STM32 course

Analog-to-Digital Converter and vice versa

Outline

- PWM
- DAC
- ADC

Digital vs Analog

1) Discrete logical levels (usually two)
2) Time is also discrete in most cases
3) All active elements work in switch mode
4) There is no finite spectrum

1) Continuous range of values
2) Continuous time
3) Active elements work in linear mode
4) There is finite spectrum

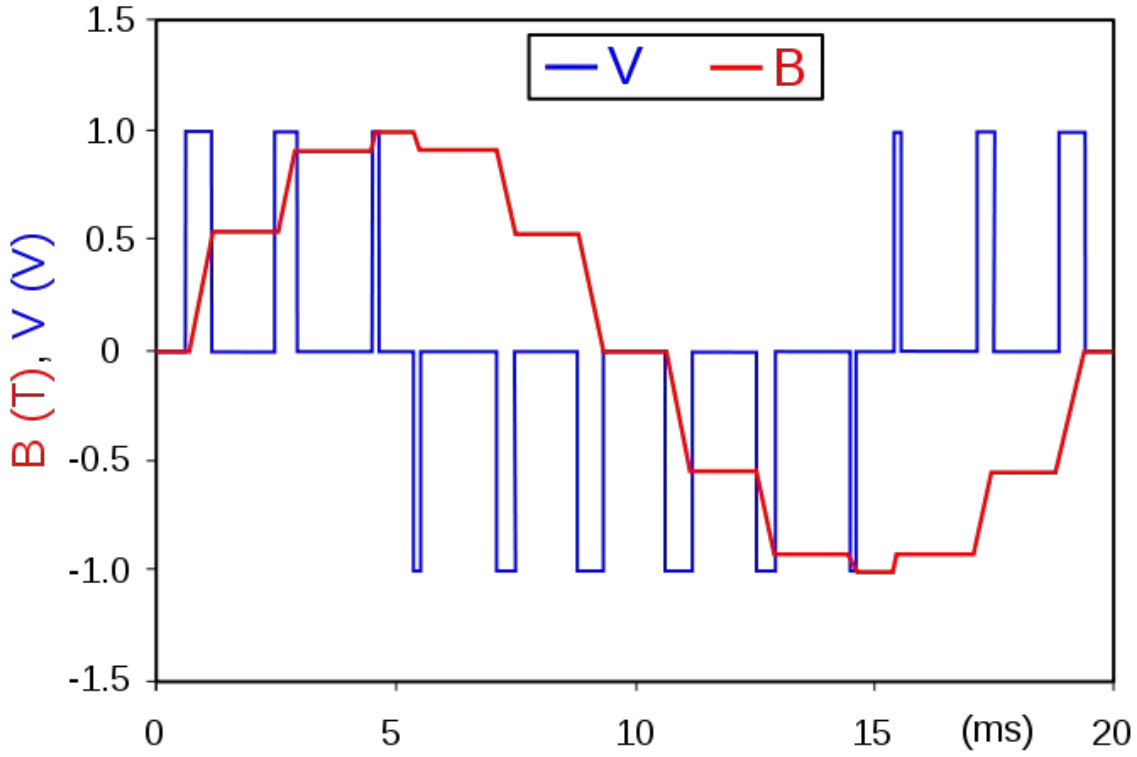
Digital to Analog Conversion

1) Time-based (sequential)
   a) PWM (Pulse Width Modulation)
   b) Delta-sigma Modulation
2) Level-based (parallel)
   a) Binary-weighted DAC
   b) Ladder DAC

PWM

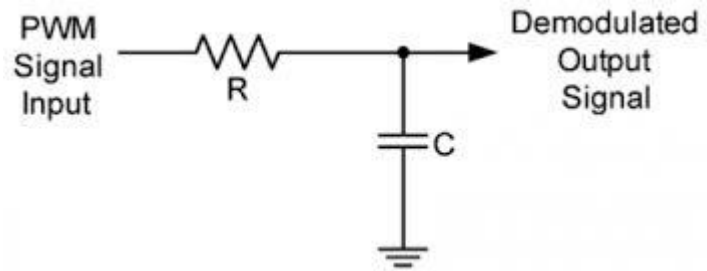
- General idea is to convert variable (but discrete!) time period to a certain voltage level
- The simplest way to do it is integration

PWM

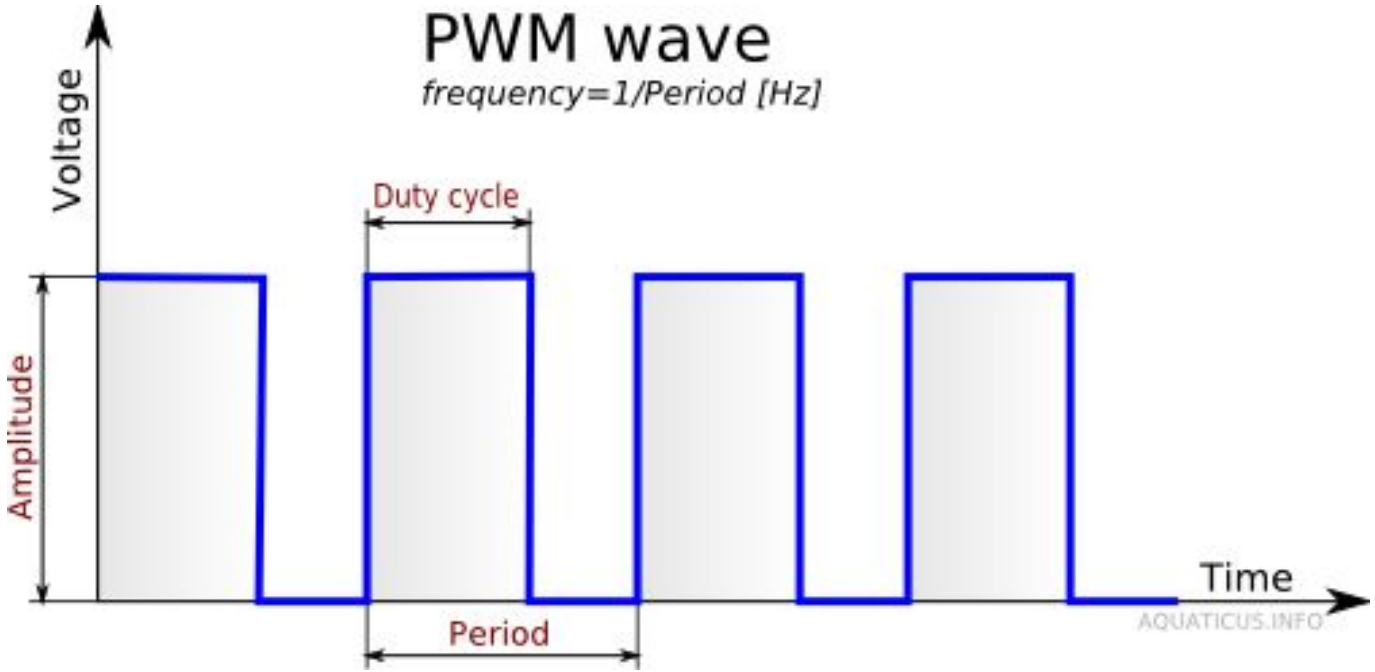


PWM

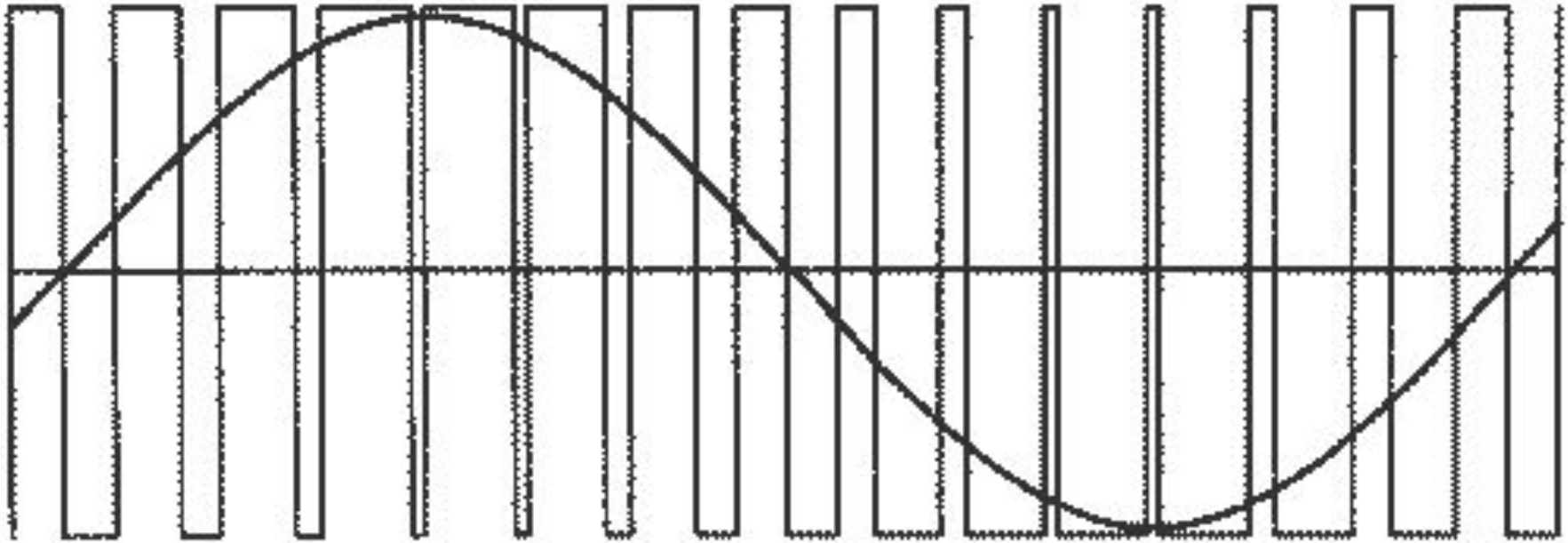
- Two main problems:
  - It is hard to construct an ideal integrator (due to resistance of the load)
  - It demands positive and negative logical levels
- The solution -- time proportioning control
- We can change duty cycle and filter the signal with common low-pass filter



PWM

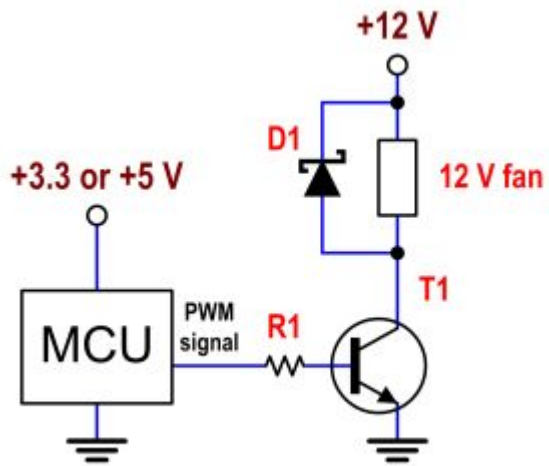

PWM wave
frequency=1/Period [Hz]
Voltage
Duty cycle
Amplitude
Time
Period
AQUATICUS.INFO

PWM



Switch Mode

1) P = U*I (U = 12, I = 0) in case logic 0
2) P = U*I (U = 0, I = Imax) in case logic 1



PWM

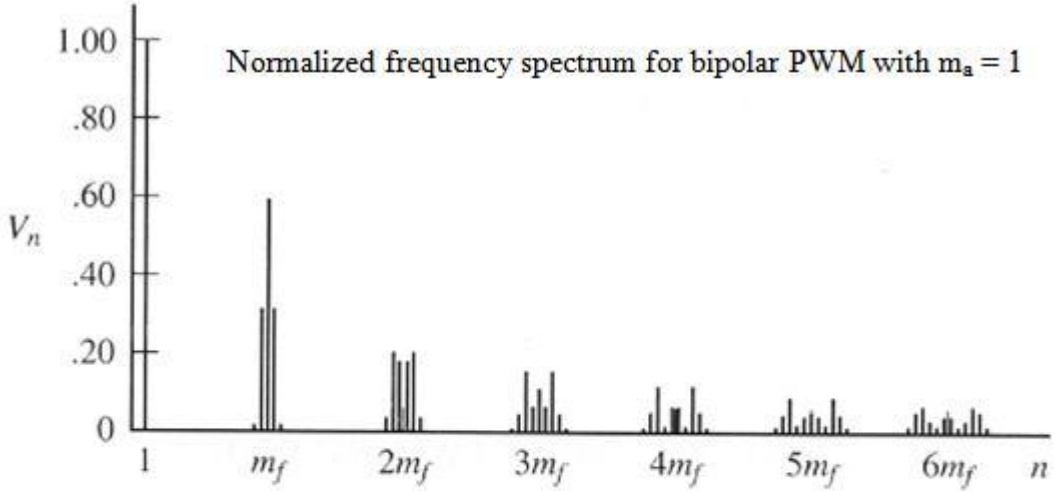


TABLE 8.3 NORMALIZED FOURIER COEFFICIENTS V_n/V_{dc} FOR BIPOLAR PWM

	$m_a = 1$	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
$n = 1$	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
$n = m_f$	0.60	0.71	0.82	0.92	1.01	1.08	1.15	1.20	1.24	1.27
$n = m_f \pm 2$	0.32	0.27	0.22	0.17	0.13	0.09	0.06	0.03	0.02	0.00

PWM

Pros:

- Easy to implement
- It takes only one pin
- In some applications (like motors) you don’t even need a filter
- Switch mode

Cons:

- Due to discrete time, to get fine levelling frequency should be seriously decreased
- Filters are not perfect and you have a lot of high-frequency noise

Binary Weighted DAC

- General idea is to map each bit of digital register to analog value and sum them
- The simplest way to do it is a resistor based ladder

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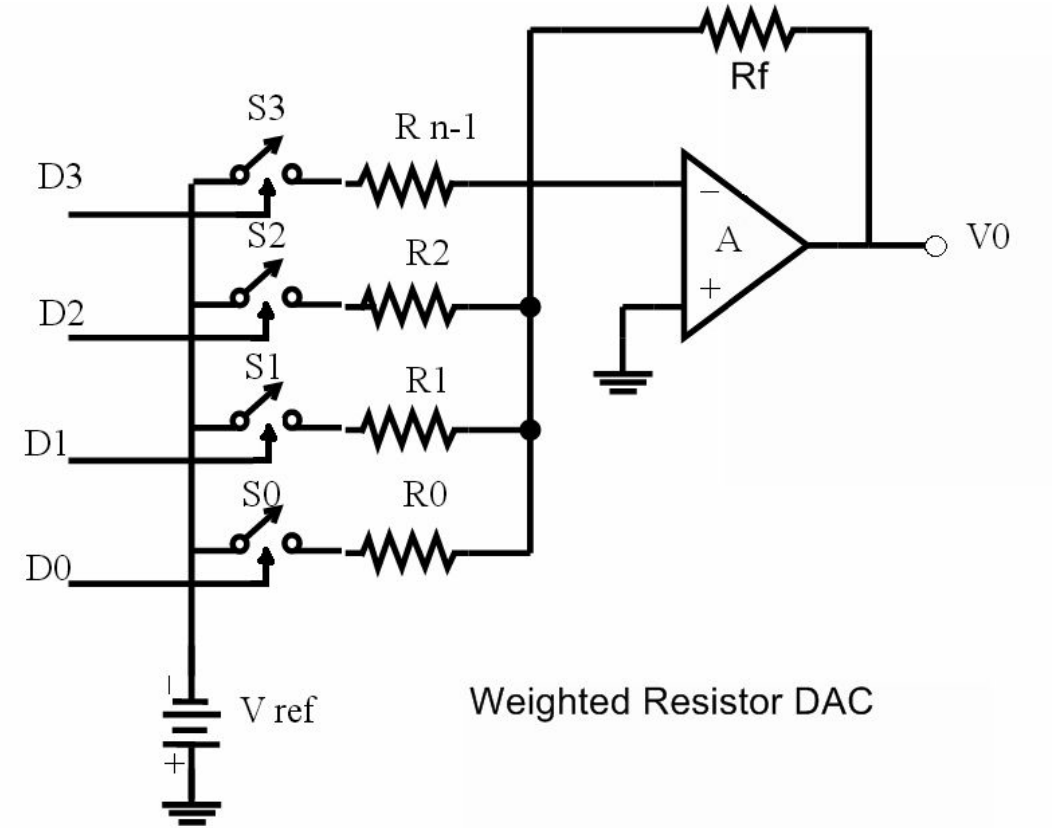
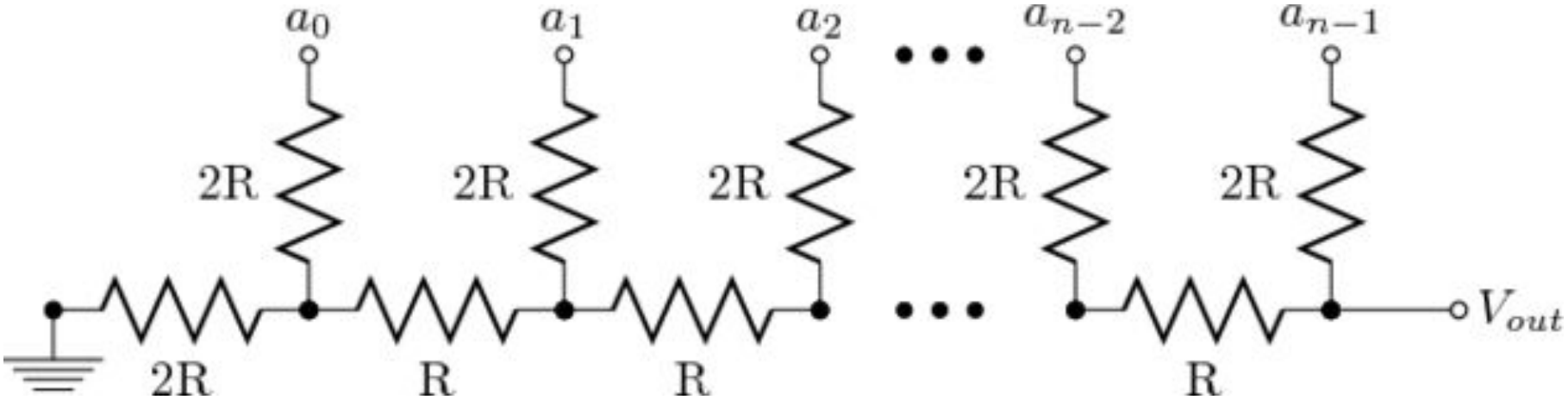
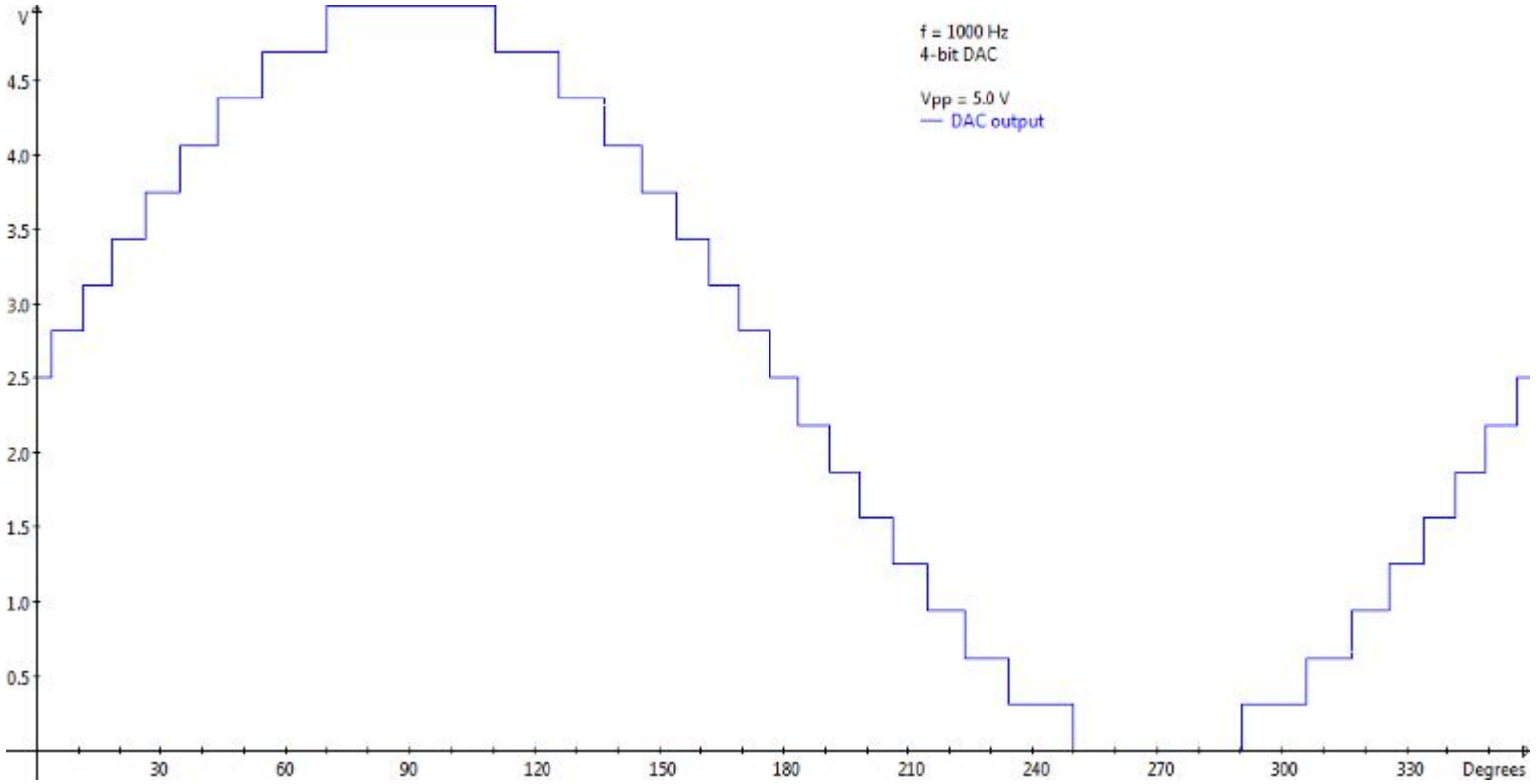


R2-R ladder



R2-R Ladder


V
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f = 1000 Hz
4-bit DAC
Vpp = 5.0 V
DAC output
30
60
90
120
150
180
210
240
270
300
330
Degrees

R2-R Ladder

Pros:

- MUCH higher frequency
- Less noises (but still need a filter)
- Precision doesn’t depend on frequency

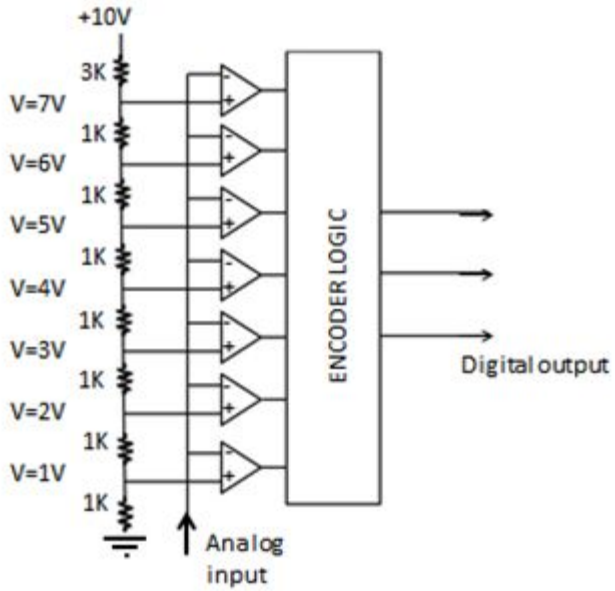
Cons:

- Without external devices takes n pins
- Precision depends on resistors quality (it’s better to use 1% resistors)
- Signal must be amplified
- Usually, n <= 8 bit.

Analog to Digital Conversion

Methods are the same!

Direct Conversion ADC



Direct Conversion ADC

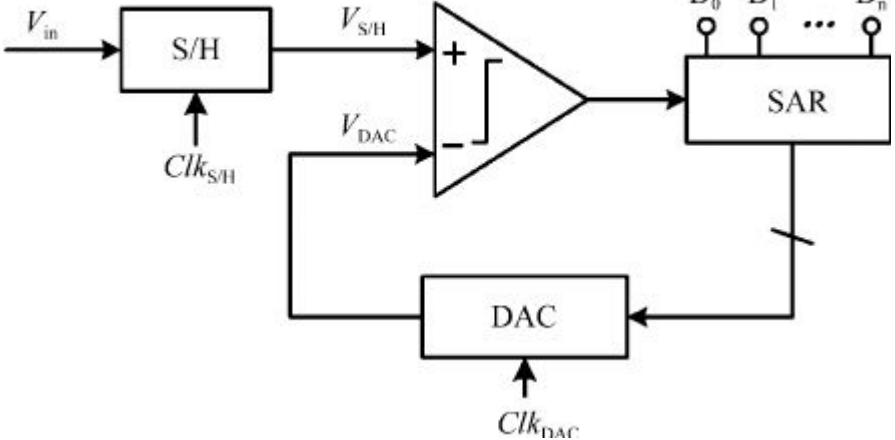
Pros:

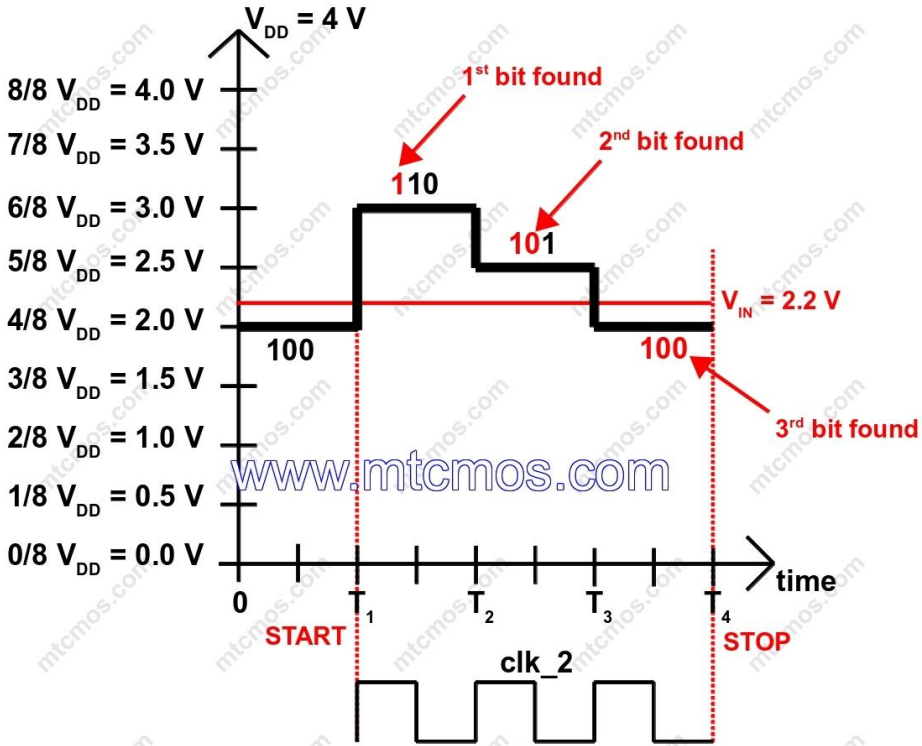
- The highest sampling rate (up to 1GSPS)
- There is no output noise

Cons:

- Expensive
- 6-8 bit

SAR ADC


V_{in}
S/H
$V_{S/H}$
V_{DAC}
$Clk_{S/H}$
D_0 D_1 ... D_n
SAR
DAC
Clk_{DAC}


V_{DD} = 4 V
8/8 V_{DD} = 4.0 V
7/8 V_{DD} = 3.5 V
6/8 V_{DD} = 3.0 V
5/8 V_{DD} = 2.5 V
4/8 V_{DD} = 2.0 V
3/8 V_{DD} = 1.5 V
2/8 V_{DD} = 1.0 V
1/8 V_{DD} = 0.5 V
0/8 V_{DD} = 0.0 V
1st bit found
2nd bit found
3rd bit found
110
101
100
100
V_{IN} = 2.2 V
time
0
T_1
T_2
T_3
T_4
START
STOP
clk_2
www.mtcmos.com

SAR ADC

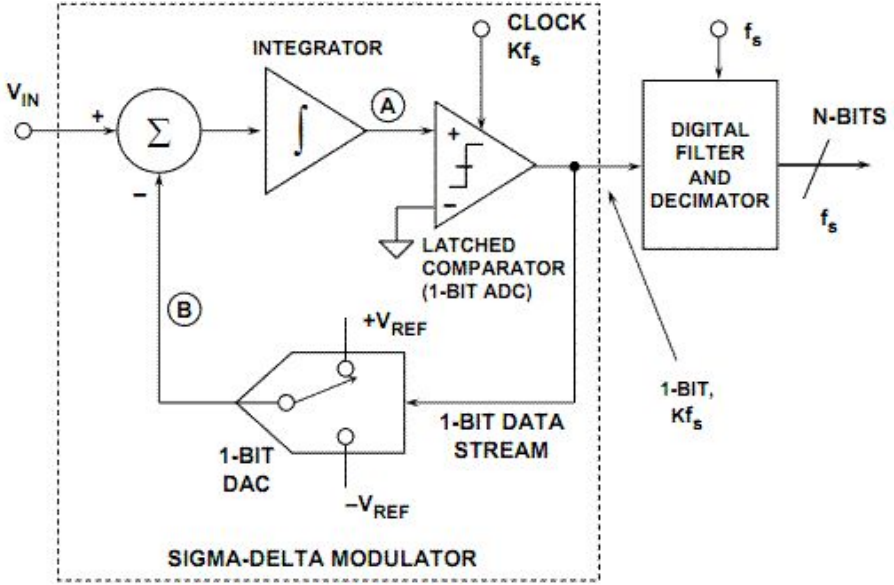
Pros:

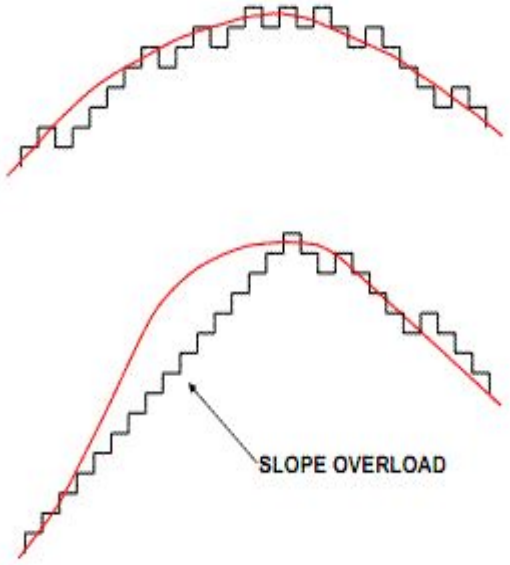
- Good resolution
- Cheap

Cons:

- Low frequency
- Noise

Sigma-Delta ADC





http://www.analog.com/en/design-center/interactive-design-tools/sigma-delta-adc-tutorial.html

Sigma-Delta ADC

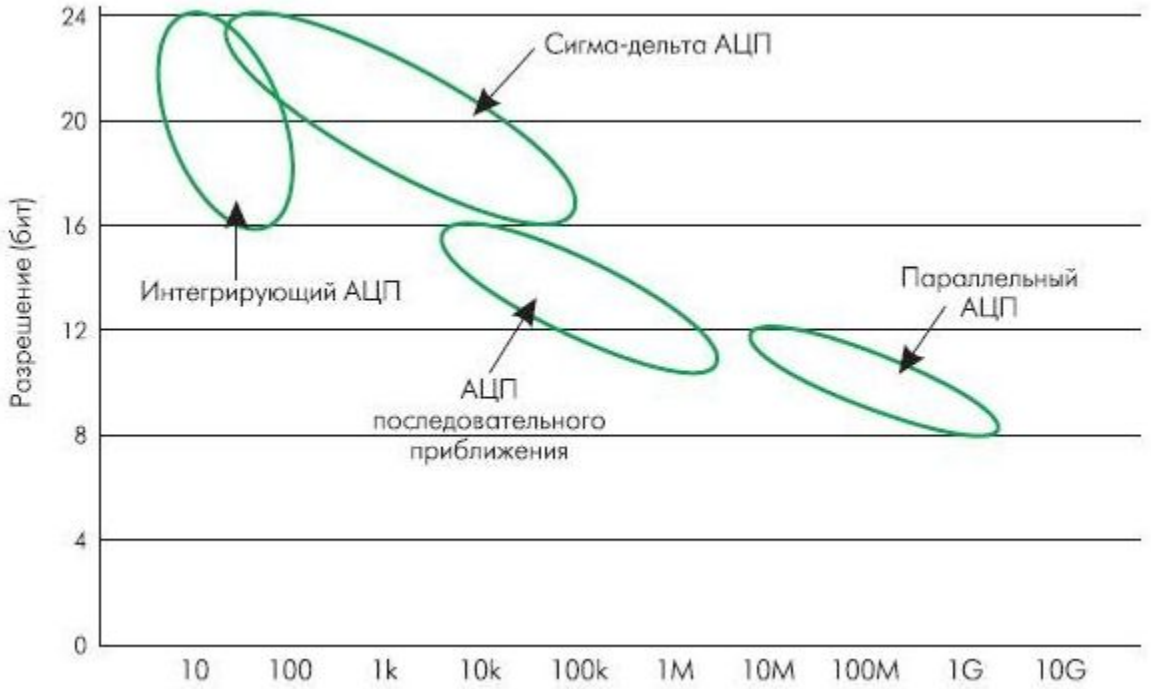
Pros:

- Good resolution
- Fast
- Low noise

Cons:

- Expensive

How to choose?



QUESTIONS?