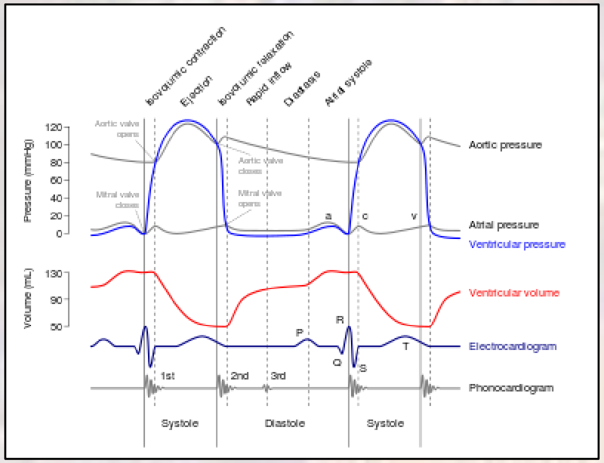
Analog to Digital Converter - Basics

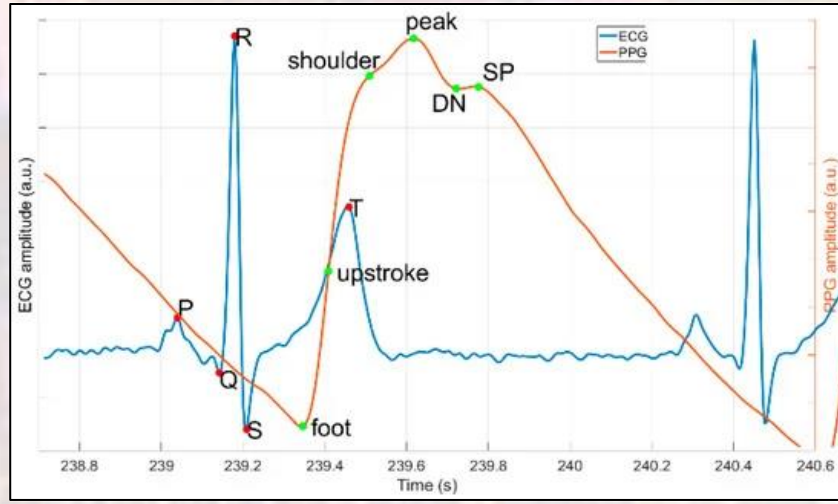
Last updated 5/12/21

ADC Basics

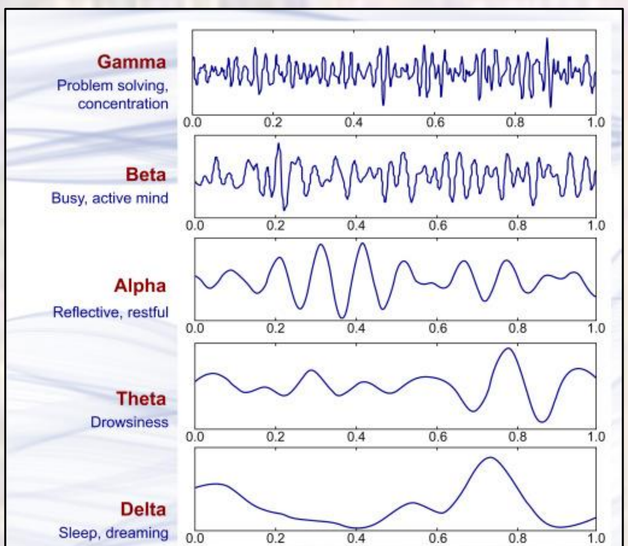
Wiggers Diagram



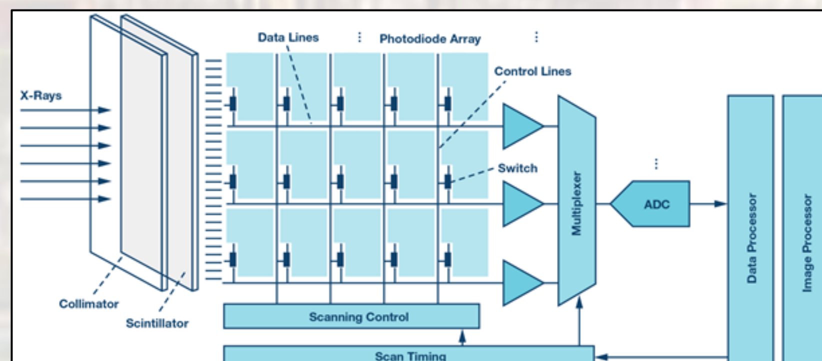
ECG



Brain Waves



X-Rays



ADC Basics

- Analog to Digital Conversion

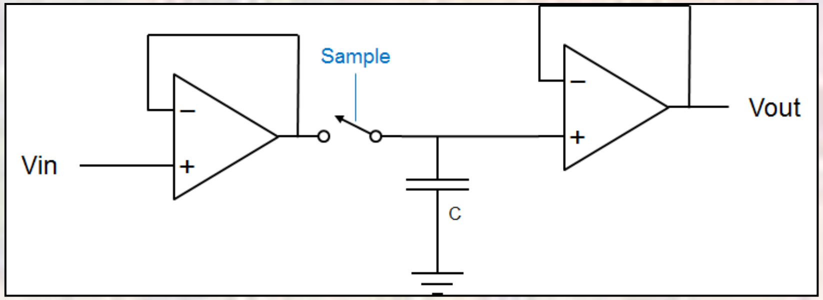
  - Most of the real world is analog
    - temperature, pressure, voltage, current, …

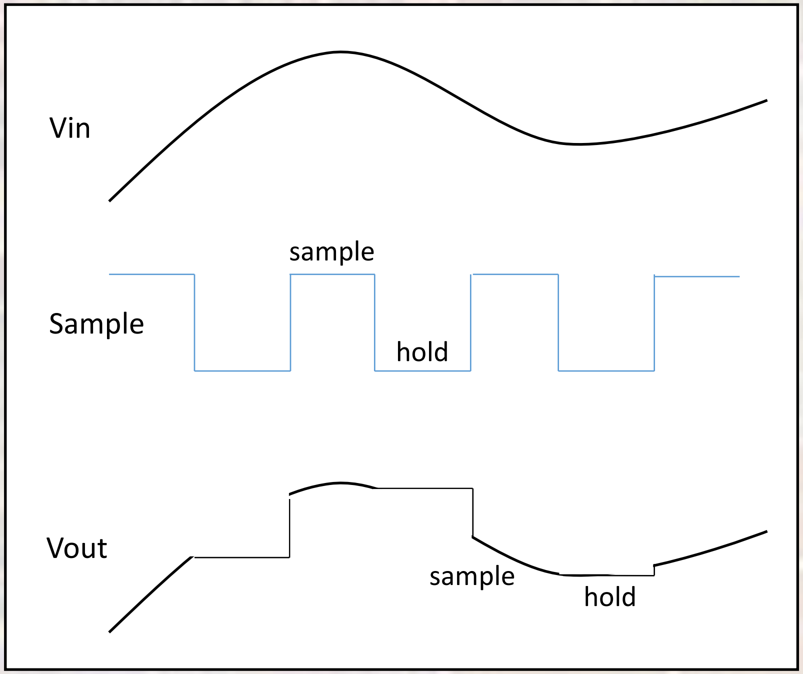
  - To work with these values in a computer we must convert them into digital representations

  - Three steps to this conversion
    - Sampling
    - Quantizing
    - Encoding

ADC Basics

- Sampling
  - A to D Conversion takes a finite amount of time
  - What if the input changes during this time?
  - We must take a snapshot of the input → Sample and Hold



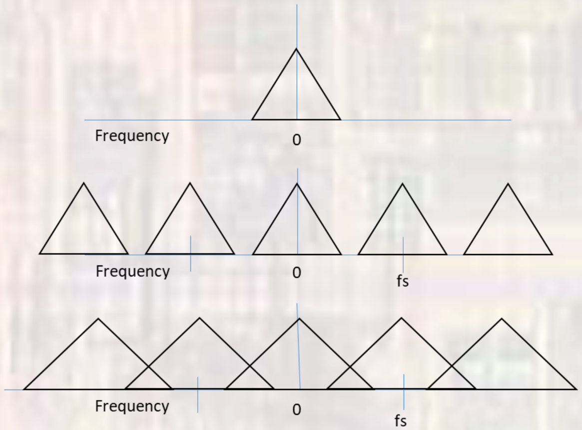


ADC Basics

- Sampling

  - Sampling is a kind of MODULATION
  - Modulation systems are subject to corruption called Aliasing

  - $f_{in} < f_s/2$
    - f_{in} – input signal maximum frequency
    - f_s – sampling frequency
      - Nyquist Rate = required sampling frequency

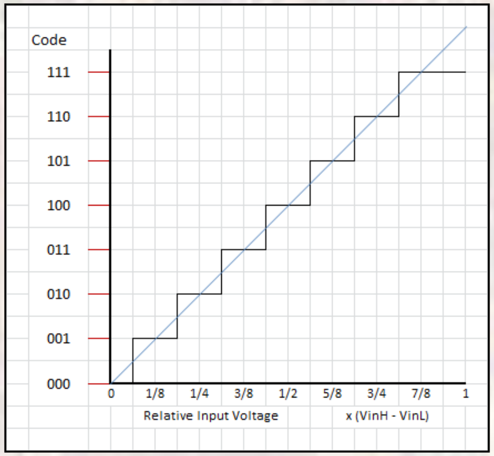


→ LPF the input (anti-aliasing filter)

ADC Basics

- Quantizing
  - In the A to D process, we are converting an "infinite" resolution analog signal into a finite number of digital bits
  - Converters use reference voltages to set the range of allowed input voltages - Vref-H , Vref-L
    - Each binary step represents

      $(V_{ref\text{-}H} – V_{ref\text{-}L}) / 2^n$ for an n bit conversion



  - The difference (error) between the original analog signal and the digital equivalent is called quantization error
  - This error looks like noise in the system

ADC Basics

- Encoding
  - The digital result of the A/D conversion can be encoded (represented) in many ways.
    - Thermometer code
      - N bits for N levels

Decimal	Thermometer code						
	D1	D2	D3	D4	D5	D6	D7
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1
2	0	0	0	0	0	1	1
3	0	0	0	0	1	1	1
4	0	0	0	1	1	1	1
5	0	0	1	1	1	1	1
6	0	1	1	1	1	1	1
7	1	1	1	1	1	1	1

    - Binary code
      - $\log_2 N$ bits for N levels

Decimal	Binary		
	A0	A1	A2
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

ADC Basics

- A/D Conversion Example 1
- 10 bit converter with VrefH=3.0V, VrefL=0.0V
- If the input is 2V, what is the output code?

VrefH-VrefL = 3V range

10 bit converter step size = range/2^{10} = 2.9297mV/step

2V / 2.9297mV/step = 682 steps from VrefL

10 1010 1010

ADC Basics

- A/D Conversion Example 2
- 8 bit converter with VrefH=5.0V, VrefL=0.0V
- If the output code is 0x22, what was the input voltage?

VrefH-VrefL = 5V range

8 bit converter step size = range/2^8 = 19.5mV/step

0x22 → 34 steps → ~0.664V

remember – there is always some error

ADC Basics

- Types of A/D converters

  - Successive Approximation (SAR) ADC
    - Most common – moderate speed and resolution
  - Delta-sigma ($\Delta\Sigma$) ADC
    - Best resolution
  - Dual Slope ADC
  - Pipelined ADC
  - Flash ADC
    - Fastest