Visionary Course

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System and Modeling

System

- What is the definition of system?
  - A system is a group of interacting or interrelated elements that act according to a set of rules to form a unified whole.

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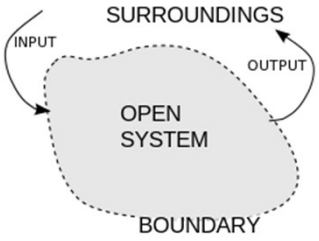
  - A system is a group of interacting or interrelated elements that act according to a set of rules to form a unified whole.

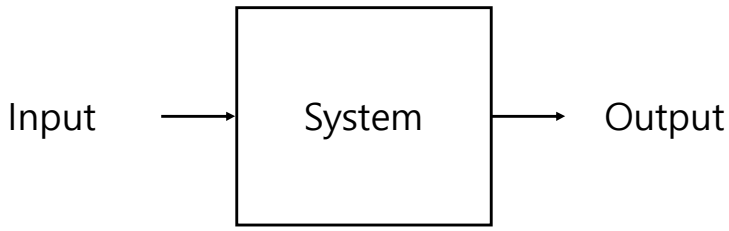


Open systems have input and output flows, representing exchanges of matter, energy or information with their surroundings.

System Model

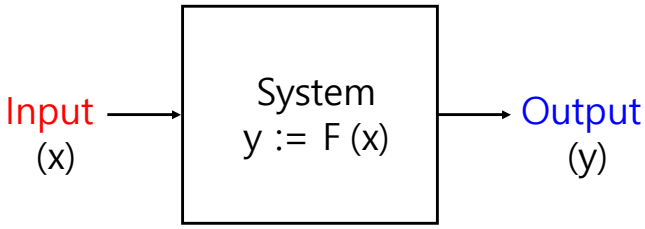
- What is the definition of model?
  - A model is an informative representation of an object, person or system.

Modeling A System

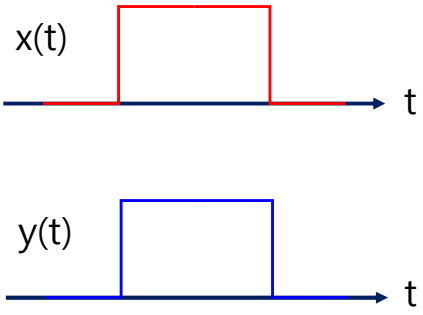


How to define the system?

Example 1)

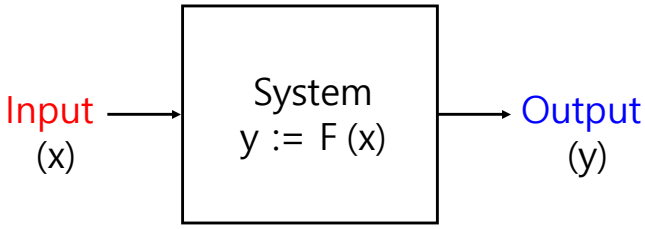


If x = y, then F(x) = x

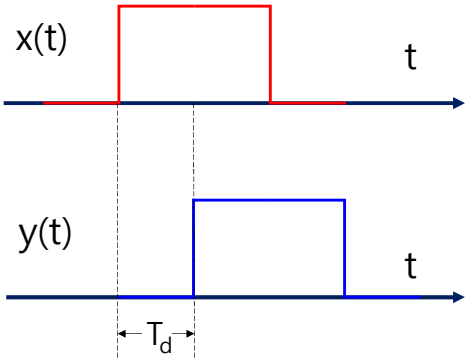


Real life example?

Example 2) Delay T_d

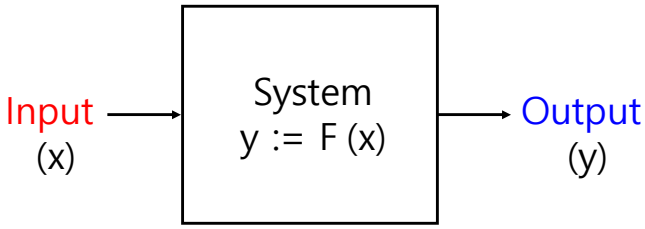


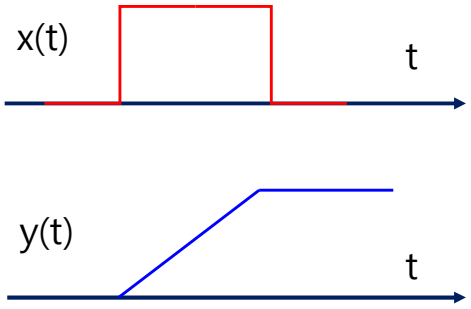
$y(t) = x(t-T_d)$



Real life example?

Example 3)





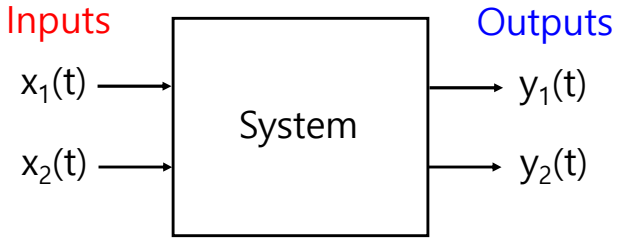
$y(t) = \int x(t)dt$

$y'(t) = x(t)$

Real life example?

Example 4) MIMO Linear System

- 2x2 MIMO System



$$\begin{bmatrix} y_1(t) \\ y_2(t) \end{bmatrix} = \begin{bmatrix} 0.5 & 0.5 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$$

Linear Algebra, Vector, Matrix ...

$y_1(t) = x_1(t) + 2 \cdot x_2(t)$

$y_2(t) = x_2(t)$

Real life example?

Categories of Systems

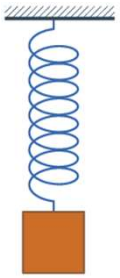
- # of inputs and outputs
  - Multiple Inputs and Multiple Output (MIMO)
  - Single Input and Single Output (SISO)
- Input and output types
  - Continuous system
  - Discrete system
- Relationship
  - Linear system
  - Non-linear system

Group Discussion and Presentation

Make a 3-page ppt and give a 3-min presentation!

- Pick a system
  (e.g. mechanical, electrical, biological, economical, communication, automatic control …)
- Define inputs and outputs of your system
- Describe the behaviors / dynamics / rules for the system
  (Is it possible to make a mathematical/logical representation?)

Example 5) Forced Spring Mass System



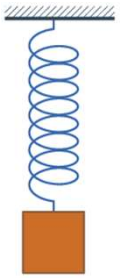
Dynamics equation: $mx''(t) + kx(t) = f(t)$

$$x_1(t) = x(t)$$
$$x_2(t) = x_1'(t)$$

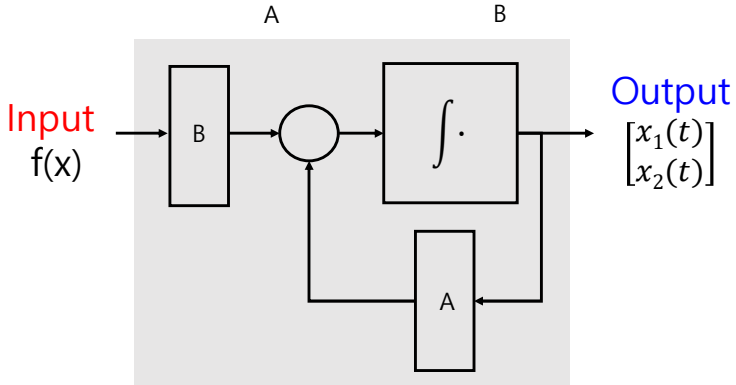
$$x_1'(t) = x_2(t)$$
$$x_2'(t) = x_1''(t) = -\frac{k}{m}x1(t) + \frac{1}{m}f(t)$$

$$\begin{bmatrix} x_1'(t) \\ x_2'(t) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\frac{k}{m} & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{m} \end{bmatrix} f(t)$$

Example 5) Forced Spring-Mass System

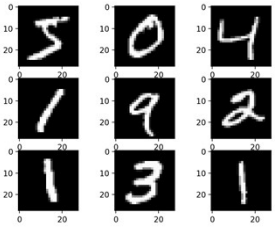


$$\begin{bmatrix} x_1'(t) \\ x_2'(t) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\frac{k}{m} & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{m} \end{bmatrix} f(t)$$

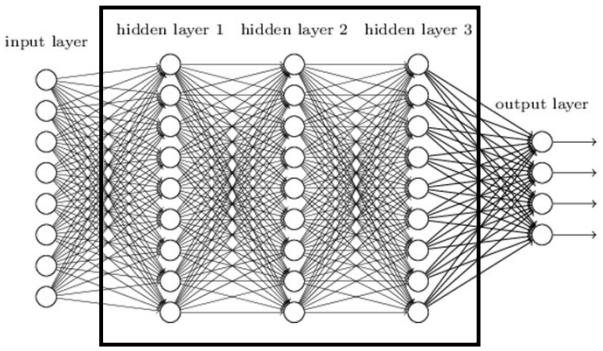


Example 6) Artificial Neural Network

Pattern
(28x28 grayscale image)



MNIST dataset



28x28=784 inputs

10 outputs

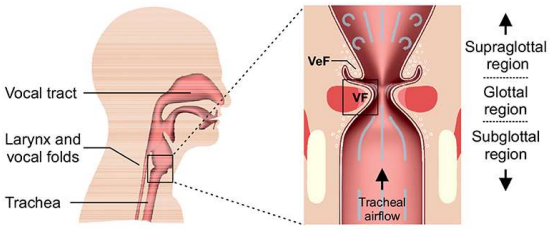
Signals

Signal

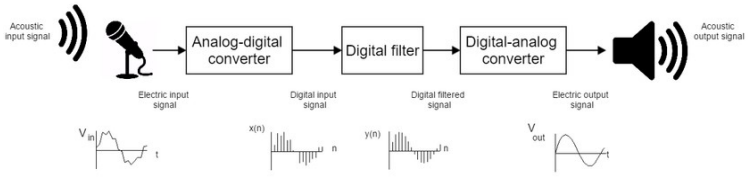
- In signal processing, a signal is **a function that conveys information** about a phenomenon.
- In electronics and telecommunications, it refers to any time **varying voltage, current, or electromagnetic wave** that carries information.
- A signal may also be defined as **an observable change in a quality** such as quantity.

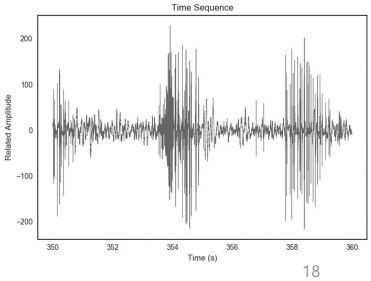
1) Acoustic Signal

- Voice production



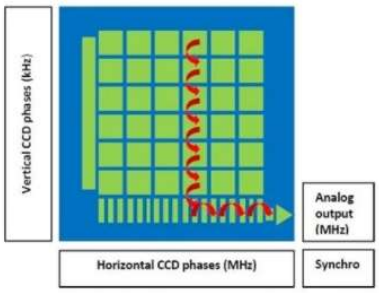
- Capture and signal processing "system"





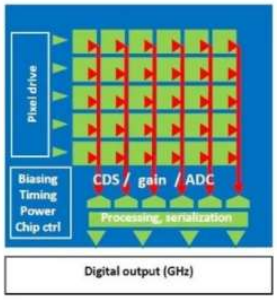
2) Image Signal

Charge Coupled Devices (CCDs)

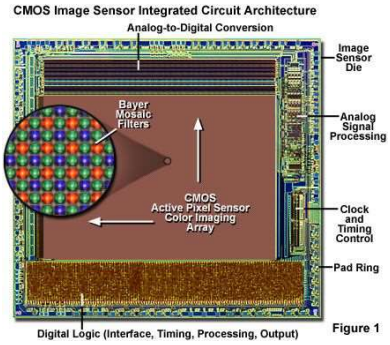


CCD = Photon-to-electron conversion (analog)

Complementary Metal–Oxide–Semiconductor (CMOS) Sensor



CIS = Photon-to-Voltage conversion (digital)

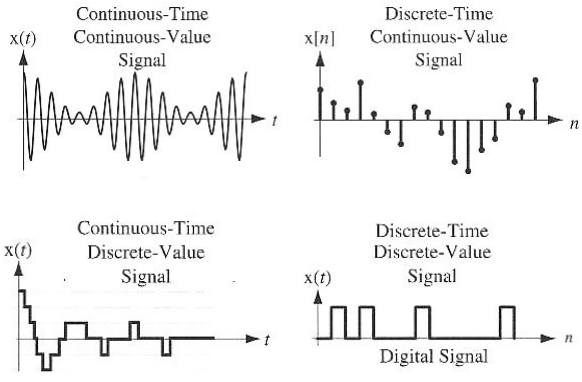


https://www.azom.com/article.aspx?ArticleID=16321

https://www.olympus-lifescience.com/ko/microscope-resource/primer/digitalimaging/cmosimagesensors/

Signal Types

	Continues Time	Discrete Time
Continues Value	Analog	Discrete
Discrete Value	Continues-Time Discrete Value Signal	Digital



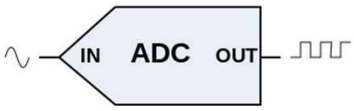
Analogy to Digital Conversion

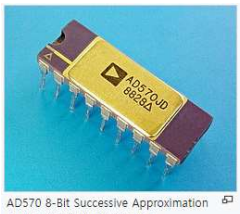
- Sampling and quantization

	Continues Time	Discrete Time
Continues Value	Analog	Discrete
Discrete Value	Continues-Time Discrete Value Signal	Digital

Sampling

Quantization





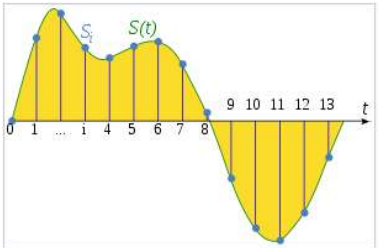
AD570 8-Bit Successive Approximation Analog-to-Digital Converter.

AD570/AD571 silicon die

Sampling

WIKIPEDIA
The Free Encyclopedia

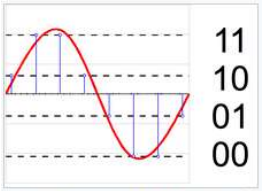
- In signal processing, sampling is the reduction of a continuous-time signal to a discrete-time signal.
- A common example is the conversion of a sound wave to a sequence of "samples".
- A sample is a value of the signal at a point in time and/or space.



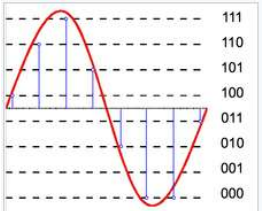
Signal sampling representation. The continuous signal S(t) is represented with a green colored line while the discrete samples are indicated by the blue vertical lines.

Quantization

- Quantization, in mathematics and digital signal processing, is the process of mapping input values from a large set (often a continuous set) to output values in a (countable) smaller set, often with a finite number of elements.



2-bit resolution with four levels of quantization compared to analog.[8]



3-bit resolution with eight levels.

Any tradeoff?

Group Discussion and Presentation

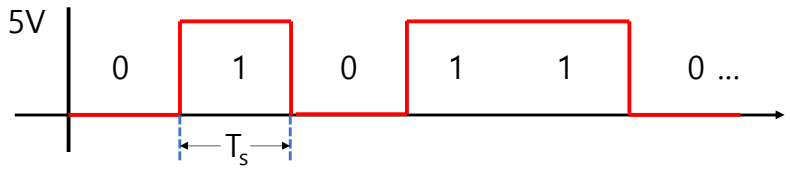
Make a 3-page ppt and give a 3-min presentation!

- Pick one of your smartphones
- Investigate its hardware and software including Apps.
- Any signal, sampling, quantization techniques are used?
- What are the specification of ADC/DAC?

3) Communication Signal

For a given series of binary values,
how can we generate a signal (waveform)? → Modulation

010110 …



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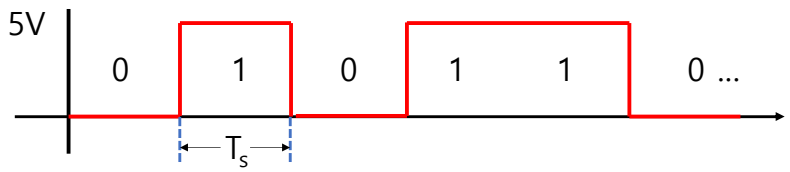
010110 …



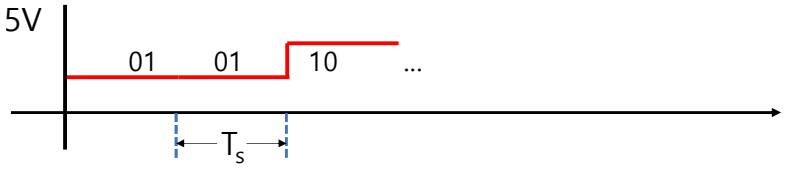
Transmit Speed: 1 bit/T_s

Can be higher?

3) Communication Signal

Change amplitude: 00 → 0V, 01 → 1.6V, 10 → 3.3V, 11 → 5V

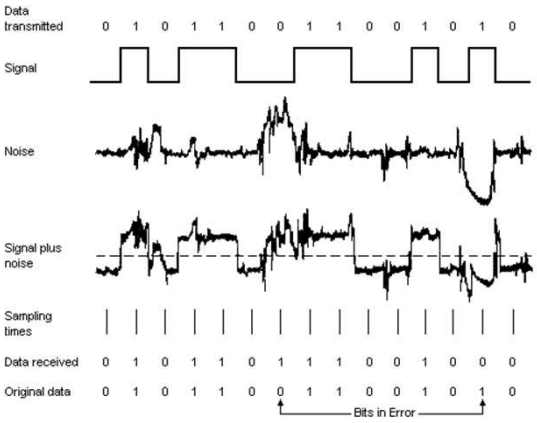
010110 ➔ 01/01/10 ➔ 1.6V/1.6V/3.3V



Transmit Speed: 2 bit/T_s

Can be higher and higher?
Any Tradeoff?

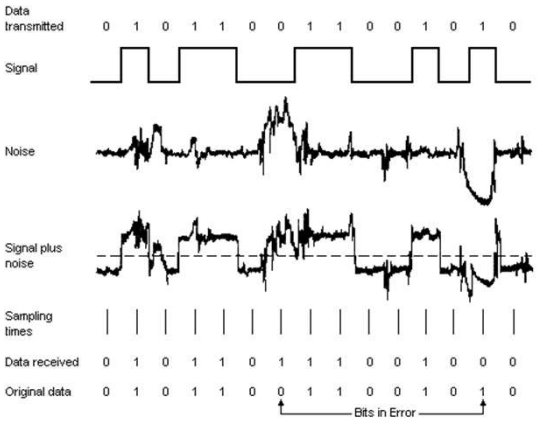
Noisy Signal

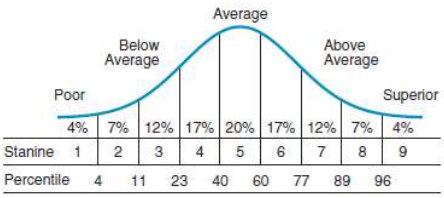


https://www.autodesk.com/products/eagle/blog/top-5-techniques-terminating-transmission-lines/

Calculate bit error rate?

Noisy Signal





Normal distribution

Statistics, probability, distribution

Noisy Signal

The original image. Noisy image (noise density 50%). Image denoised with linear interpolation and median filter.

Noisy Signal

- How much noisy is the signal?

Noisy Signal

- How much noisy is the signal?
- Signal-to-noise ratio (SNR)
  Signal-to-interference-plus-noise ratio (SINR)

$$SINR = \frac{S}{I + N}$$

S : signal power, I : interference power, N : noise

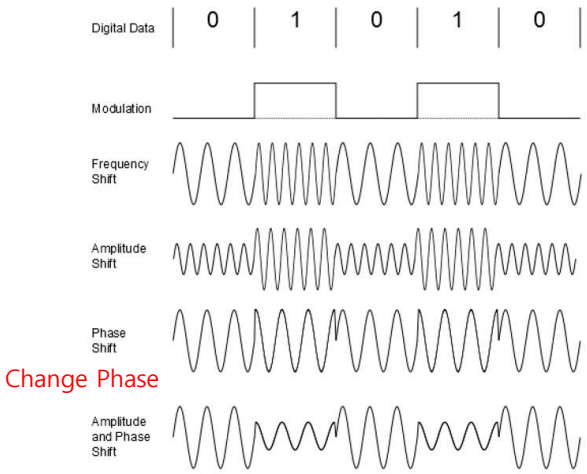
Shannon Limit

- Shannon-Hartley theorem
  - Proved by Bell Labs research Claude Shannon in 1948.
  - Gives the capacity of a communication channel.
  - Many communication systems in use do not achieve the capacity, however, it provides a useful upper bound.

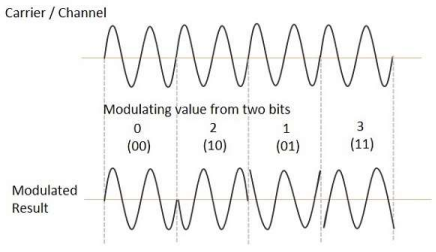
  - C: max capacity in bits per second
    W: bandwidth in Hertz

$$C \leq W \log_2(1 + \frac{S}{N})$$

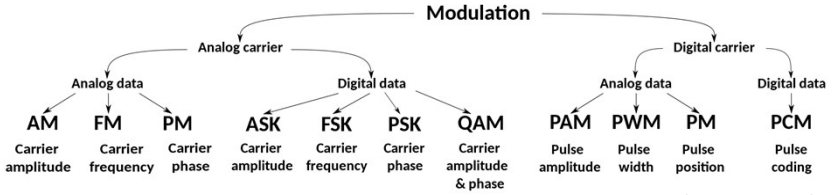
3) Communication Signal



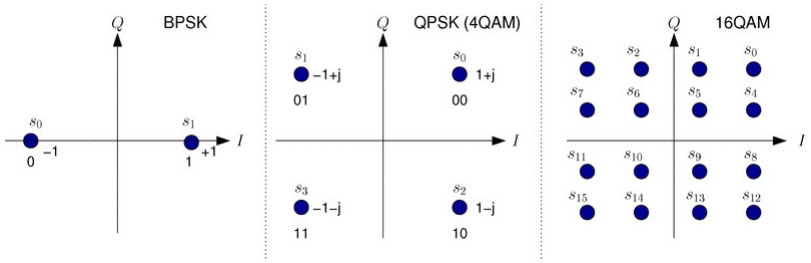
Change Phase



3) Communication Signal



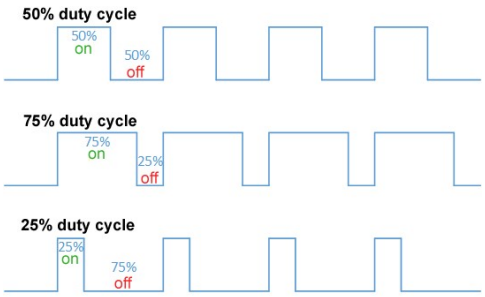
https://www.wikiwand.com/en/Modulation



Complex number

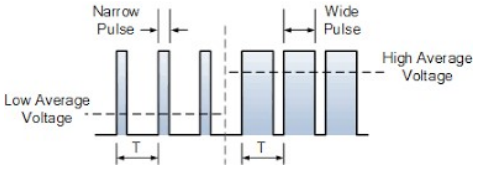
4) Pulse-width Modulation (PWM)

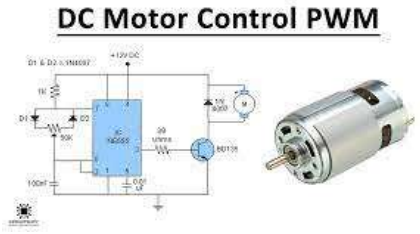
- Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts.



4) Pulse-width Modulation (PWM)

- The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate.
- The longer the switch is on compared to the off periods, the higher the total power supplied to the load.
- PWM is particularly suited for running inertial loads such as motors, which are not as easily affected by this discrete switching, because their inertia causes them to react slowly.





Any Questions?

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