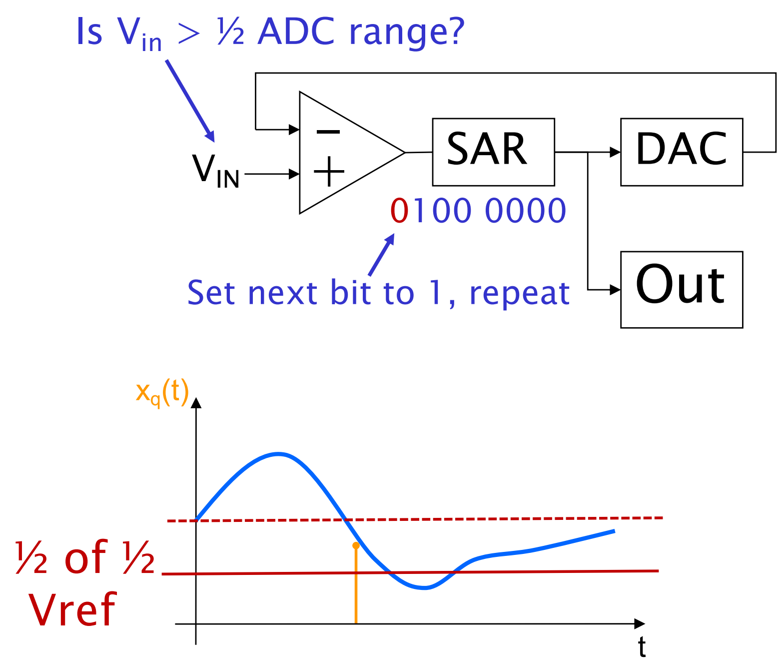

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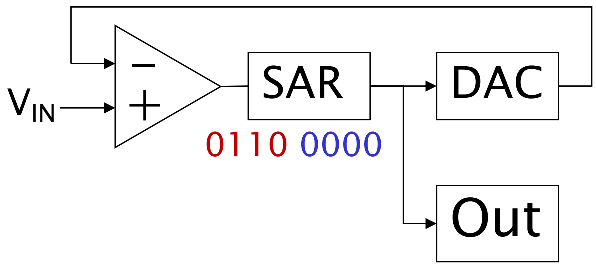

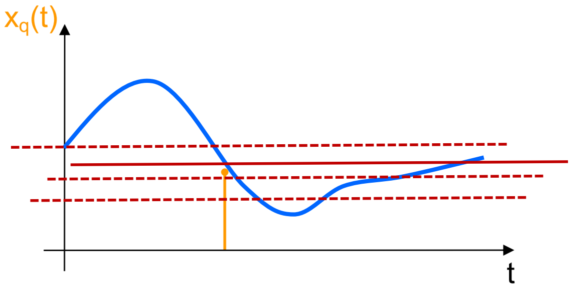

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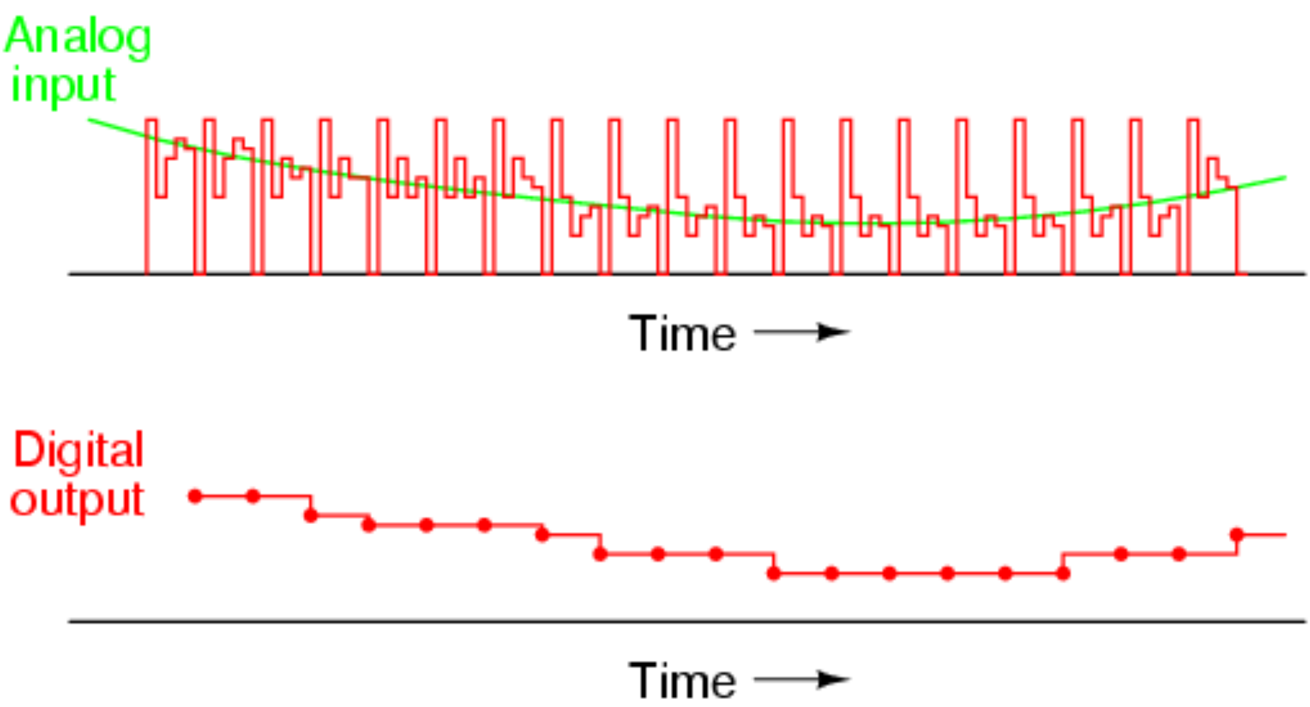
Successive Approximation ADC



Successive Approximation ADC

Advantages	Disadvantages
• Capable of high speed • Medium accuracy compared to other ADC types • Good tradeoff between speed and cost	• Higher resolution successive approximation ADCs will be slower • Speed limited ~5Msps

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ATmega ADC features

- As seen in the datasheet:

- **10-bit Resolution**
- **0.5 LSB Integral Non-linearity**
- **± 2 LSB Absolute Accuracy**
- **13 - 260 μs Conversion Time**
- **Up to 76.9 kSPS (Up to 15 kSPS at Maximum Resolution)**
- **6 Multiplexed Single Ended Input Channels**
- **2 Additional Multiplexed Single Ended Input Channels (TQFP and QFN/MLF Package only)**
- **Temperature Sensor Input Channel**
- **Optional Left Adjustment for ADC Result Readout**
- **0 - V_{CC} ADC Input Voltage Range**
- **Selectable 1.1V ADC Reference Voltage**
- **Free Running or Single Conversion Mode**
- **Interrupt on ADC Conversion Complete**
- **Sleep Mode Noise Canceler**

ADC