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Royal University of Phnom Penh

Data Communication I

Chapter 2.1 : Analog signals

Lecturer: **CHHORN SYLUN**

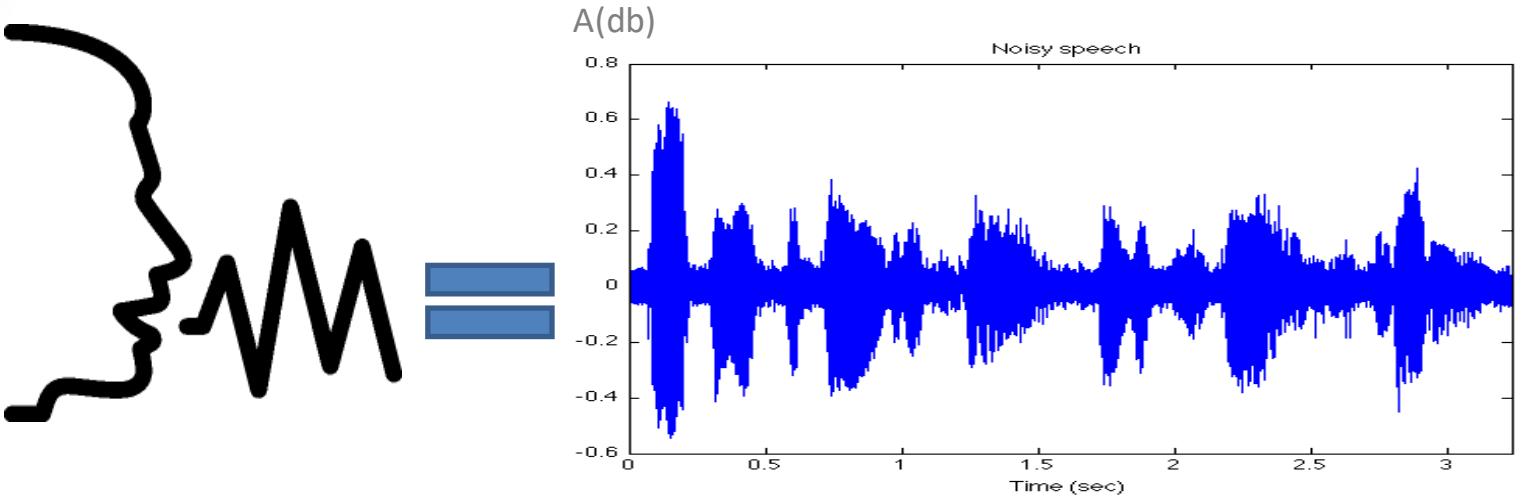
Email: chhorn.sylun@rupp.edu.kh

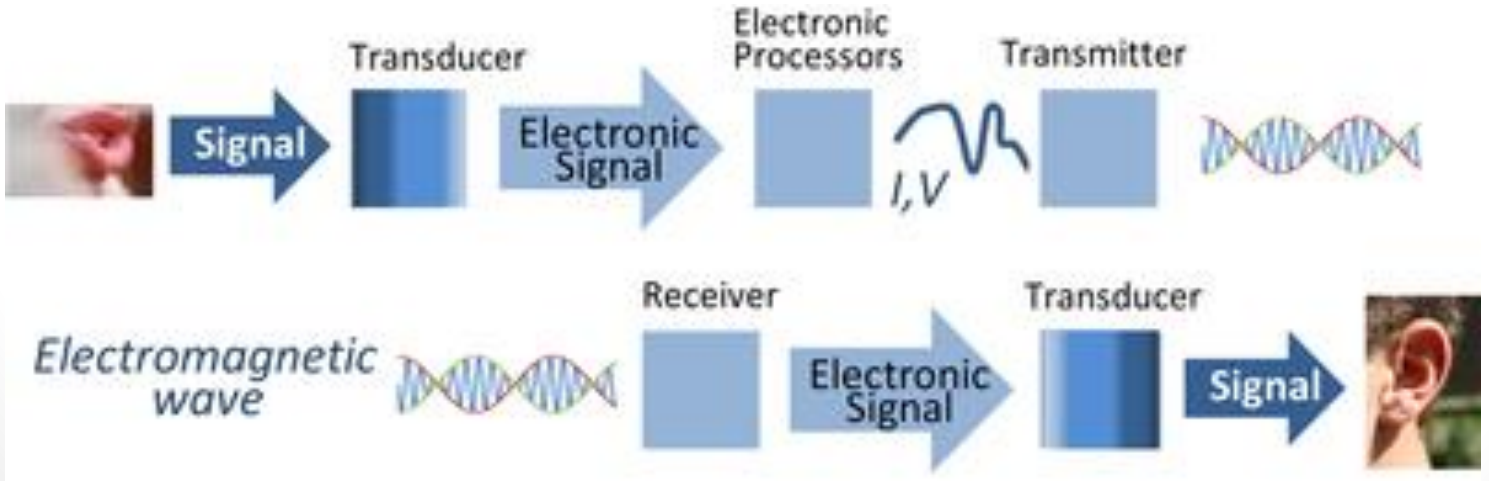
Room: 302, STEM Building, RUPP

Outline

- What is Signals?
- Analog and Digital Signals
- Periodic and Aperiodic Signals
- Analog Signals Characteristics

What is signals?





What is signals?

- To be transmitted, data must be transformed into Electromagnetic signals.
- A signal is a function of independent variables that carry some information.

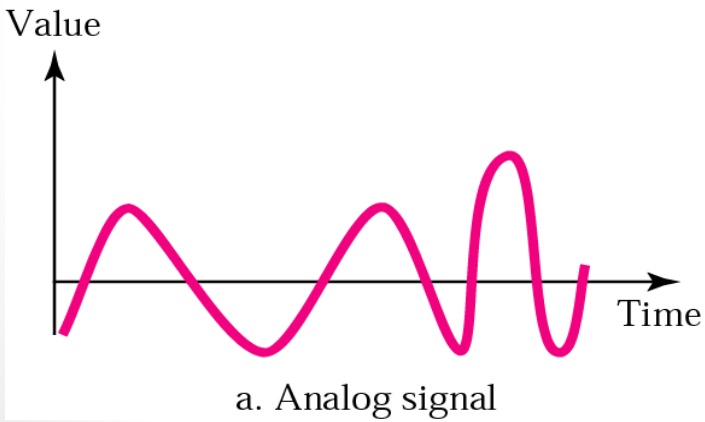
In communication system, a transmitter encodes a message into a signal, which is carried to a receiver by the communications channel.

What is signals?

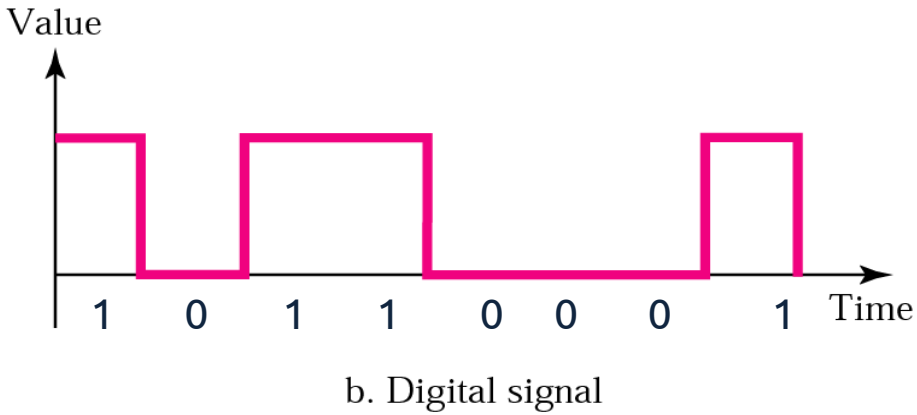
Signals can be Analog and Digital

a). Analog signals can have an infinite number of values in a range.

b). Digital signals can have only a limited number of values.



a. Analog signal



b. Digital signal

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What is signals?

Analog vs Digital Device Examples

Clock *Multimeters* *Joysticks*

What is signals?

Basic types of signal:

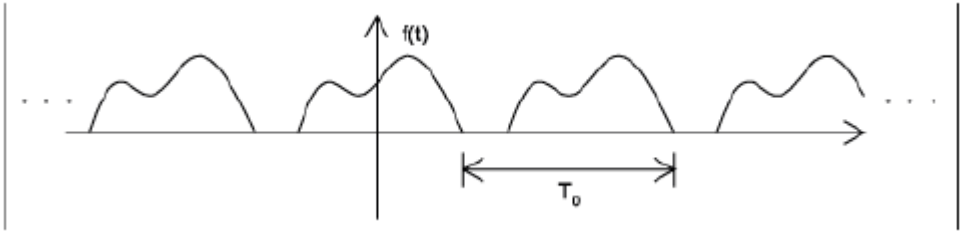
- Causal and Non causal signal
- Periodic and Aperiodic signal
- Even and Odd signal
- Unit Step signal
- Unit impulse signal
- Ramp signal
- Sinusoid signal
- Exponential signal

What is signals?

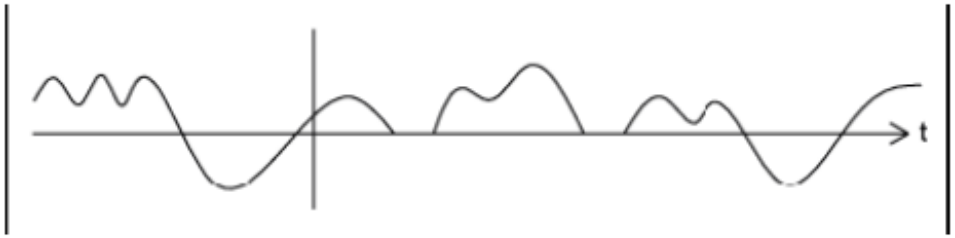
In data communication, we commonly use periodic analog signals and aperiodic digital signals.

- Periodic signal remains unchanged when time-shifted of integer multiples of the period

$$f(t + T_o) = f(t) \quad \forall t$$



- Aperiodic signal always changed when time-shifted of integer multiples of the period



Analog Signals

In this analog signals part, we will discuss the following

1. Sine Wave
2. Examples of Sine Waves
3. Time and Frequency Domains
4. Composite Signals
5. Signal corruption
6. Bandwidth

Analog Signals

1. Sine Wave

$x(t) = A \sin(\omega_0 t \pm \emptyset)$

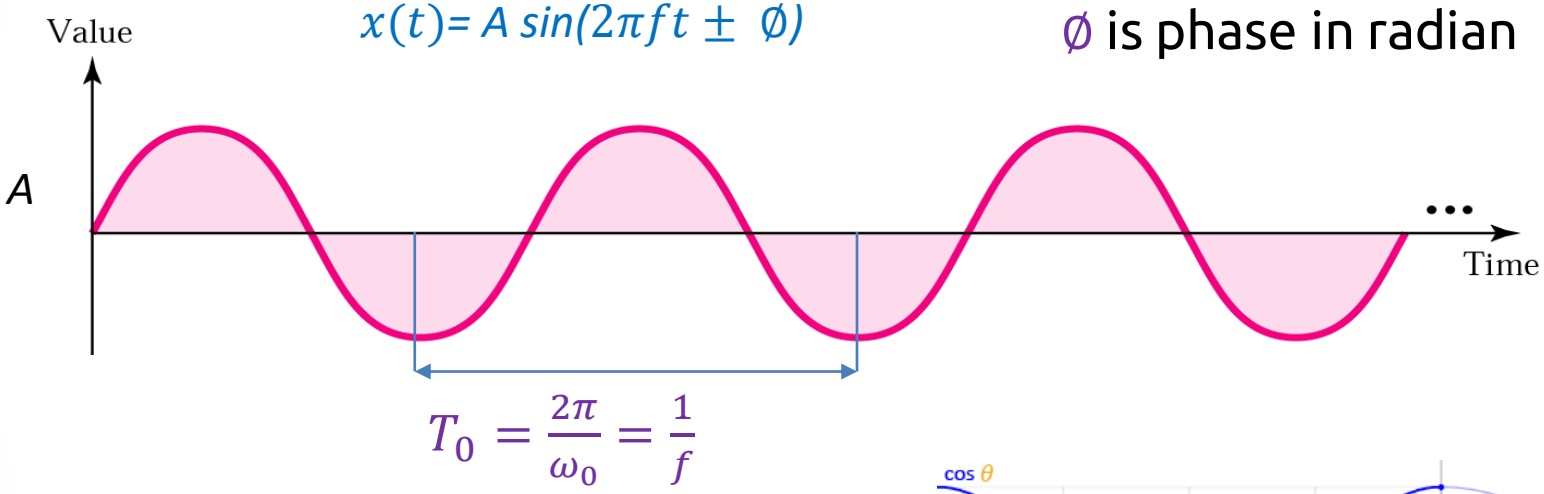
$x(t) = A \sin(2\pi f t \pm \emptyset)$

A is Amplitude

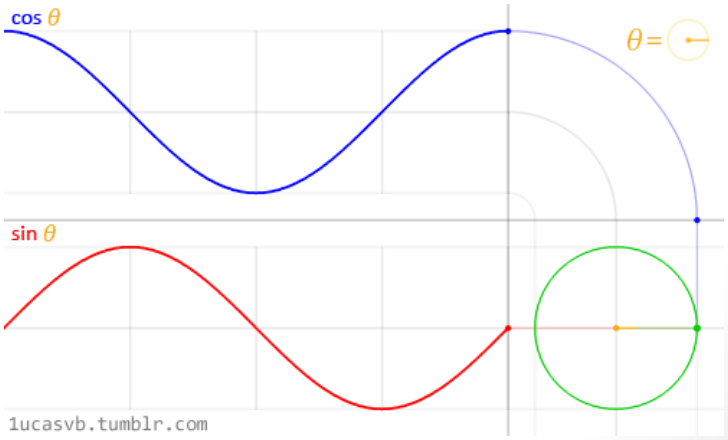
ω_0 is frequency in radian

$\omega_0 = 2\pi f$ in Hz

$\emptyset$ is phase in radian

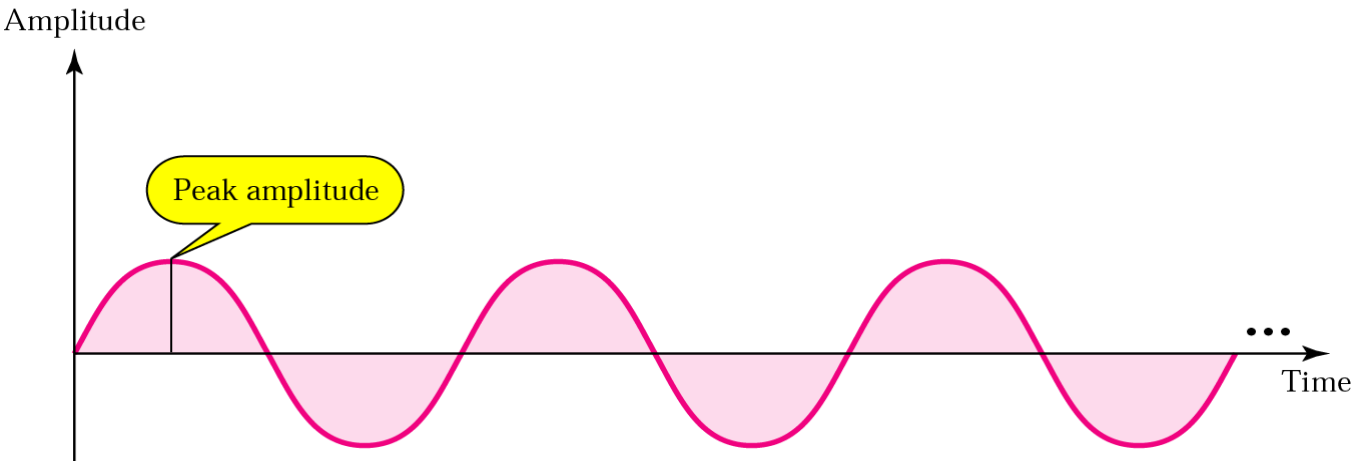


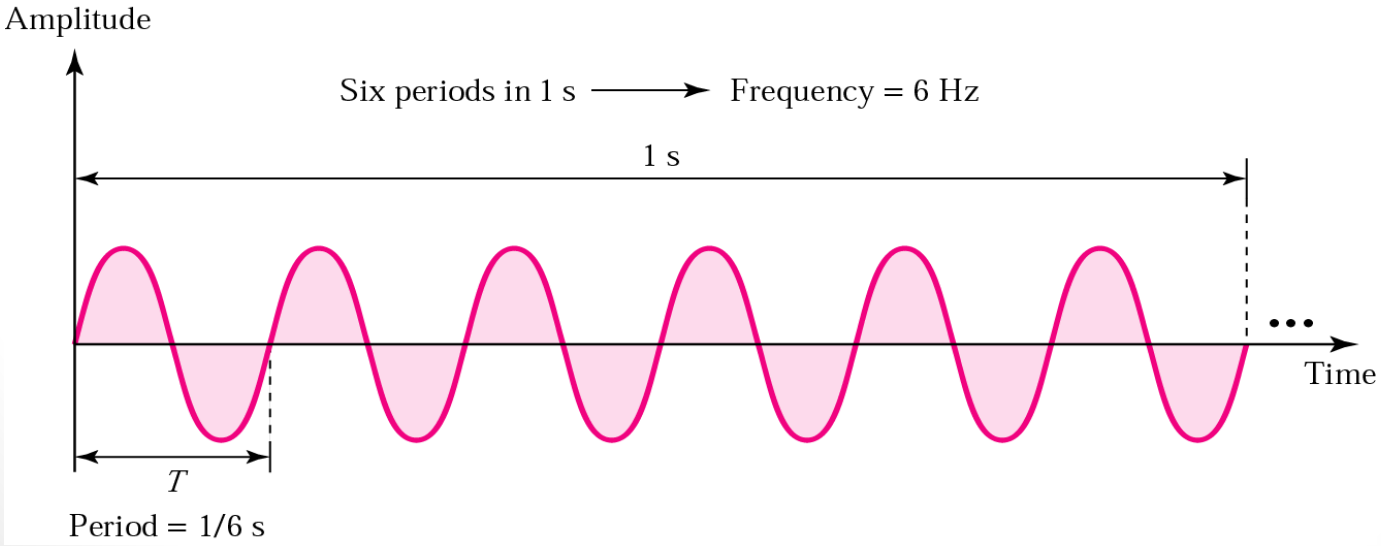
$$T_0 = \frac{2\pi}{\omega_0} = \frac{1}{f}$$



Analog Signals

1. Sine Wave





Analog Signals

1. Sine Wave

Unit	Equivalent	Unit	Equivalent
Seconds (s)	1 s	hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	kilohertz (KHz)	10^{3} Hz
Microseconds (μs)	10^{-6} s	megahertz (MHz)	10^{6} Hz
Nanoseconds (ns)	10^{-9} s	gigahertz (GHz)	10^{9} Hz
Picoseconds (ps)	10^{-12} s	terahertz (THz)	10^{12} Hz

Units of periods and frequencies

Analog Signals

2. Sine Wave Example

Example1: Express a period of 100ms in microseconds, and express the corresponding frequency in kilohertz?

Analog Signals

2. Sine Wave Example

Note:

- Frequency is the rate of change with respect to time. Change in a **short** span of time means **high** frequency. Change over a **long** span of time means **low** frequency.

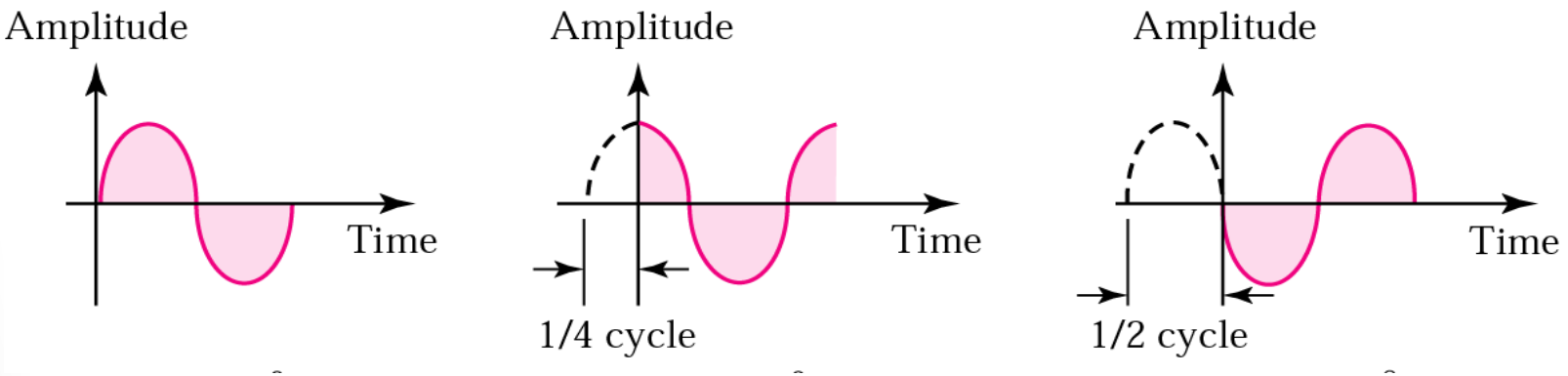
- If a signal **does not change** at all, its frequency is **zero**. If a signal **changes instantaneously**, its frequency is **infinite.**

- Phase describes the position of the waveform relative to time zero.

Analog Signals

2. Sine Wave Example

Define the phase on each signals?



Analog Signals

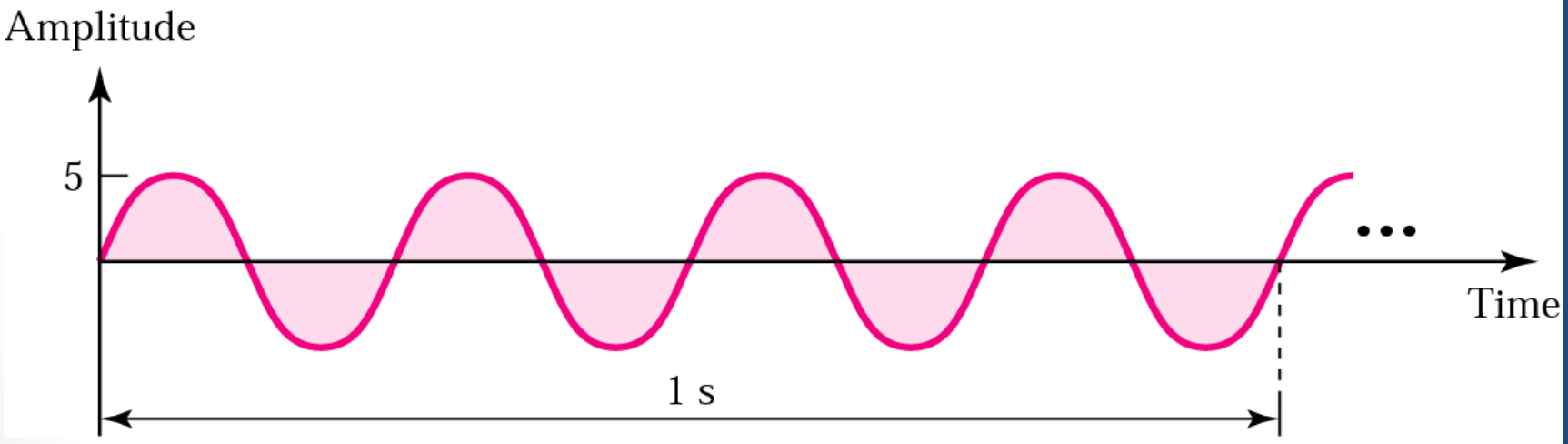
2. Sine Wave Example

Example2: A sine wave is offset one-sixth of a cycle with respect to time zero. What is its phase in degrees and radians?

Analog Signals

2. Sine Wave Example

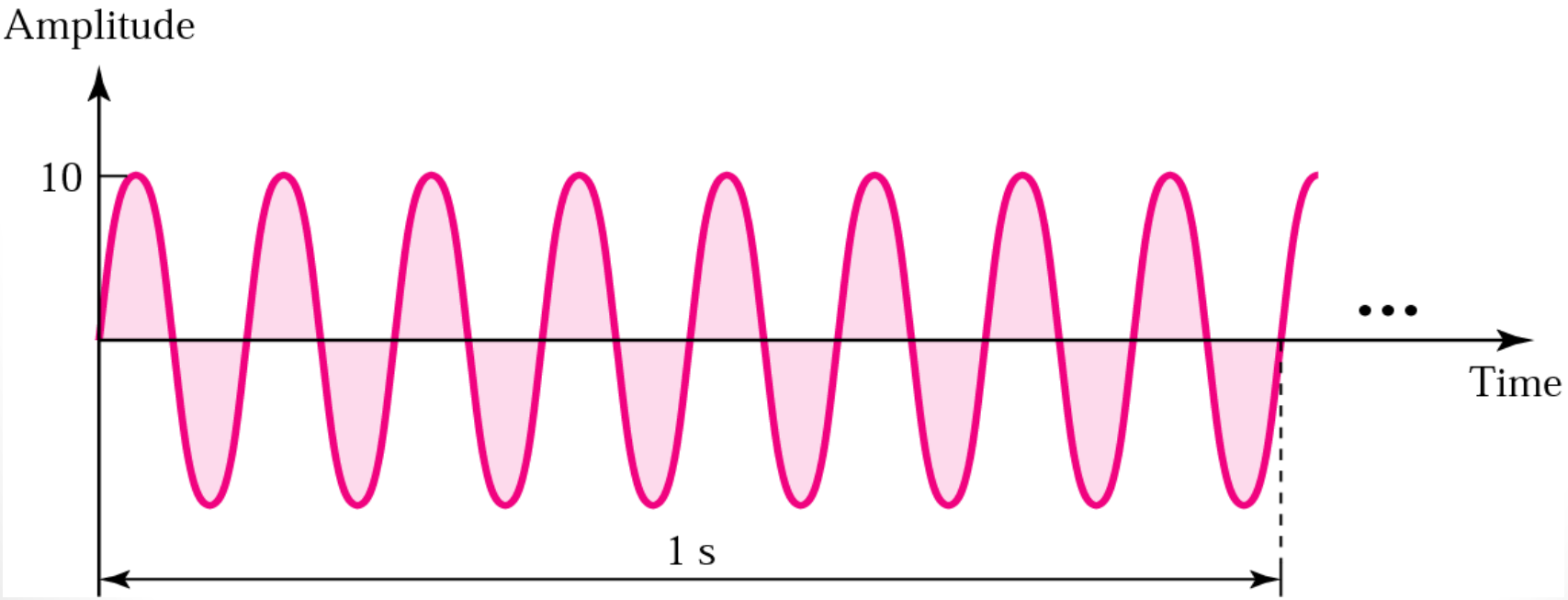
Check amplitude, frequency, phase and create signal function on the below graph?



Analog Signals

2. Sine Wave Example

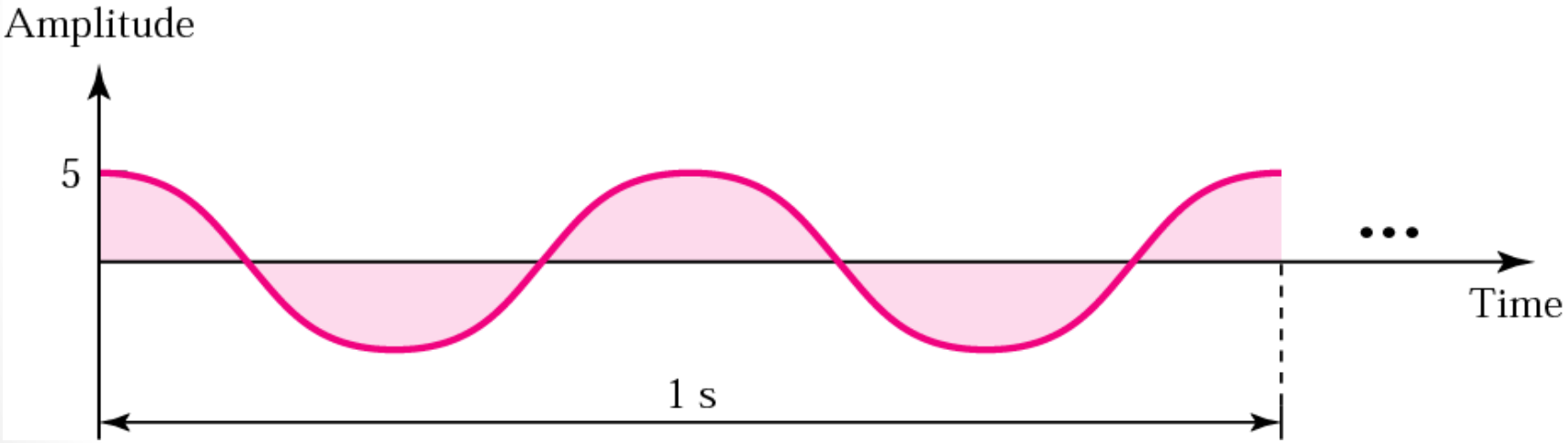
Check amplitude, frequency, phase and create signal function on the below graph?



Analog Signals

2. Sine Wave Example

Check amplitude, frequency, phase and create signal function on the below graph?



Analog Signals

3. Time and Frequency Domain
   - What is Frequency?
   - Why Frequency Domain?
   - How to transform from Time to Frequency domain?

Analog Signals

3. Time and Frequency Domain

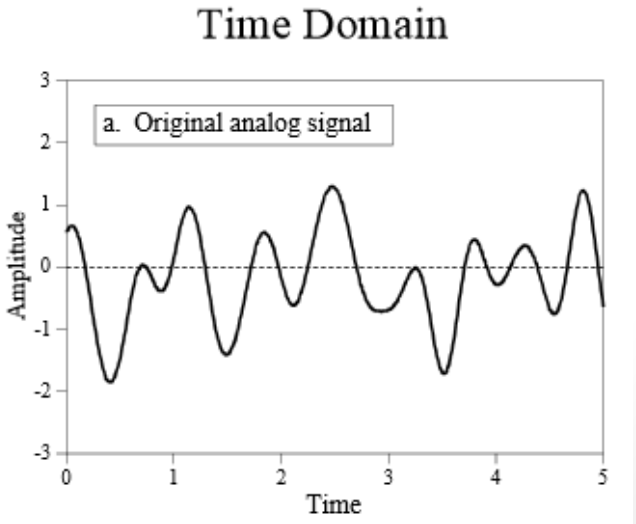
- For example we record signal from 3 difference types:
  - Singing sound: $y_1(t) = a_1 x_1(t)$
  - Piano sound: $y_2(t) = a_2 x_2(t)$
  - Guitar sound: $y_3(t) = a_3 x_3(t)$

$$\rightarrow y(t) = y_1(t) + y_2(t) + y_3(t) = a_1 x_1(t) + a_2 x_2(t) + a_3 x_3(t)$$

- What happen if we add noise $y_n(t)$, while singing?

$$\rightarrow y(t) = a_1[x_1(t) + x_n(t)] + a_2 x_2(t) + a_3 x_3(t)$$

$\rightarrow Problem?$

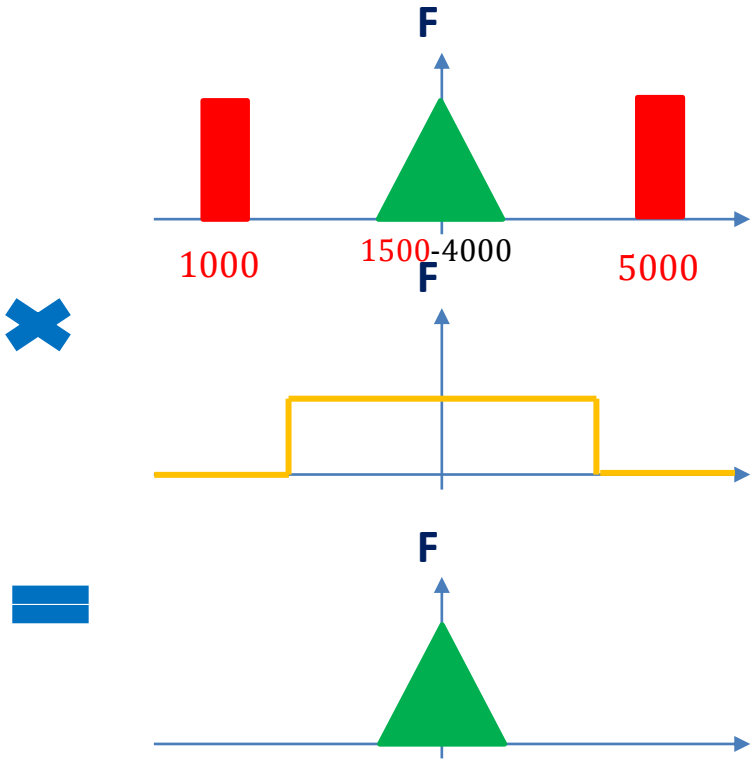


Analog Signals

3. Time and Frequency Domain

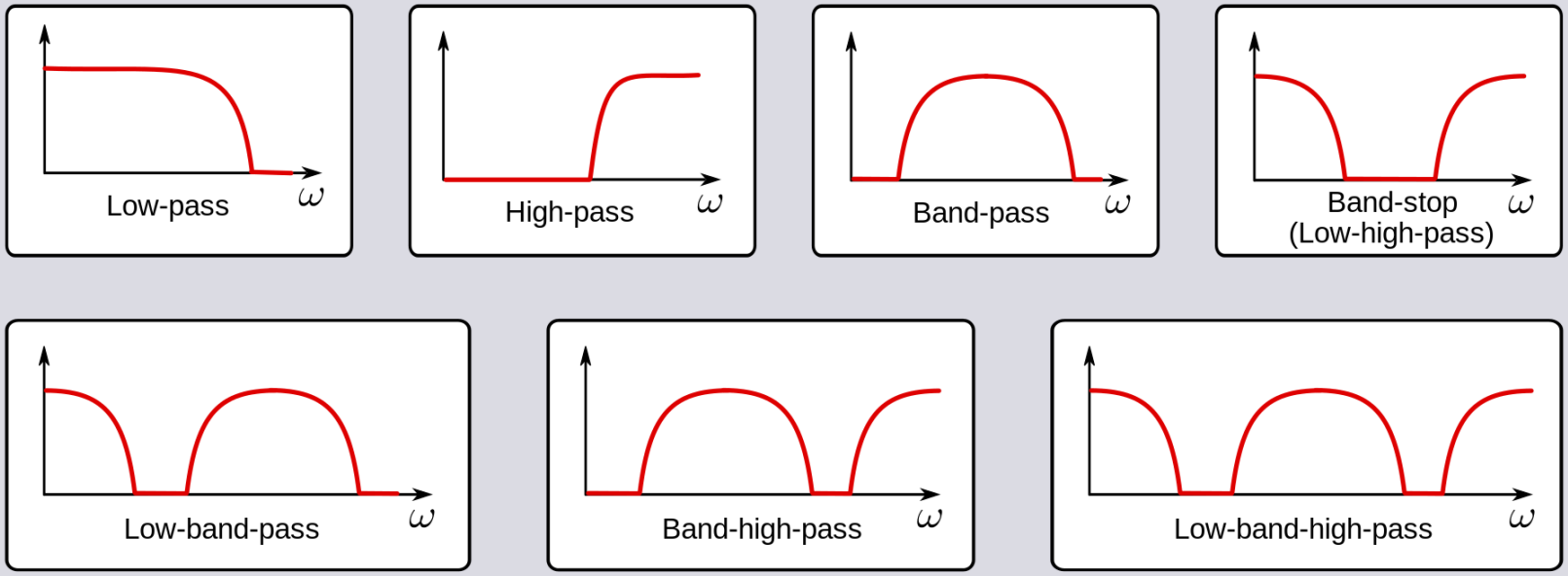
- Now let's check with Frequency Domain

$$y(t) = a_1[x_1(t) + x_n(t)] + a_2x_2(t) + a_3x_3(t)$$



Analog Signals

3. Time and Frequency Domain



Signal Filtering Methods

https://www.youtube.com/watch?v=I8_E1ppC3-Q&t=11s&ab_channel=YoungmooKim

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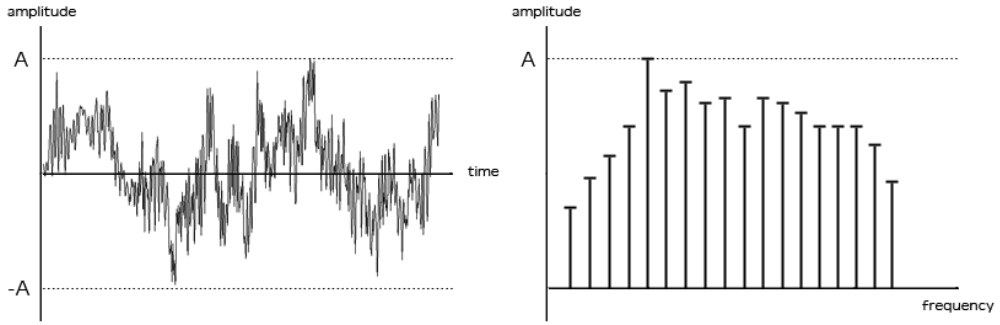
Analog Signals

3. Time and Frequency Domain

- Frequency domain gives you the representation of the signal as basic building blocks.
- It answers questions such as:
  - What are the various frequencies available in the signal?
  - What is the amplitude of each of the frequencies?
  - If I want some specific part of the signal, which frequency should I eliminate?

(This is not possible in time domain- - You cant reduce or modify the signal at particular 'instant' and expect it to reflect all over the signal).



Analog Signals

3. Time and Frequency Domain

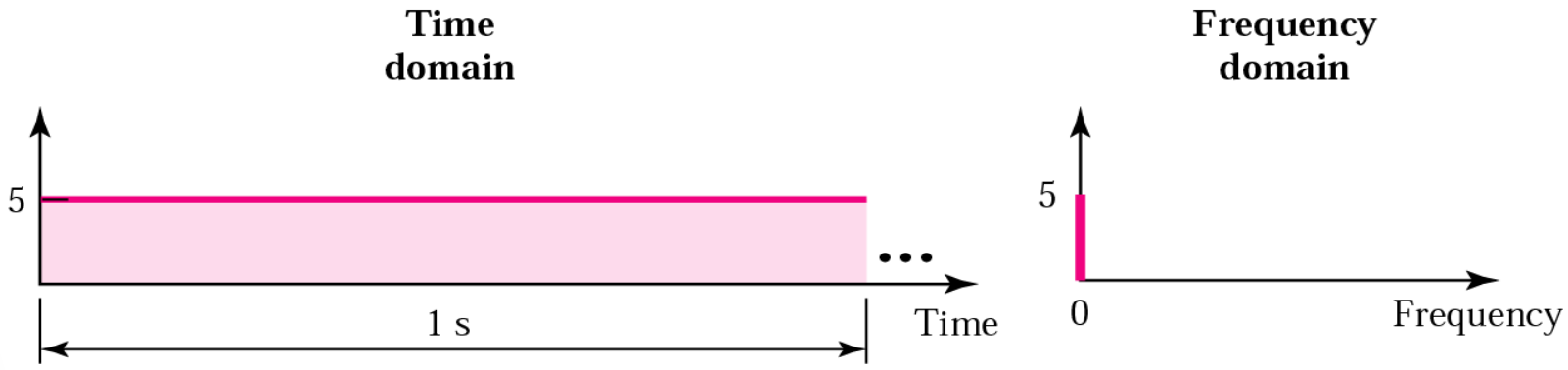
Frequency domains can be obtained through the transformation from one (Time or Spatial) domain to the other (Frequency) via:

- Fourier Series: repetitive signal, oscillating systems
- Fourier Transform: non repetitive signals, transients (audio,..)
- Laplace Transform: Electronic circuit and control systems
- Z-Transform: discrete signals or digital signal processing
- Wavelet Transform: Data Compression
- Discrete Cosine Transform: Image Processing (JPEG)

Analog Signals

3. Time and Frequency Domain

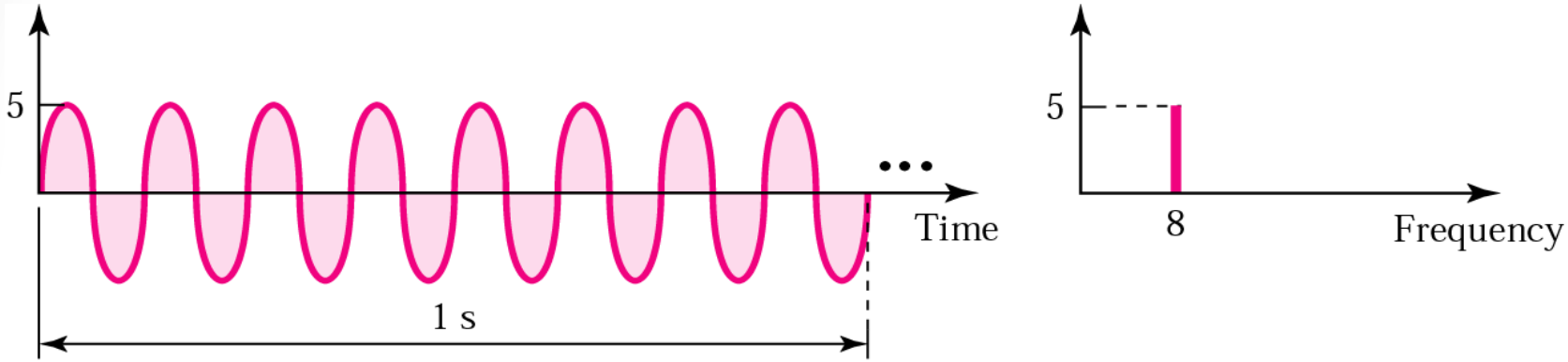
An analog signal is best represented in the frequency domain.



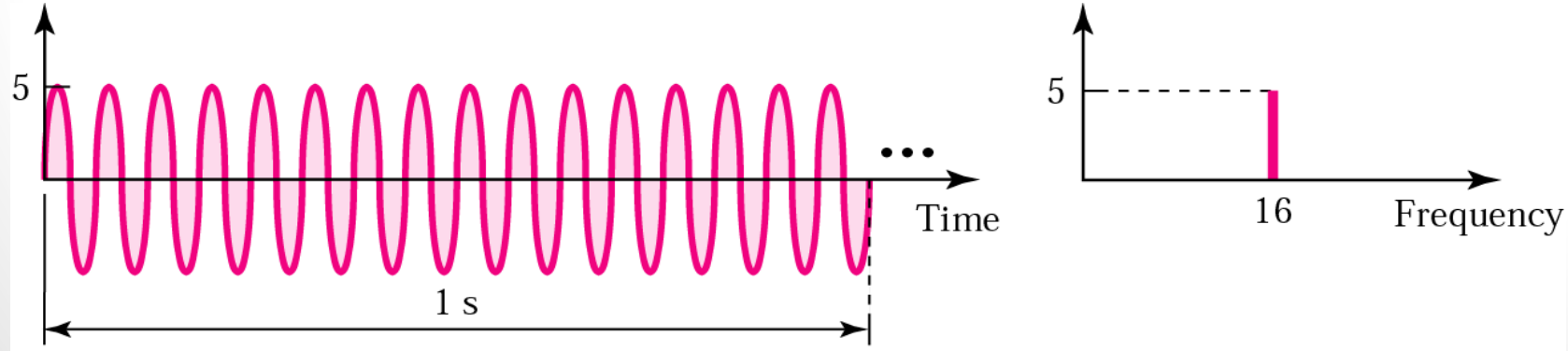
a. A signal with frequency 0

Analog Signals

3. Time and Frequency Domain



b. A signal with frequency 8



c. A signal with frequency 16

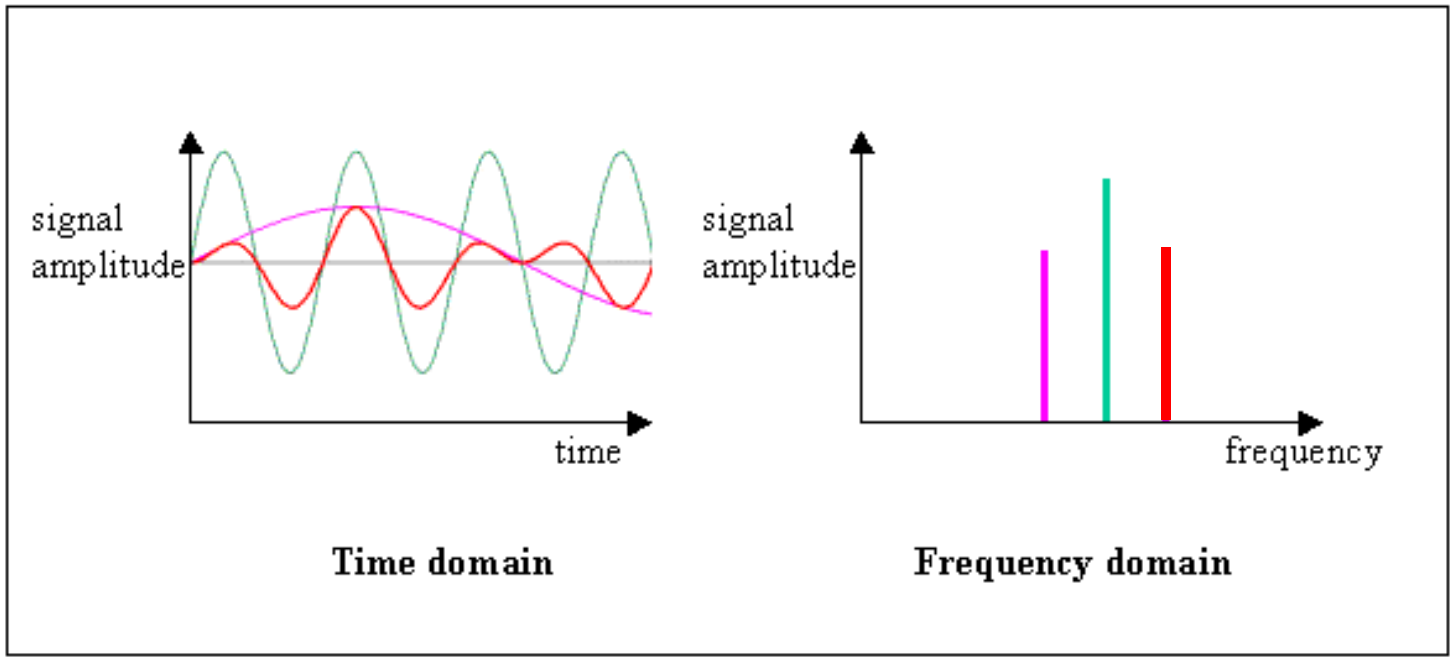
Analog Signals

3. Time and Frequency Domain

- A single-frequency sine wave is not useful in data communications; we need to change one or more of its characteristics to make it useful.
- When we change one or more characteristics of a single-frequency signal, it becomes a composite signal made of many frequencies.
- According to **Fourier analysis**, any composite signal can be represented as a combination of simple sine waves with different frequencies, phases, and amplitudes.

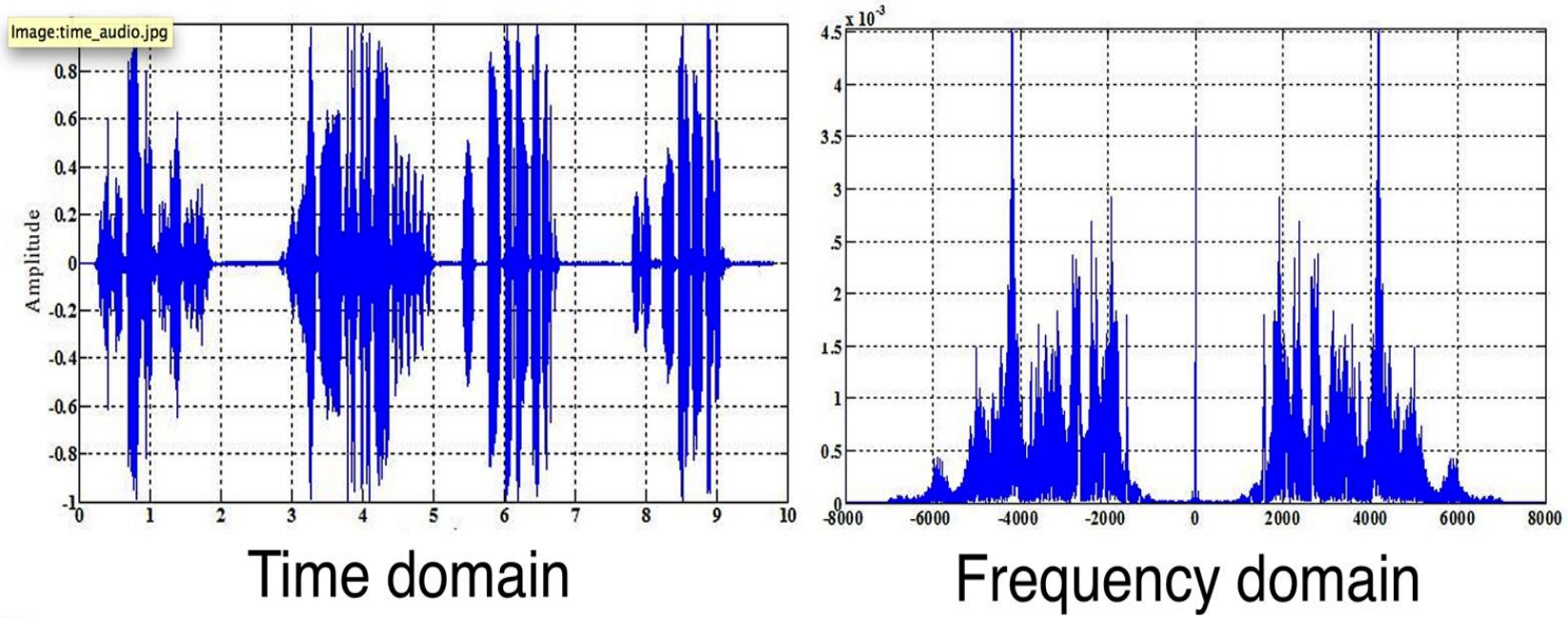
Analog Signals

3. Time and Frequency Domain



Analog Signals

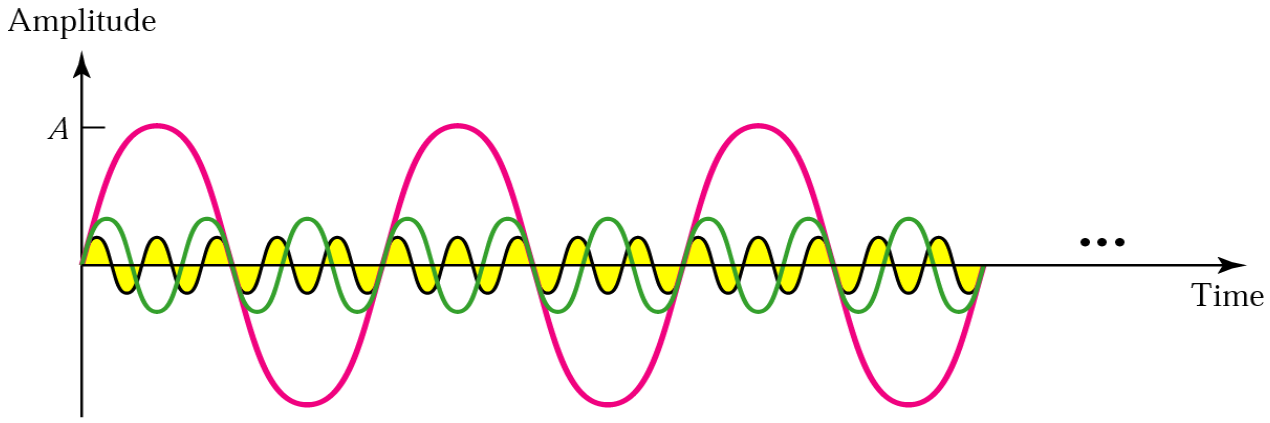
3. Time and Frequency Domain



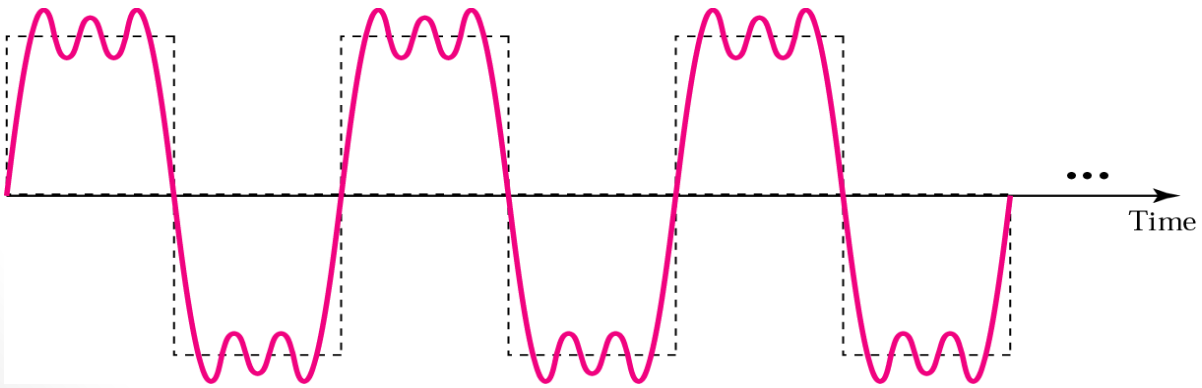
Example: *the audio signal in Time Domain and Frequency Domain*

Analog Signals

4. Composite Signals



Adding with three difference harmonic



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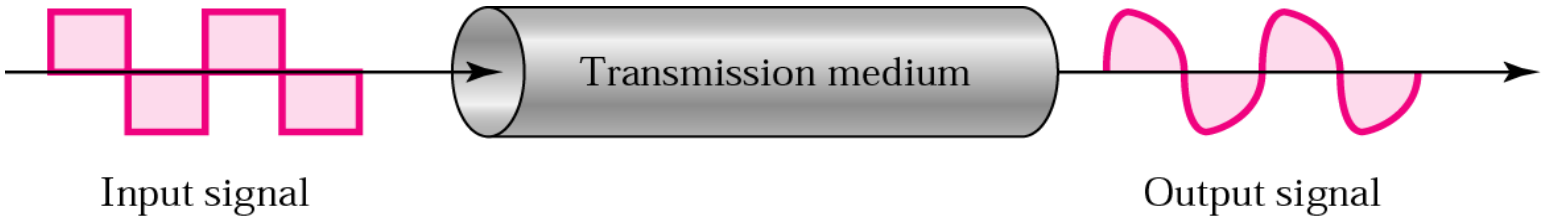
Analog Signals

5. Signal Corruption



- Noise: Extra noise on networks, like radio frequencies, electrical current , wire leakage, interfere with the other signals, etc..
- Physical surroundings: temperature, wall barriers, non professional wire installation, etc..
- Travel distance: long transmission, etc..

Analog Signals

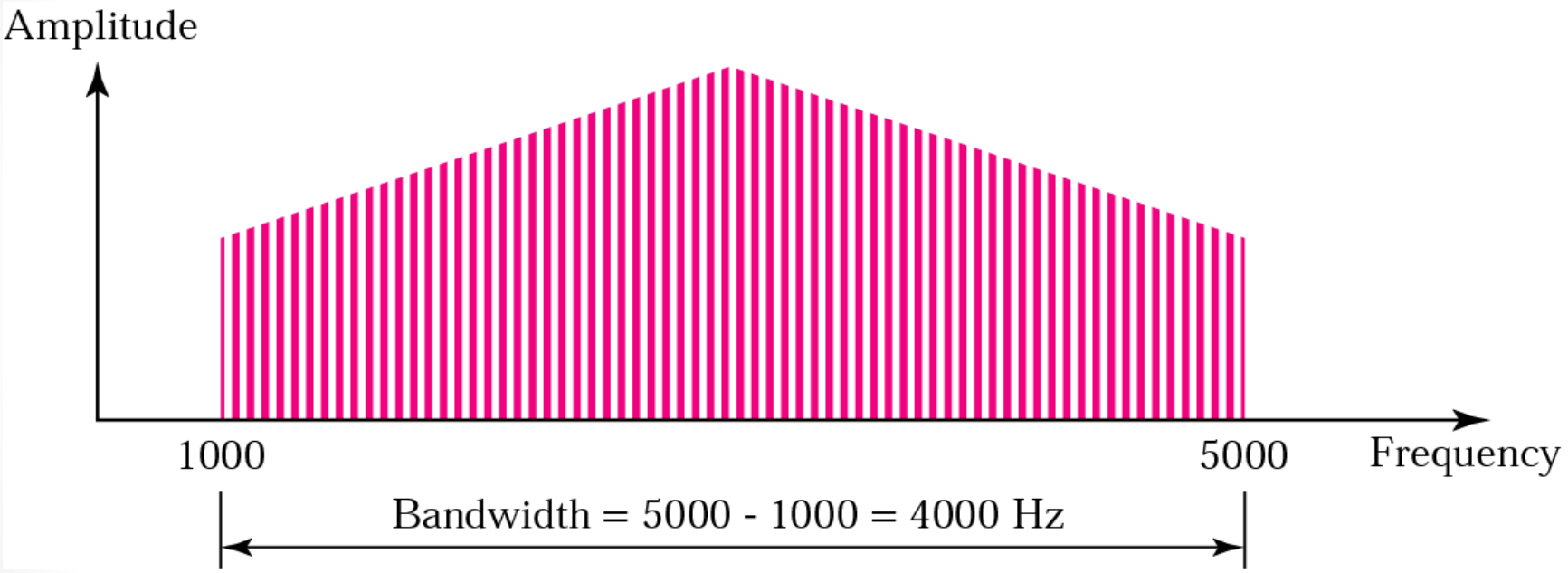
6. Bandwidth

- The bandwidth is a property of a medium: It is the difference between the highest and the lowest frequencies that the medium can satisfactorily pass.

- In this book, we use the term **bandwidth to refer to the property of a medium or the width of a single spectrum.**

Analog Signals

6. Bandwidth



Analog Signals

6. Bandwidth

Why should we care about Bandwidth?

We need to know the bandwidth of signal to make sure the communication channel is wide enough to transmit it.

Analog Signals

6. Bandwidth

Example 3: If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700, and 900 Hz, what is the bandwidth? Draw the spectrum, assuming all components have a maximum amplitude of 10 V.

Analog Signals

6. Bandwidth

Example 4: A signal has a bandwidth of 20 Hz. The highest frequency is 60 Hz. What is the lowest frequency? Draw the spectrum if the signal contains all integral frequencies of the same amplitude.

Analog Signals

6. Bandwidth

Example 5: What is the bandwidth of this signal?

$$y(t) = \sin(4\pi t) + 0.5\sin(8\pi t + \pi) + 2\sin(10\pi t)$$

Analog Signals

6. Bandwidth

Type of signal	Frequency Range	Bandwidth
Speech Signal	300 Hz to 3100 Hz	2800 Hz
Music Signal	20 Hz to 20,000 Hz	20 KHz
Video Signal		4.2 MHz
TV Signal		6 MHz
AM Broadcast		540 KHz to 1600 KHz
FM Broadcast		**88 MHz to 108 MHz**
Cellular Mobile Radio		840 MHz to 935 MHz

Bandwidth of transmission medium

Analog Signals

6. Bandwidth

- Apsara Radio FM 97
- Angel Radio 96.3Mhz Kampot
- Dance Radio 96.6Mhz
- DAP Radio FM 93.75
- Family FM 99.5
- Hang Meas Radio FM 104.5
- Koh Santepheap Daily FM 87.75
- National Radio Kampuchea
- Phnom Penh Radio FM 103
- Radio FM 90.5
- Radio Beehive FM 105
- DaunPenh eFM 87.50Mhz
- ABC News FM 107.5
- Lotus Radio FM 100.5hz
- Radio Free Asia
- Radio Khmer FM 107
- Radio Love FM 97.5
- Radio Town FM 102.3 MHz
- Raksmey Hang Meas Radio FM 95.7000
- Royal Cambodia Armed Forces Radio FM 98
- Voice of America Khmer
- Women's Media Centre of Cambodia (WMC) Radio FM 102

Radio Frequency division in Phnom Penh

Analog vs Digital

Comparison element	Analog signal	Digital signal
Analysis	Difficult	Possible to analyze
Representation	Continuous	Discontinuous
Accuracy	More accurate	Less accurate
Storage	Infinite memory	Easily stored
Subject to Noise	Yes	No
Recording Technique	Original signal is preserved	Samples of the signal are taken and preserved
Examples	Human voice, Analog phones e.t.c	Computers, Digital Phones, e.t.c

Q&A