Analog to Digital Converter

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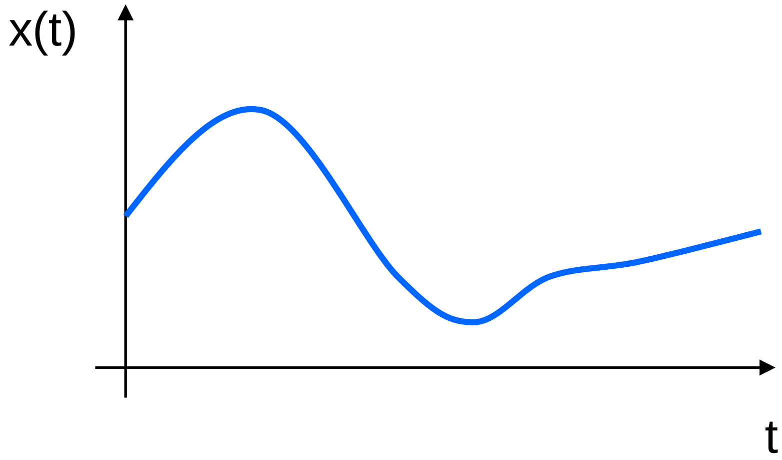
- Types of ADCs

What is ADC ?

- Definition
- Examples of use
- Conversion process
- Accuracy

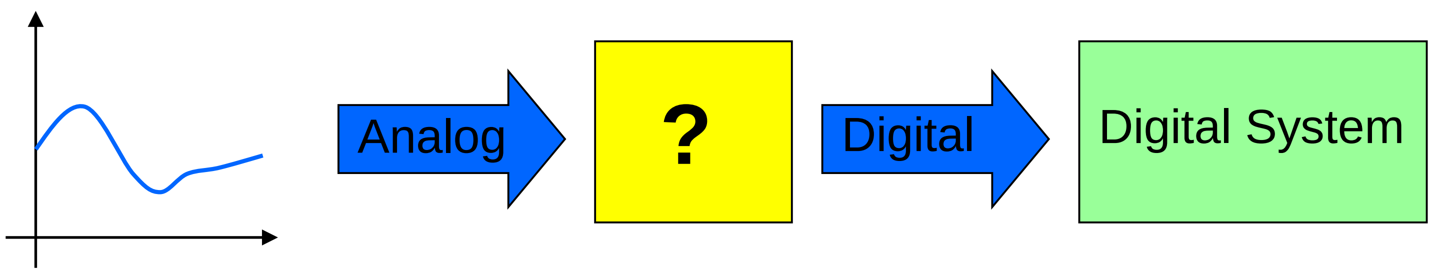
Definition

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



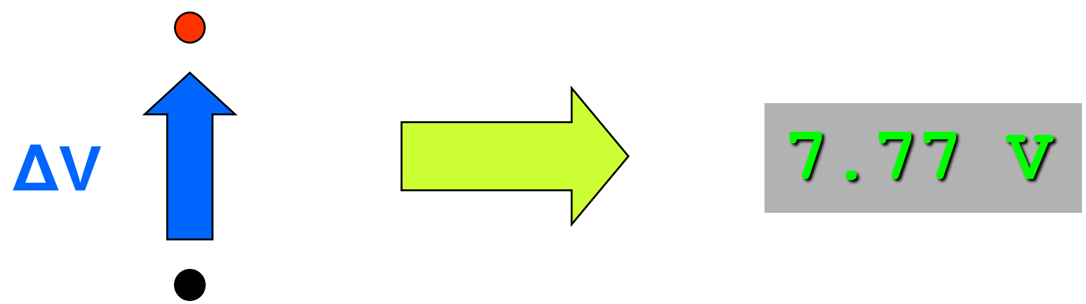
Definition

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

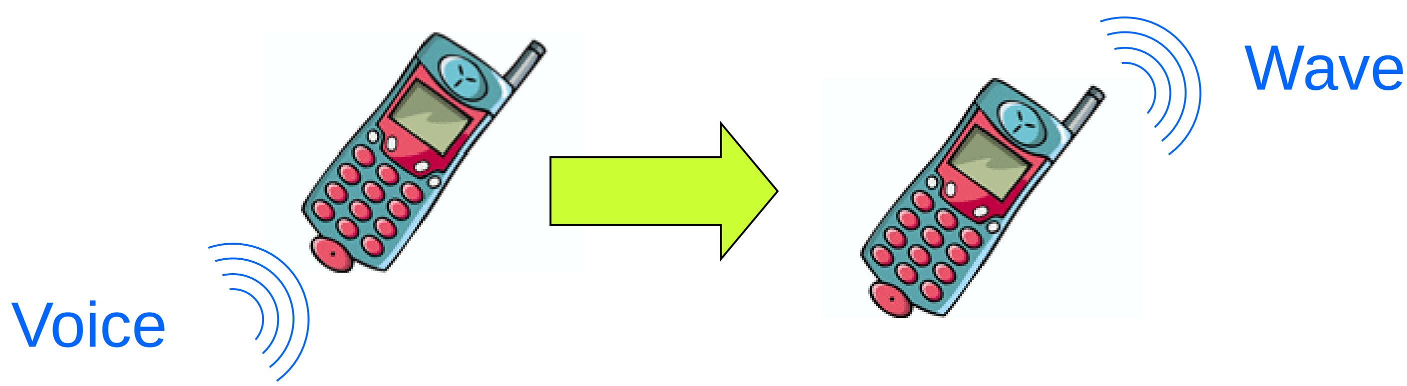


Examples of use

- Voltmeter



- Cell phone (microphone)



Conversion process

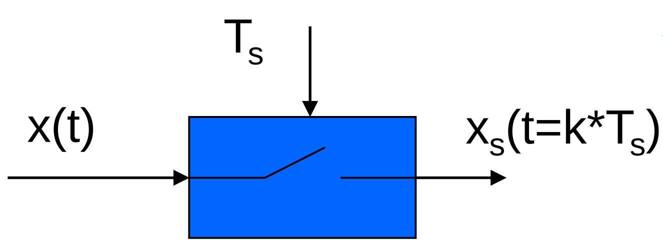
3 steps:

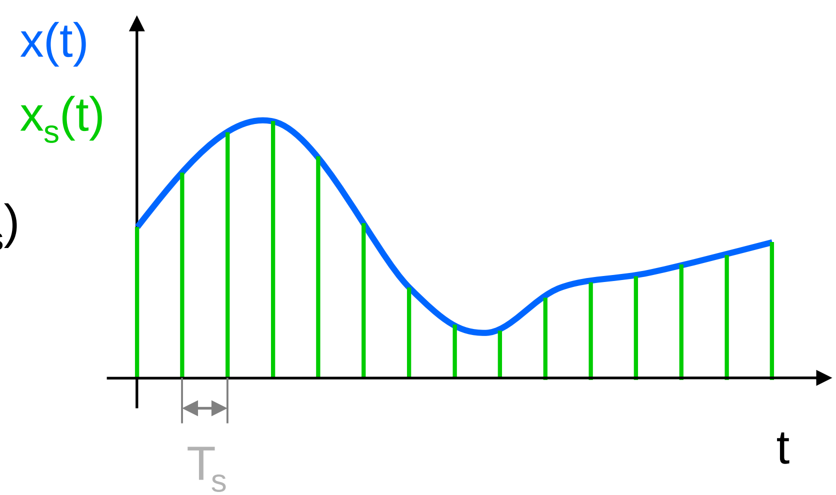
- Sampling
- Quantification
- Coding

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**)





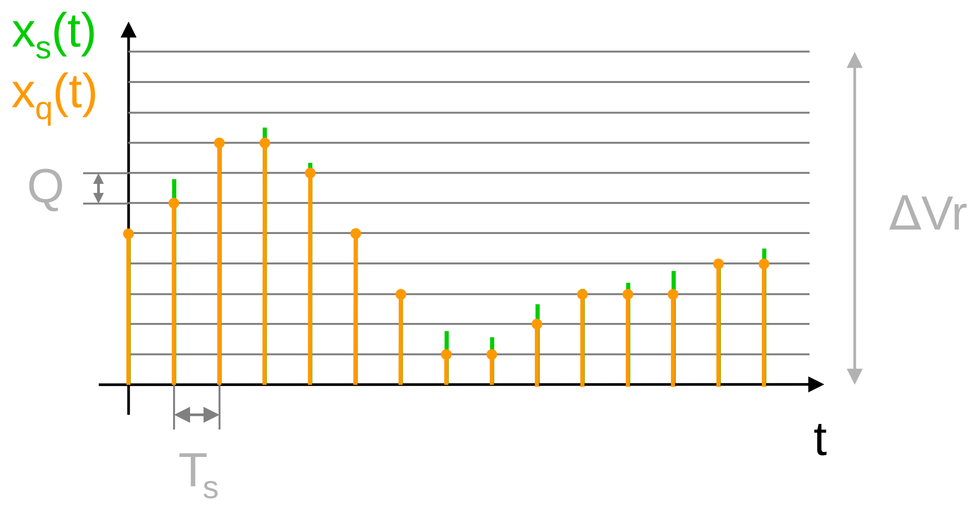
Conversion process: Quantification

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:

  $N=2^n$ where n is number of bits
- Resolution: **$Q= \Delta V_r/N$**



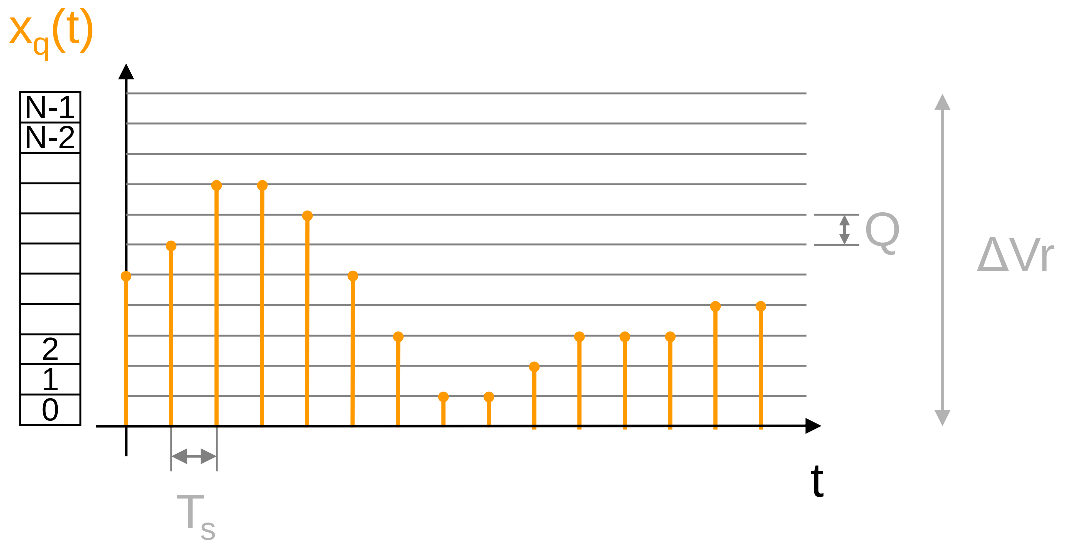
Conversion process: Coding

What is ADC ?

Types of ADCs

HC11 & ADC

- 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 increasing:

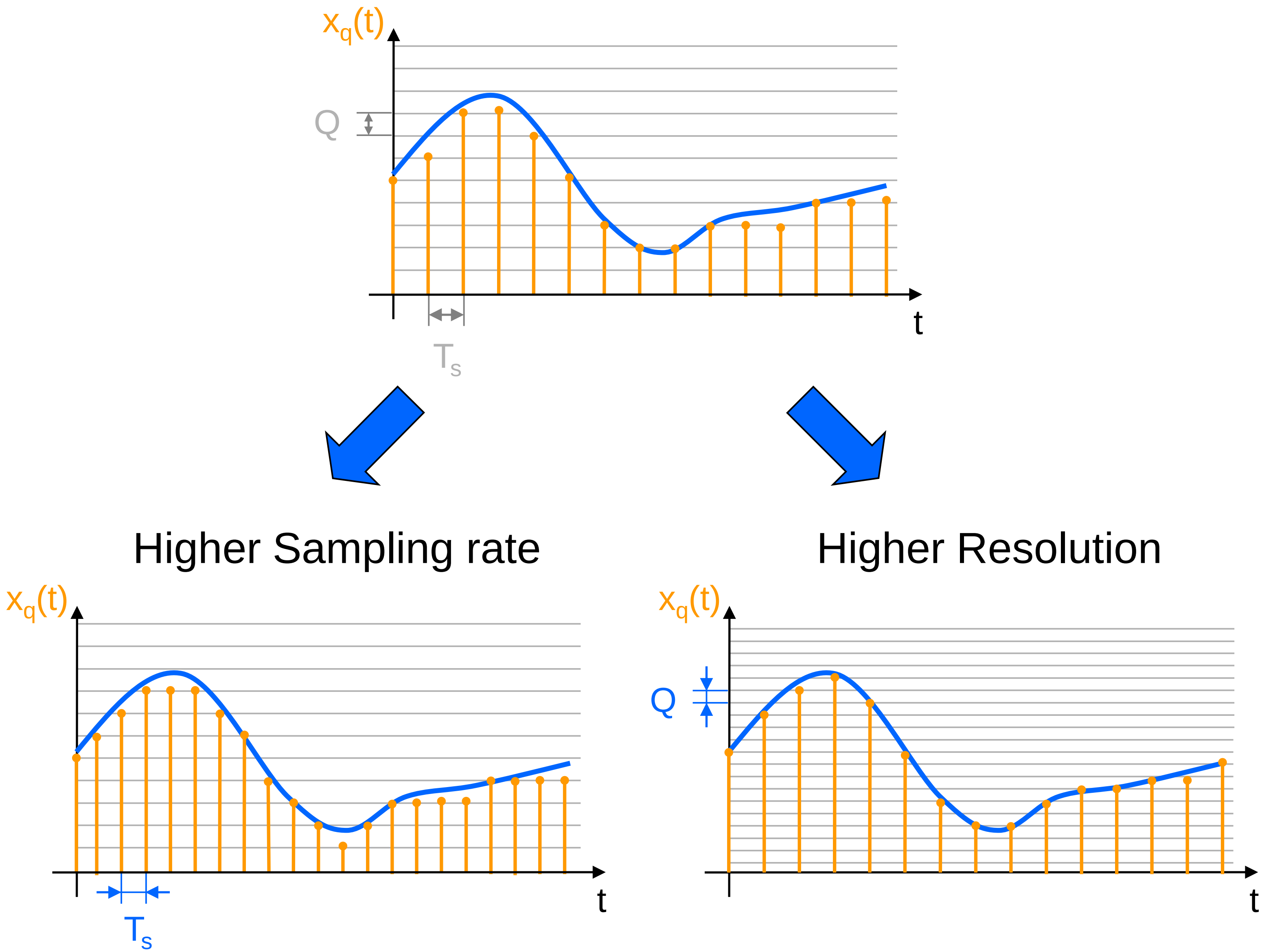
- The sampling rate (T_s)
- The resolution (Q)

What is ADC ?

Types of ADCs

HC11 & ADC

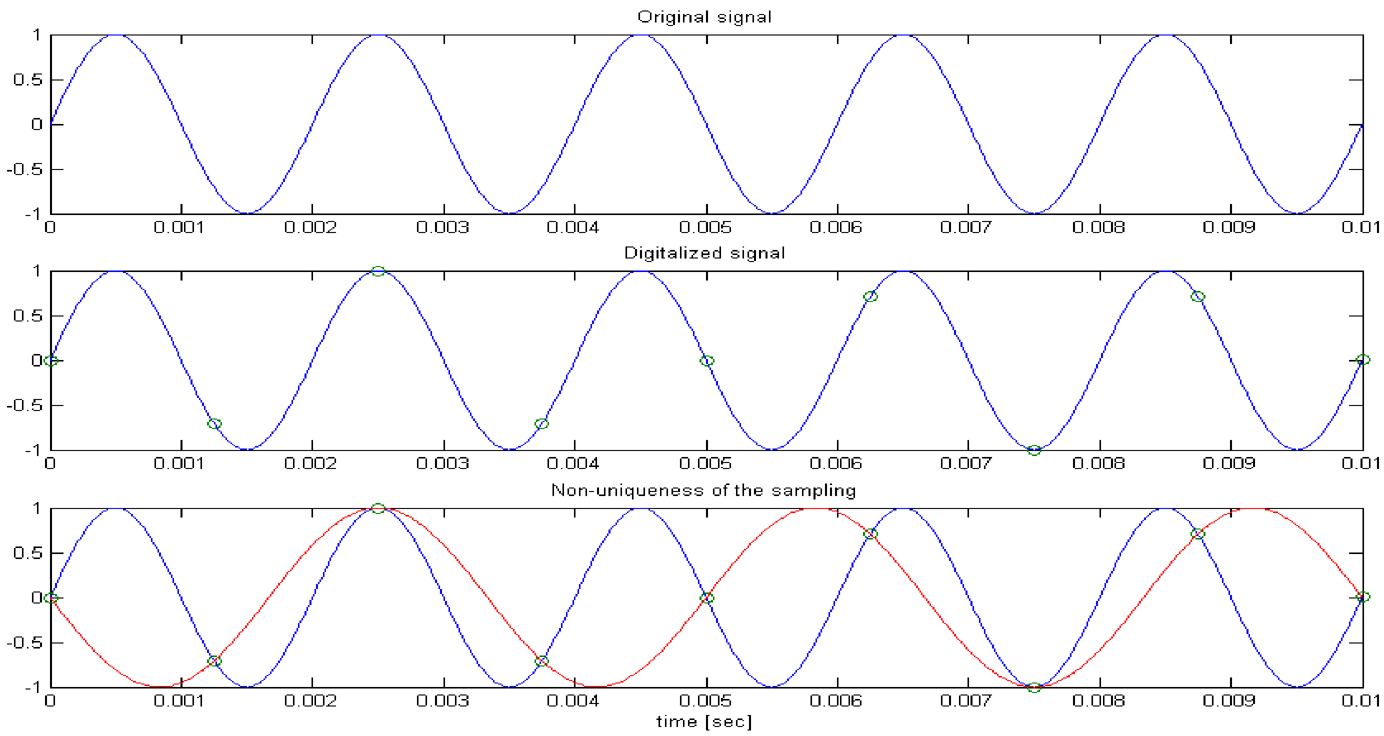
Accuracy



Sampling rate

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

$f_s > 2 * f_{max}$



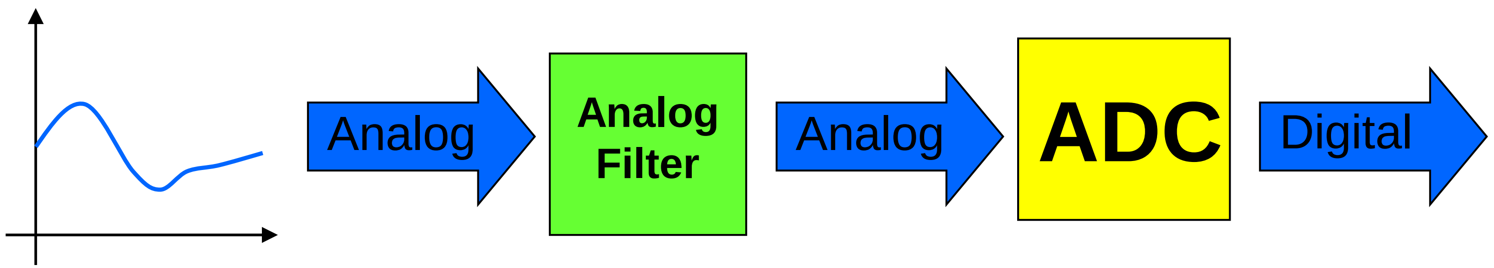
What is ADC ?

Types of ADCs

HC11 & ADC

Sampling rate

- Analog signals are composed of an infinity of harmonics
- Need to limit the frequency band to its useful part
- Use of an analog filter

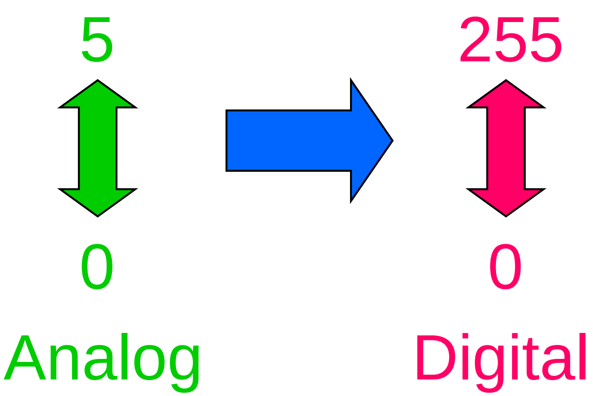


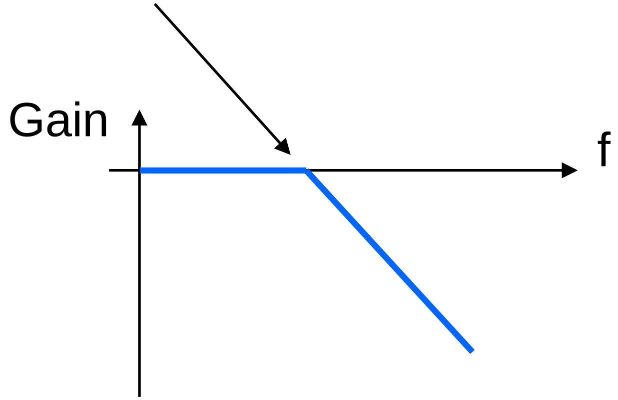
In practice: $f_s \approx (3\ldots5)_* f_{filter}$

Example

- 8 bits converter: $n=8$
- Range of conversion: $\Delta Vr=5V$
- Sampling time: $T_s=1ms$

- Number of possible states: $N=2^8=256$
- Resolution: $Q=\Delta Vr/N=19.5$ mV
- Analog Filter: $f_{filter} \approx fs/5 = 200$ Hz

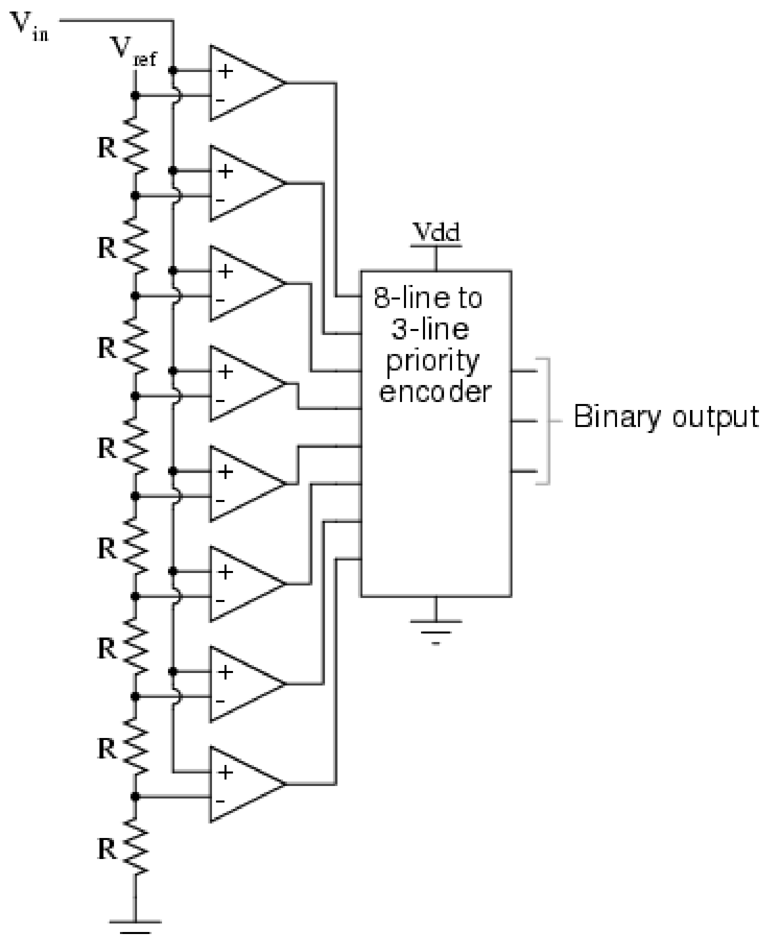




Types of ADCs

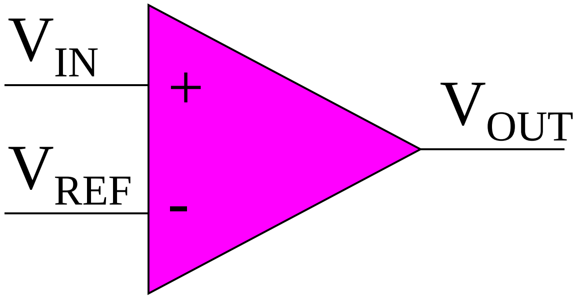
- Flash ADC
- Sigma-delta ADC
- Dual slope converter
- Successive approximation converter

Flash ADC



- "parallel A/D"
- Uses a series of comparators
- Each comparator compares V_{in} to a different reference voltage, starting w/ $V_{ref} = 1/2$ lsb

Flash ADC



Comparator is one use of an Op-Amp

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

Flash ADC

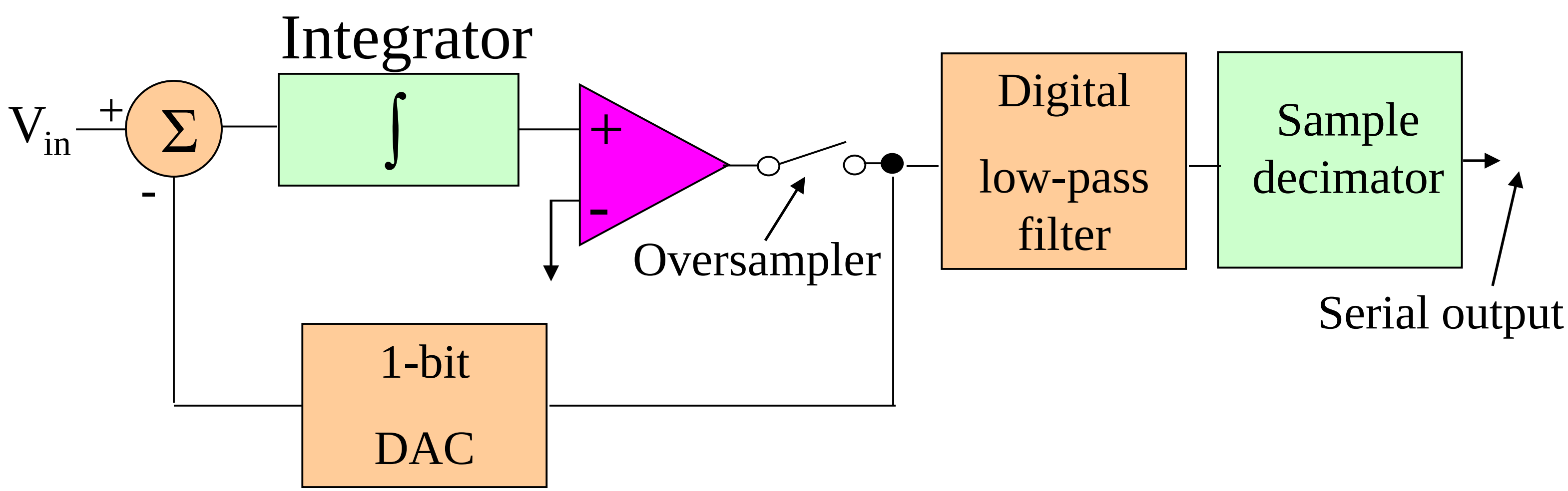
Advantages

- Very fast

Disadvantages

- Needs many parts (255 comparators for 8-bit ADC)
- Lower resolution
- Expensive
- Large power consumption

Sigma-Delta ADC



- Oversampled input signal goes in the integrator
- Output of integration is compared to GND
- Iterates to produce a serial bitstream
- Output is serial bit stream with # of 1's proportional to V_{in}

Sigma-Delta ADC

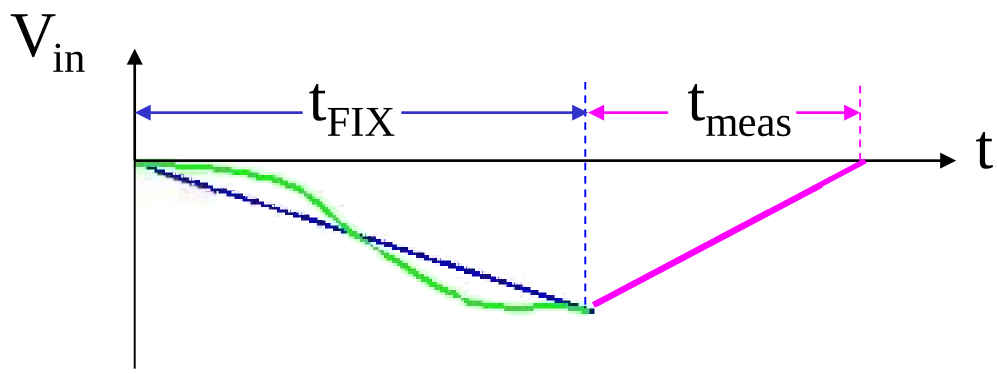
Advantages

- High resolution
- No precision external components needed

Disadvantages

- Slow due to oversampling

Dual Slope converter



- The sampled signal charges a capacitor for a fixed amount of time
- By integrating over time, noise integrates out of the conversion.
- Then the ADC discharges the capacitor at a fixed rate while a counter counts the ADC's output bits. A longer discharge time results in a higher count.

Dual Slope converter

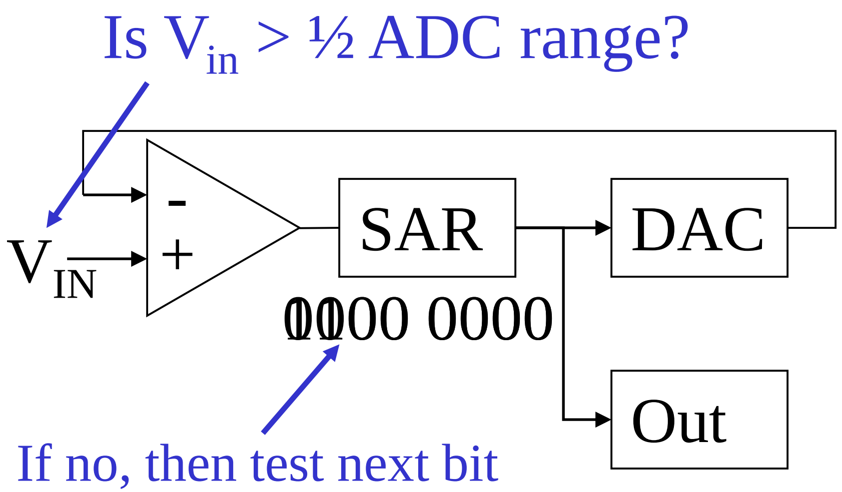
Advantages

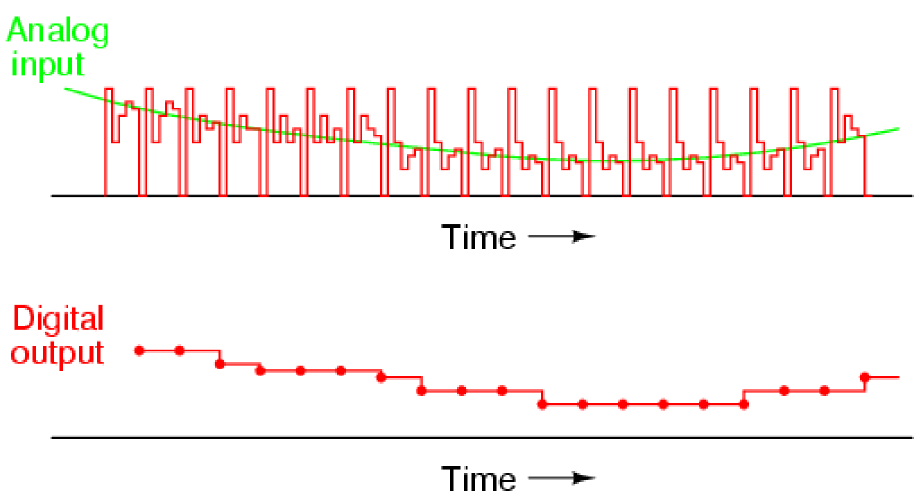
- Input signal is averaged
- Greater noise immunity than other ADC types
- High accuracy

Disadvantages

- Slow
- High precision external components required to achieve accuracy

Successive Approximation





- Sets MSB
- Converts MSB to analog using DAC
- Compares guess to input
- Set bit
- Test next bit

Successive Approximation

Advantages

- Capable of high speed
- Medium accuracy compared to other ADC types
- Good tradeoff between speed and cost

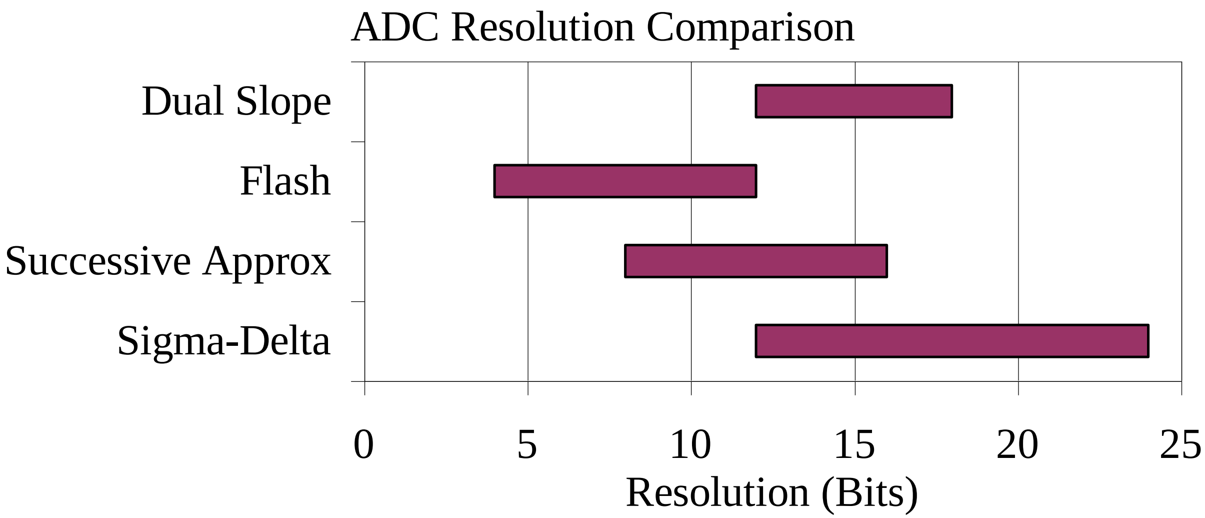
Disadvantages

- Higher resolution successive approximation ADCs will be slower
- Speed limited ~5Msps

ADC Types Comparison

What is ADC ?

Types of ADCs



Type	Speed (relative)	Cost (relative)
Dual Slope	Slow	Med
Flash	Very Fast	High
Successive Appox	Medium – Fast	Low
Sigma-Delta	Slow	Low