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کامپیوتر

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Internet of Things

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Introduction to ADC & PWM

Analog to Digital Converter (ADC)

What is ADC?

- ADC stands for Analog to Digital Converter, which converts the analog signal into the digital signal.
- ADC is an essential part of our life and by some or other way we are using in our day to day life.

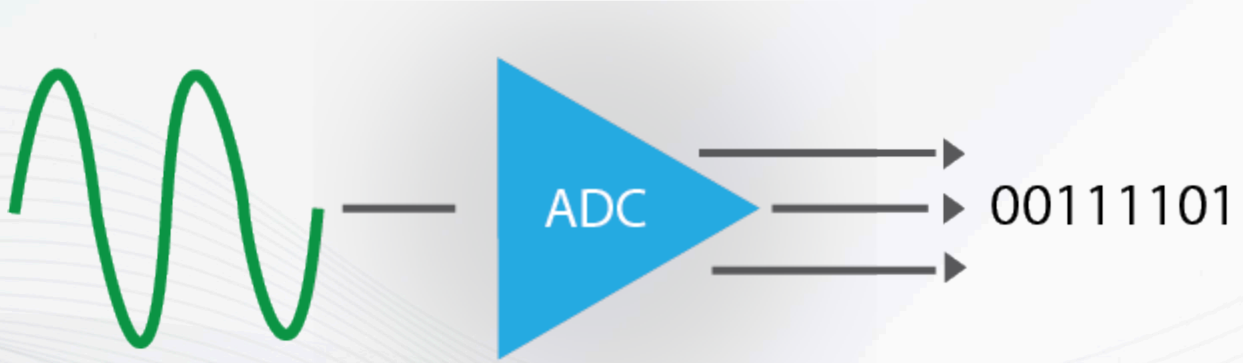

Figure1: ADC Diagram

[3] Fundamental Concepts and Key Architecture, Communication Networks

Why we use ADC?

- Everything in the physical world is an analog signal. Most of the naturally occurring signals are analog in nature.
  - Sound, Light, Temperature, Pressure, Velocity
- The analog signals are susceptible to noise and difficult to store and process. But the digital domain is easy to store and process these signals.
- That's why for storage and processing signals are converted into digital form and it is retrieved using DAC.

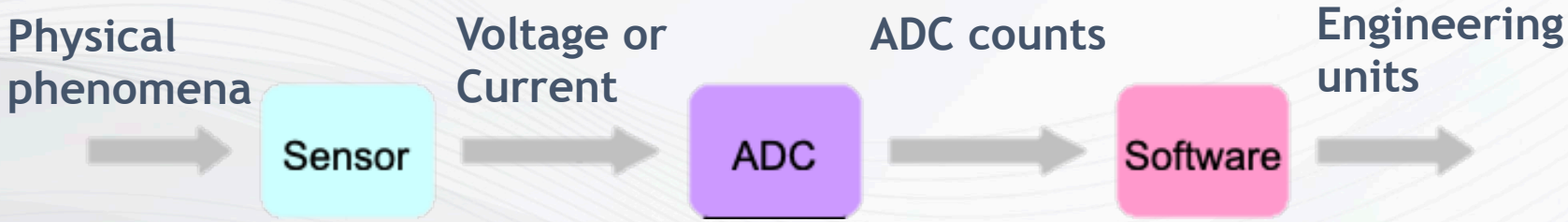

Figure2: [1]

[1] EECS 373 Design of Microprocessor-Based Systems

Steps involved for the analog to digital conversion

1. Sampling (Nyquist Theorem)
    - Represent some fraction within the range of values
    - Nyquist Theorem: fs >= 2 * fmax
2. Hold
    - Holds the sample amplitude until the next sample is taken.
3. Quantization
    - It is the process of assigning a sampled signal a value from the discrete set of values
4. Encoding
    - Convert to bits

[3] Fundamental Concepts and Key Architecture, Communication Networks
https://www.elprocus.com/analog-to-digital-converter/

Block Diagram of ADC

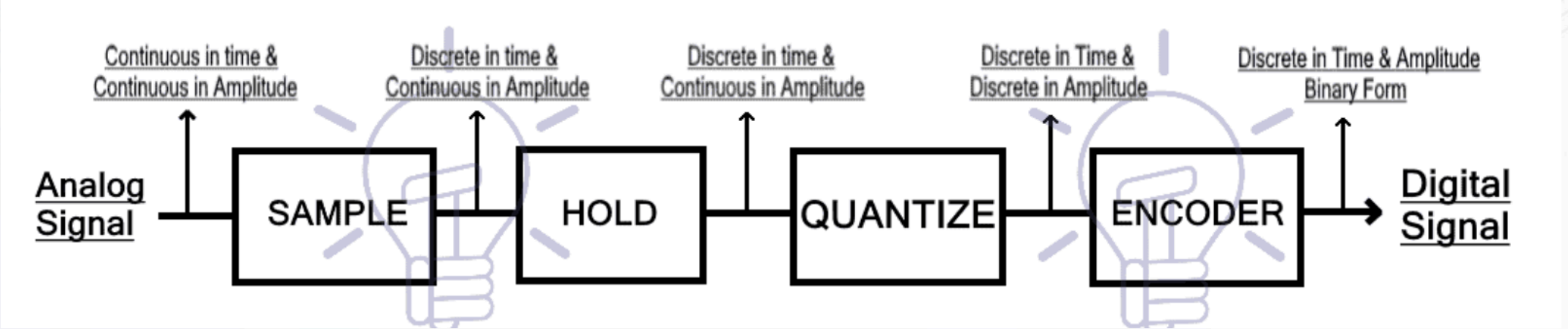

Figure3: ADC block diagram

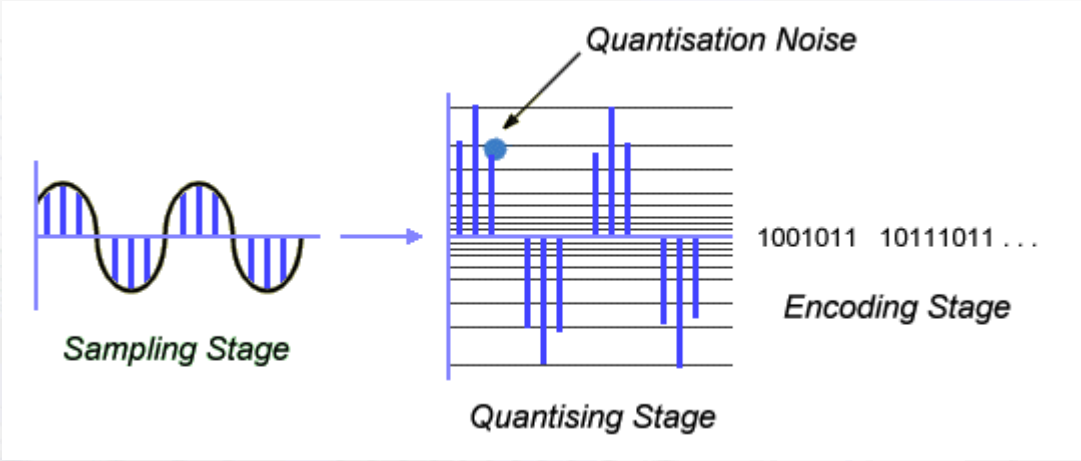

Figure4: Steps in ADC

Sampling

- The image below shows a sample rate which is too slow for the changes in the analog signal. In the latter half of the signal mapping, especially, the digital signal fails to accurately reproduce the analog one because the analog signal experiences rapid amplitude changes between samples. By doubling the sample rate, the digital signal would begin to look much more like the original analog one. (Nyquist)

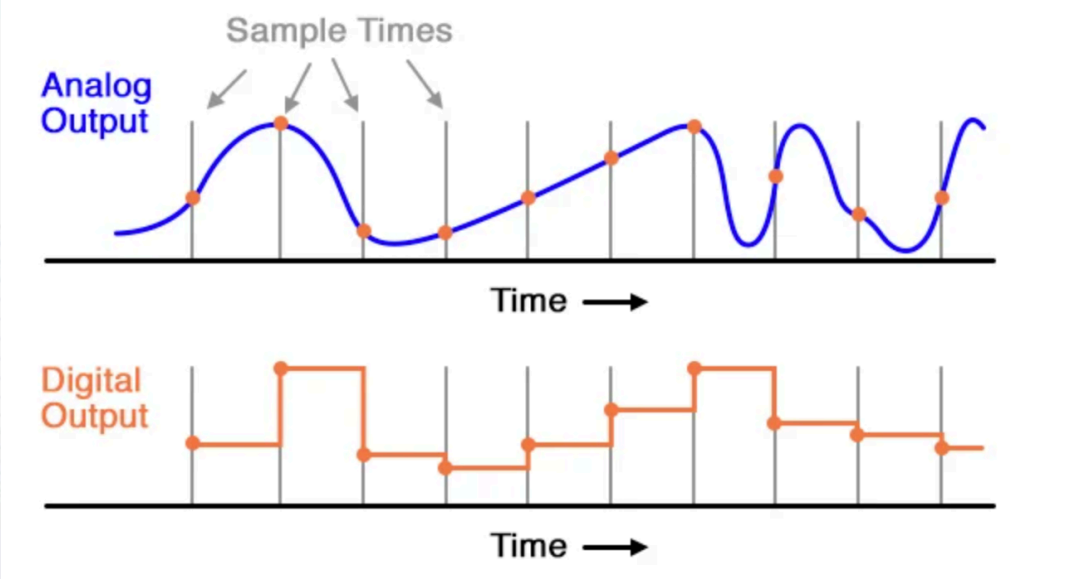

Figure5: Sample Rate

https://www.globalspec.com/learnmore/data_acquisition_signal_conditioning/

Shannon-Nyquist sampling theorem

- Nyquist Theorem: fs >= 2 * fmax

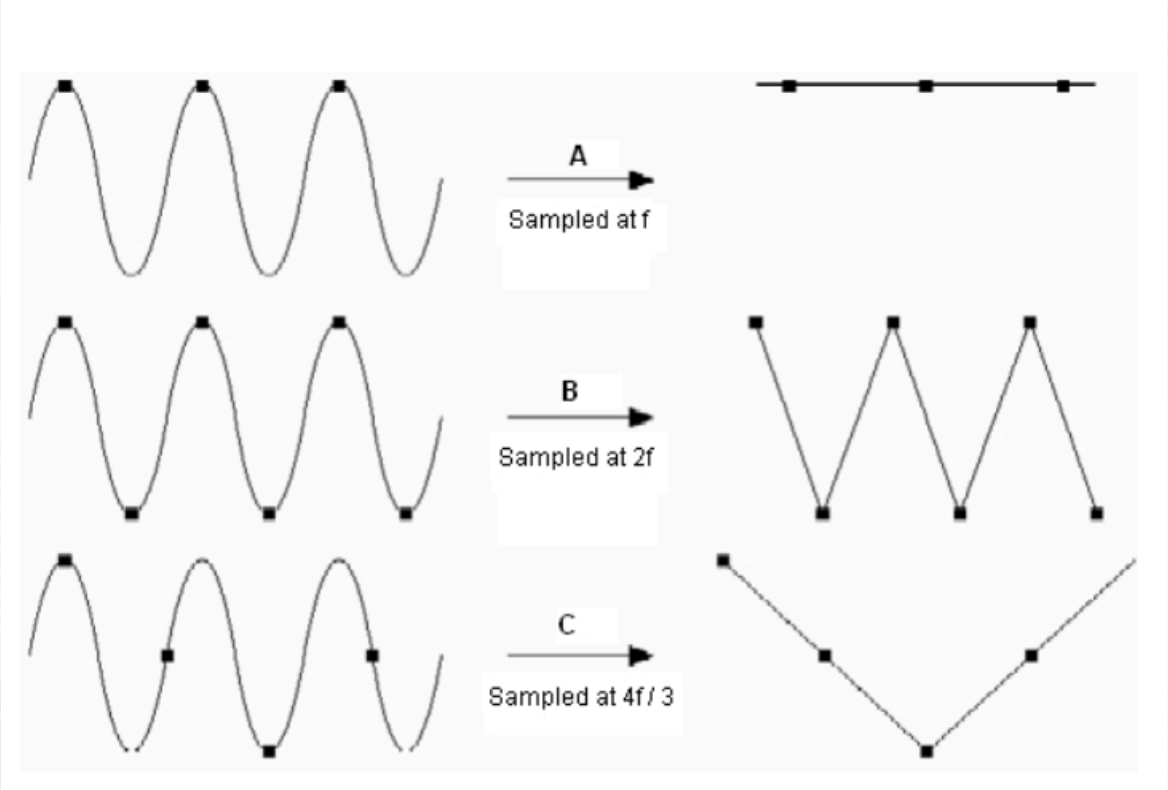

Figure6: Sample rate effects

[3] Fundamental Concepts and Key Architecture, Communication Networks

Resolution

- Number of discrete values that represent a range of analog values (No. of Bits)
- $\text{step} = \frac{Full\ Scale\ Range\ (FSR)}{2^{(No.of\ bits)}} = \frac{Vmax - Vmin}{2^{(No.of\ bits)}}$
- Larger Range → Less information

Quantization Error

- How far off discrete value is from actual
- ½ LSB → Range / 2 * $2^{(No.of\ bits)}$
- Larger Range → Larger Error

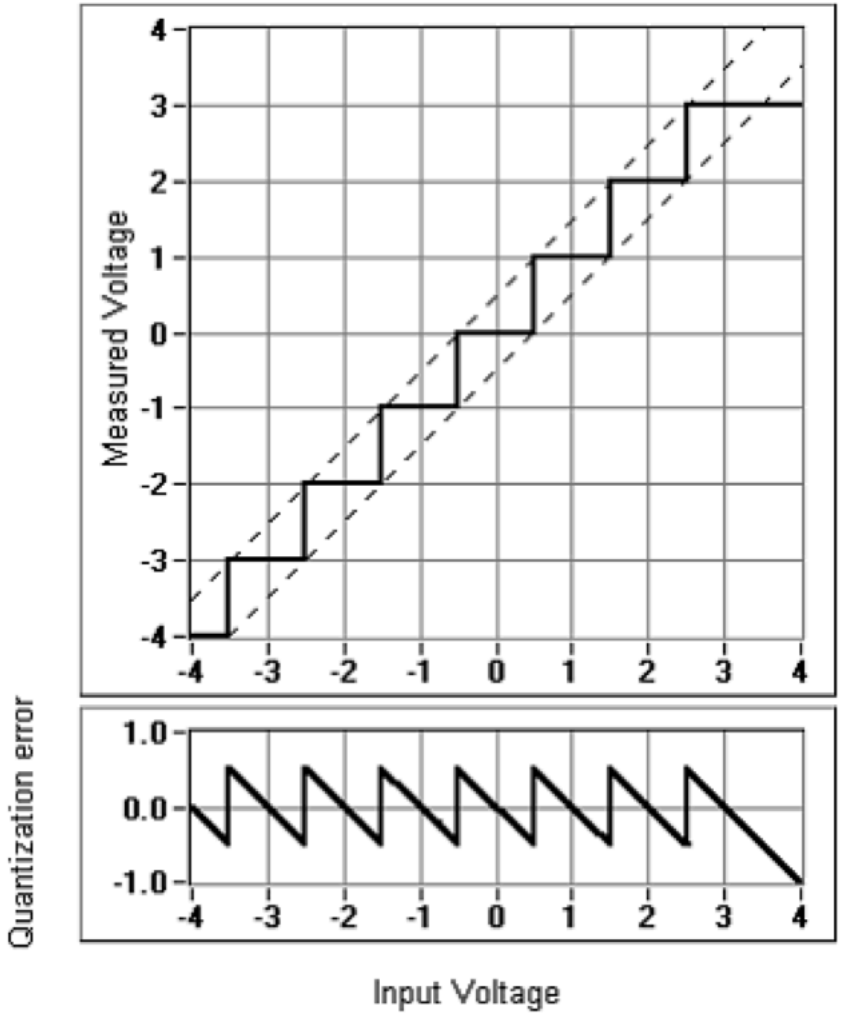

Figure7: [1]

[1] EECS 373 Design of Microprocessor-Based Systems
[2] Analog-to-digital converter survey and analysis

Pulse With Modulation (PWM)

What is Pulse With Modulation?

- It is a modulation technique where changing the width of the digital control signal, the power delivered to any load is controlled.
- PWM is a way to control analog devices with a digital output
- This technique is used in a wide range of applications because of:
  - Its precise control over the controlled parameter
  - Low power loss
  - High efficiency

[5] Use of PWM Techniques for Power Quality Improvement
https://www.analogictips.com/pulse-width-modulation-pwm/

Applications of Pulse With Modulation?

- Dimmable lights
  - Dimming the LED lights
- Variable-speed motors
  - Controlling the fan speed of CPU (Controlling the speed of DC Motor)
- Controlling the brightness of the display in laptops
- In power supplies (DC-DC converter, SMPS etc)
- Actuators
- Speakers

https://docs.arduino.cc/learn/microcontrollers/analog-output

How does PWM work?

- PWM is not true analog output
  - PWM “fakes” an analog-like result by applying power in pulses, or short bursts of regulated voltage
- A device that is driven by PWM ends up behaving like the average of the pulses
- The average voltage level can be a steady voltage or a moving target (dynamic/changing over time)
- Average Voltage = Duty Cycle * High Voltage Level

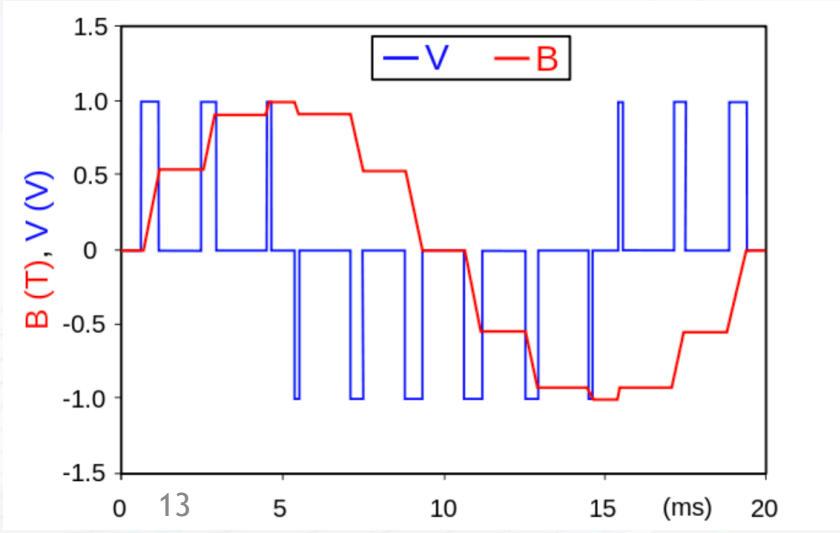

Figure8: PWM

https://www.analogictips.com/pulse-width-modulation-pwm/

Parameters of the PWM signals

- With PWM signal two parameters are always associated:
  1. Duty Cycle 2. Switching Frequency
- Switching Frequency defines how fast the switching takes place. It defines the time period of the PWM signal. (depending on the application usually, it's varies from 100 Hz to even KHz)
- The Duty Cycle defines the ON time of the pulse. It is the ratio of the On time of the pulse to the total time period.

$$\text{Duty Cycle} = \frac{On\ time}{On\ time + OFF\ time}$$

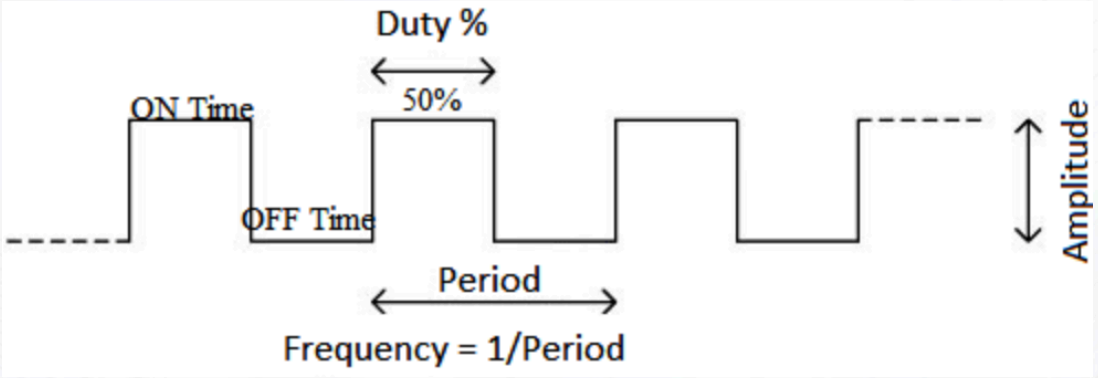

Figure9: PWM Signals

https://circuitdigest.com/tutorial/what-is-pwm-pulse-width-modulation

Duty cycle

Average Output Voltage =

Duty Cycle (%) * High Voltage Level

= 0.50 * 5 = 2.5 V

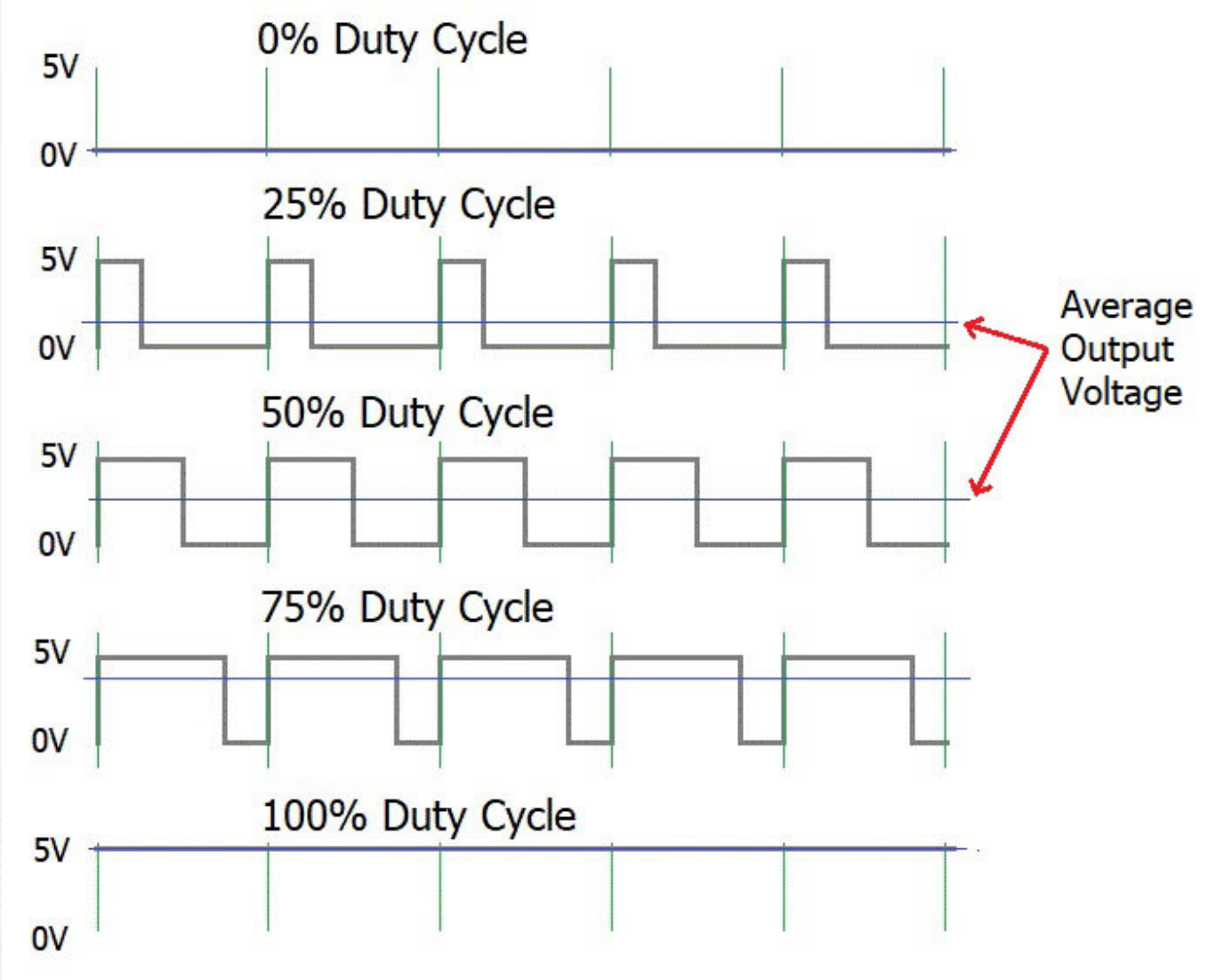

Figure10: PWM Signals

https://circuitdigest.com/tutorial/what-is-pwm-pulse-width-modulation

Reference

[1] EECS 373 Design of Microprocessor-Based Systems.

[2] R.H. Walden, “Analog-to-Digital Converter Survey and Analysis”, IEEE Journal on Selected Areas in Communications, vol.17, Iss.4, 1999.

[3] Leon-Garcia, Alberto, Chapter 3, “Fundamental Concepts and Key Architecture”, Communication Networks, 2nd ed., University of Toronto.

[4] Barr, Michael. "Pulse Width Modulation," Embedded Systems Programming, September 2001, pp. 103-104.

[5] Patel, Mahesh A; Patel, Ankit R; Vyas, Dhaval R; Patel, Ketul M, “Use of PWM Techniques for Power Quality Improvement”, International Journal of Recent Trends in Engineering; Oulu Vol. 1, Iss. 4, May 2009, pp. 99-102.