

Signals and Systems

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Course Overview

- Tentative Schedule

#	Topic	Assignment
1	Introduction	
2	Representing Signals	#1
3	Continuous-Time System	
4	Complex Numbers	
5	Fourier Series	
6	Fourier Transform	
7	Fourier Analysis of Discrete-Time System	

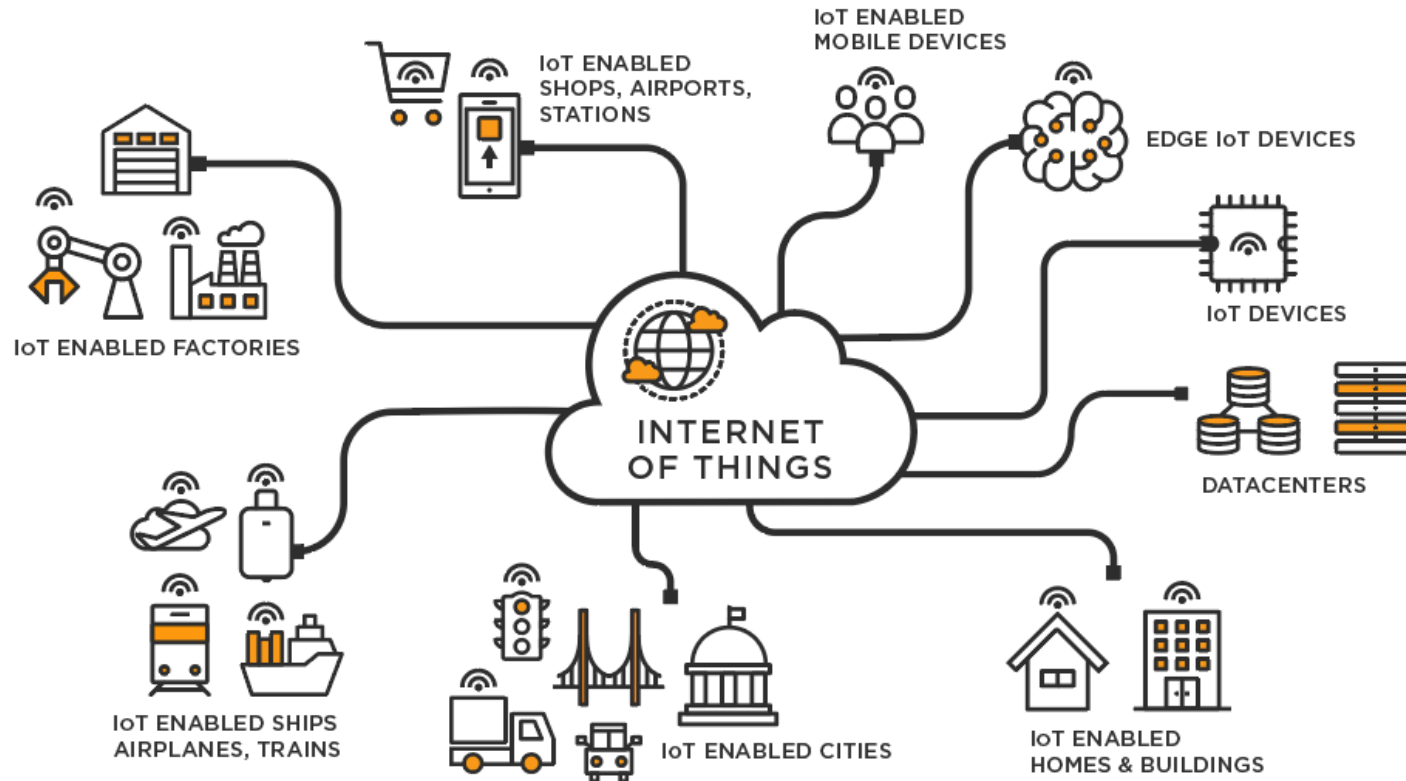
1. Introduction

Course Objectives

Overview

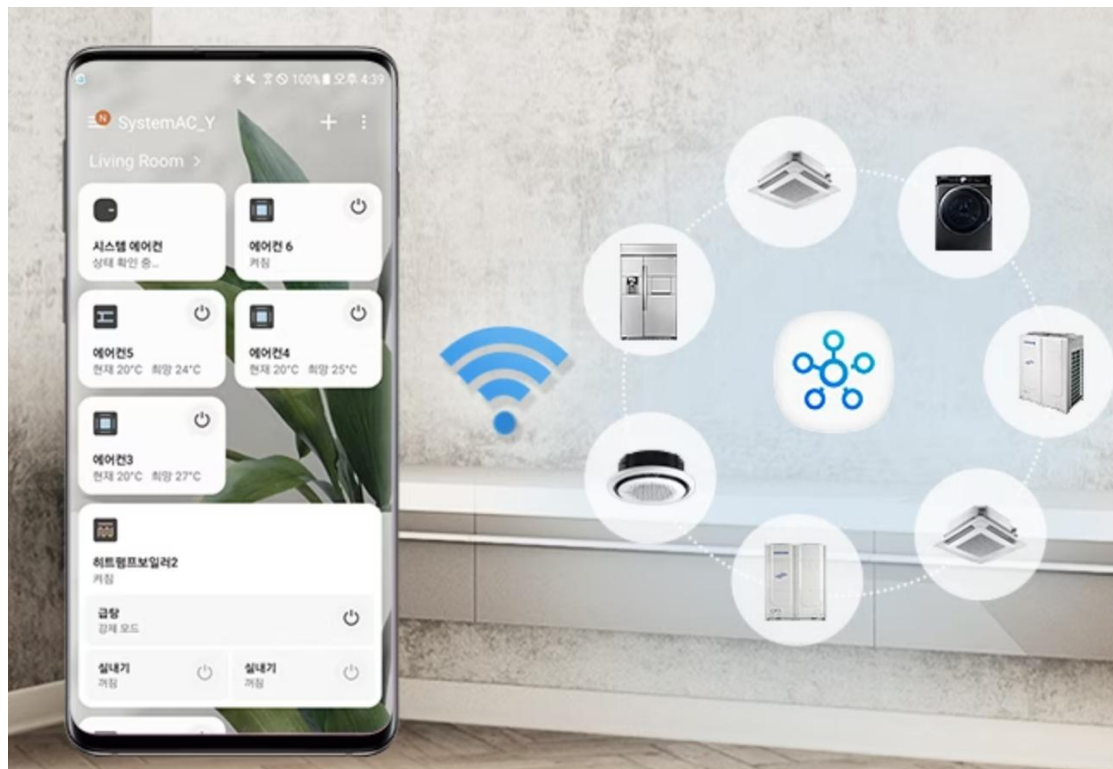
Course Objectives

- Example: Internet of Things
 - is a **computer system** that has a **dedicated function** within a larger mechanical or electronic system



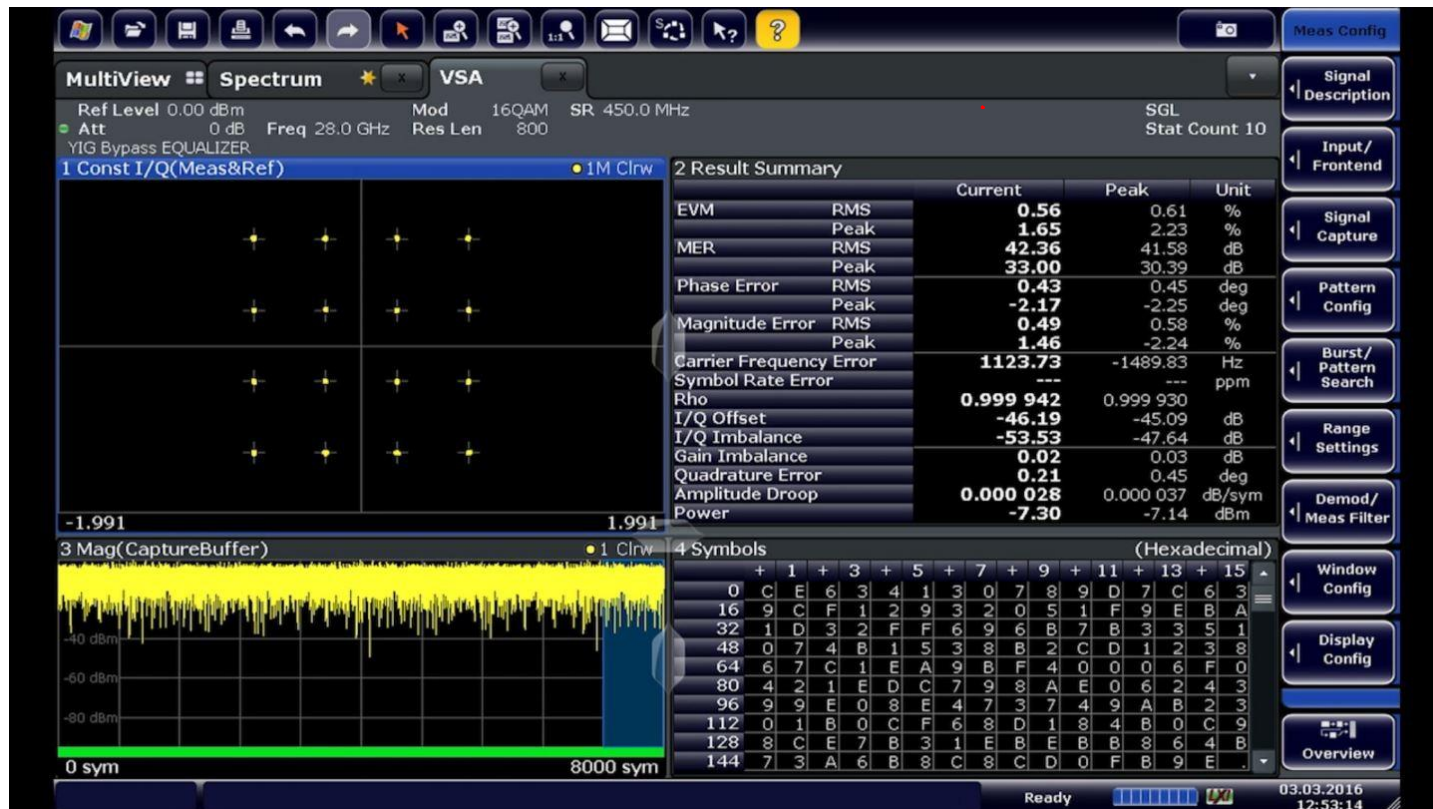
Course Objectives

- We communicate using "signals"
 - Wireless, wired, language, bits, bytes, numbers, figures, ...



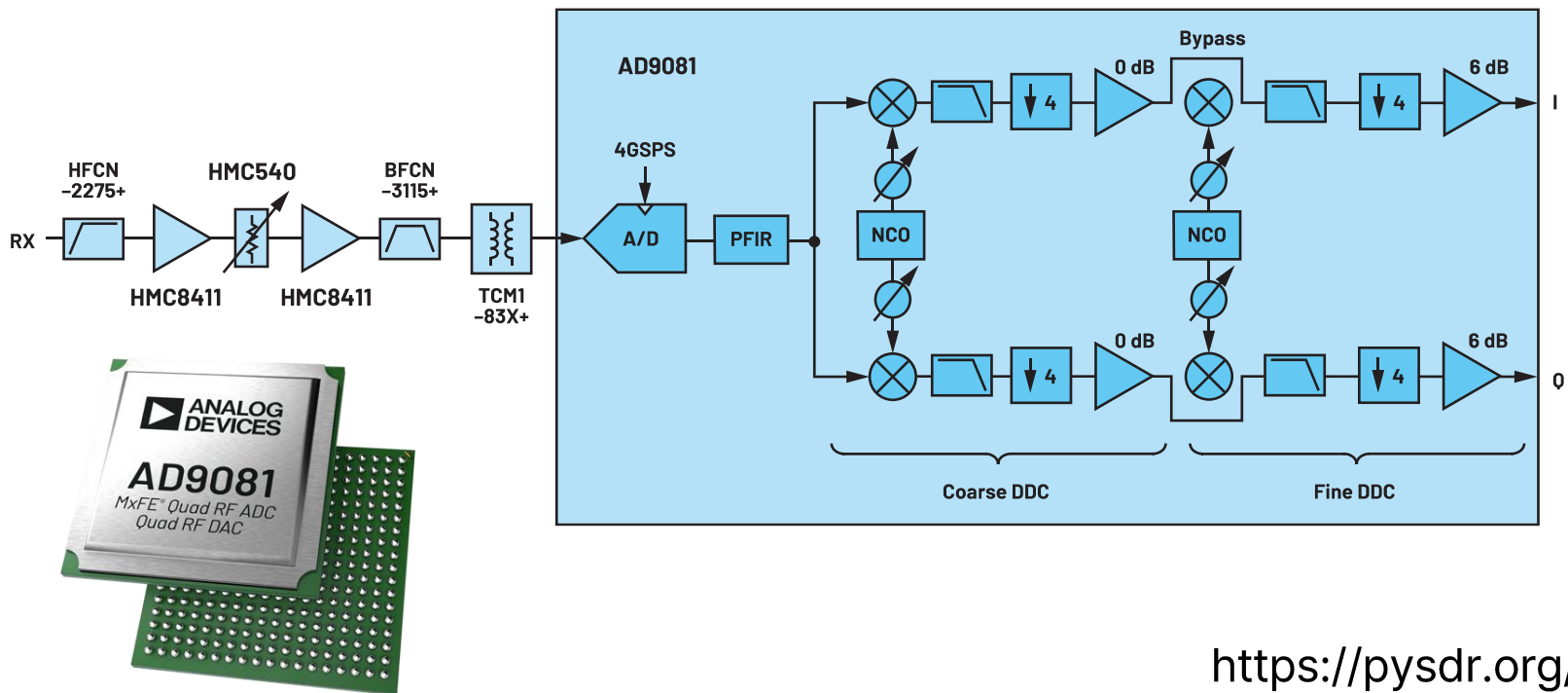
Course Objectives

- What signal is used for wireless communication?
 - We will learn this in **Wireless Embedded Systems**.



Course Objectives

- Signals are "controlled"
 - By (microwave) circuit : Physical interaction
 - By digital signal processing : Calculation



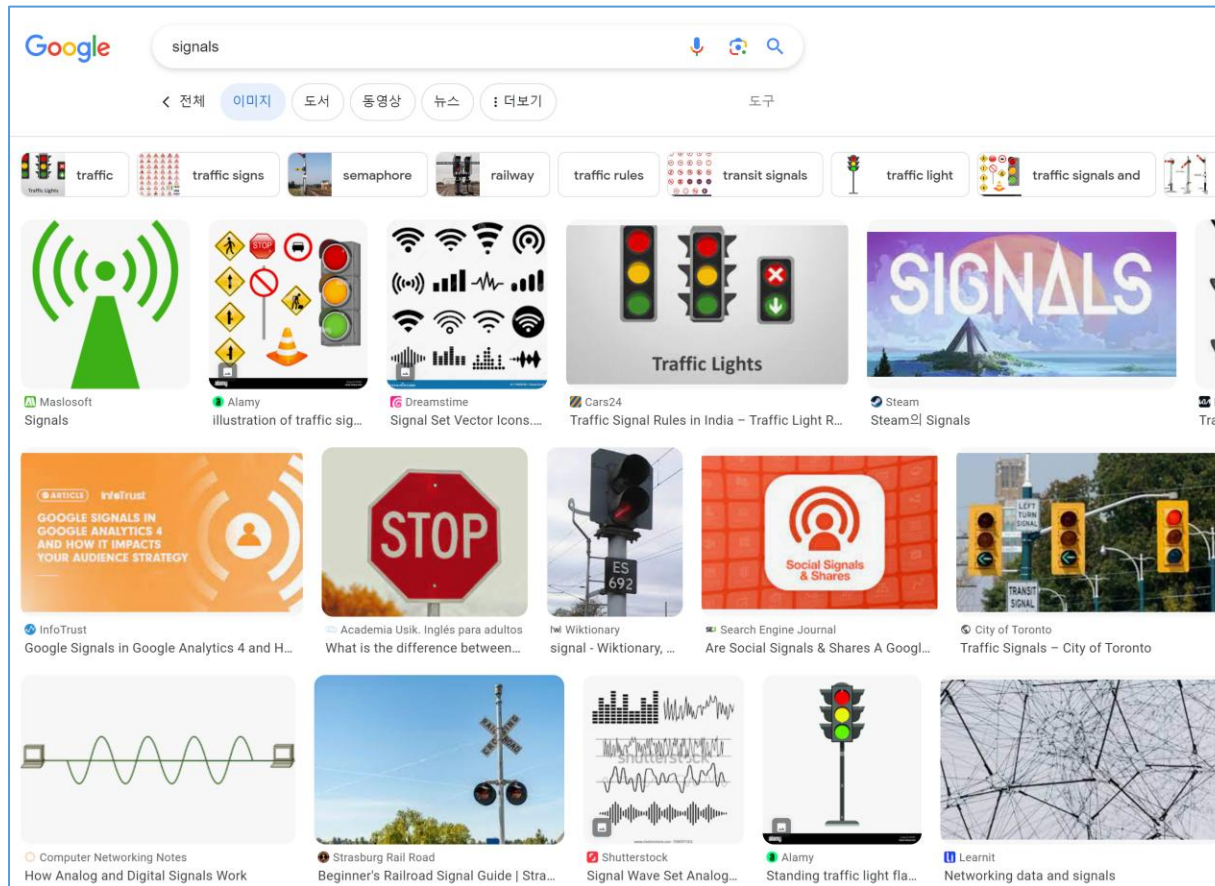
<https://pysdr.org/>

2. Representing Signals

What are Signals?

Representing Signals

- What are Signals?



Representing Signals

• What are Signals?



신호란 무엇인가?



다른 답안 보기



신호란 시간에 따라 변화하는 어떤 물리적 현상을 함수 형태로 표현한 것입니다. 신호는 통신, 전기공학, 컴퓨터공학, 신호처리 등 다양한 분야에서 사용됩니다.

신호는 크게 연속시간 신호와 이산시간 신호로 나눌 수 있습니다. 연속시간 신호는 시간의 모든 값에 대해 정의된 신호이고, 이산시간 신호는 시간의 일부 값에만 정의된 신호입니다.

신호는 또한 아날로그 신호와 디지털 신호로 나눌 수 있습니다. 아날로그 신호는 연속적인 값을 갖는 신호이고, 디지털 신호는 이산적인 값을 갖는 신호입니다.

신호는 다양한 특성으로 분류할 수 있습니다. 대표적인 특성으로는 다음과 같은 것들이 있습니다.

- 주기성: 주기적인 신호는 일정한 주기를 갖는 반면, 비주기적인 신호는 일정한 주기를 갖지 않습니다.
- 진폭: 신호의 최대값과 최소값의 차이를 진폭이라고 합니다.
- 위상: 신호의 위상은 진폭의 양의 방향으로부터의 위상차를 나타냅니다.
- 주파수: 주파수는 신호의 주기의 역수입니다.

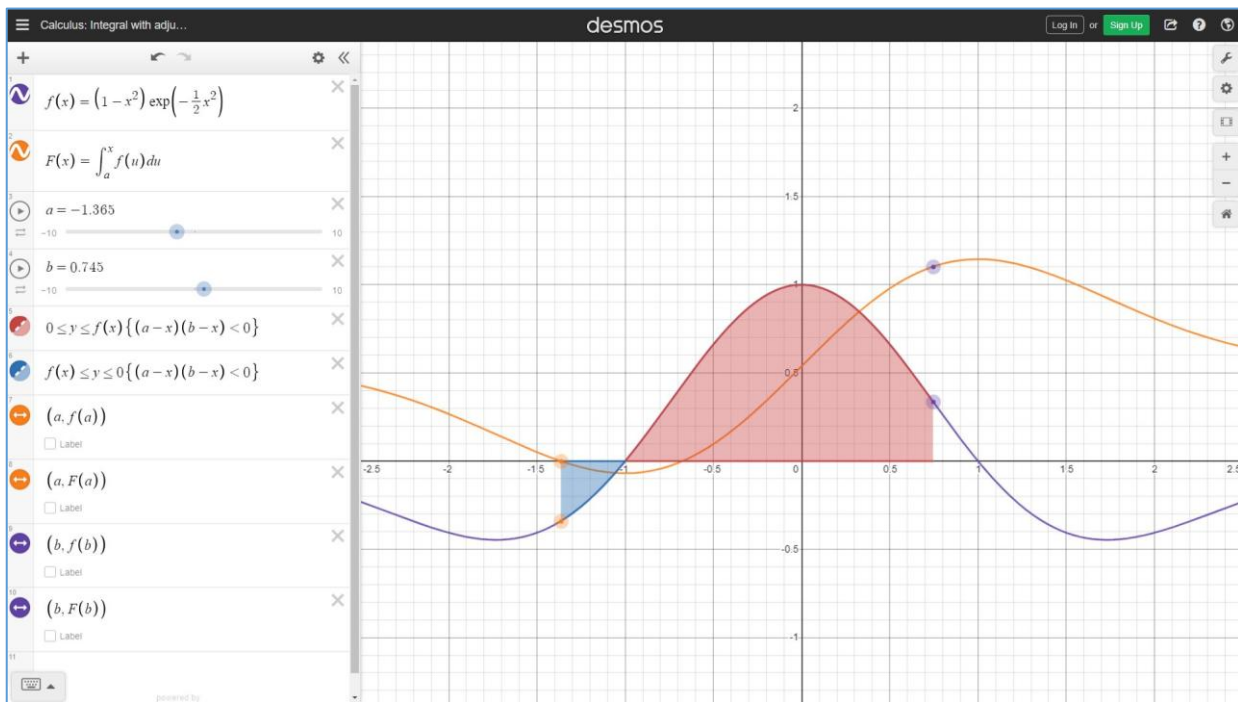
신호는 다양한 방식으로 처리될 수 있습니다. 신호 처리는 신호의 특성을 이해하고, 원하는 정보를 추출하기 위해 수행하는 작업입니다. 신호 처리에는 필터링, 변환, 추론 등이 포함됩니다.

신호는 다양한 분야에서 사용됩니다. 통신에서는 신호를 통해 정보를 전송하고 수신합니다. 전기공학에서는 신호를 통해 전력을 전송하고 제어합니다. 컴퓨터공학에서는 신호를 통해 데이터를 처리하고 분석합니다. 신호처리에서는 신호의 특성을 이해하고, 원하는 정보를 추출합니다.

Representing Signals

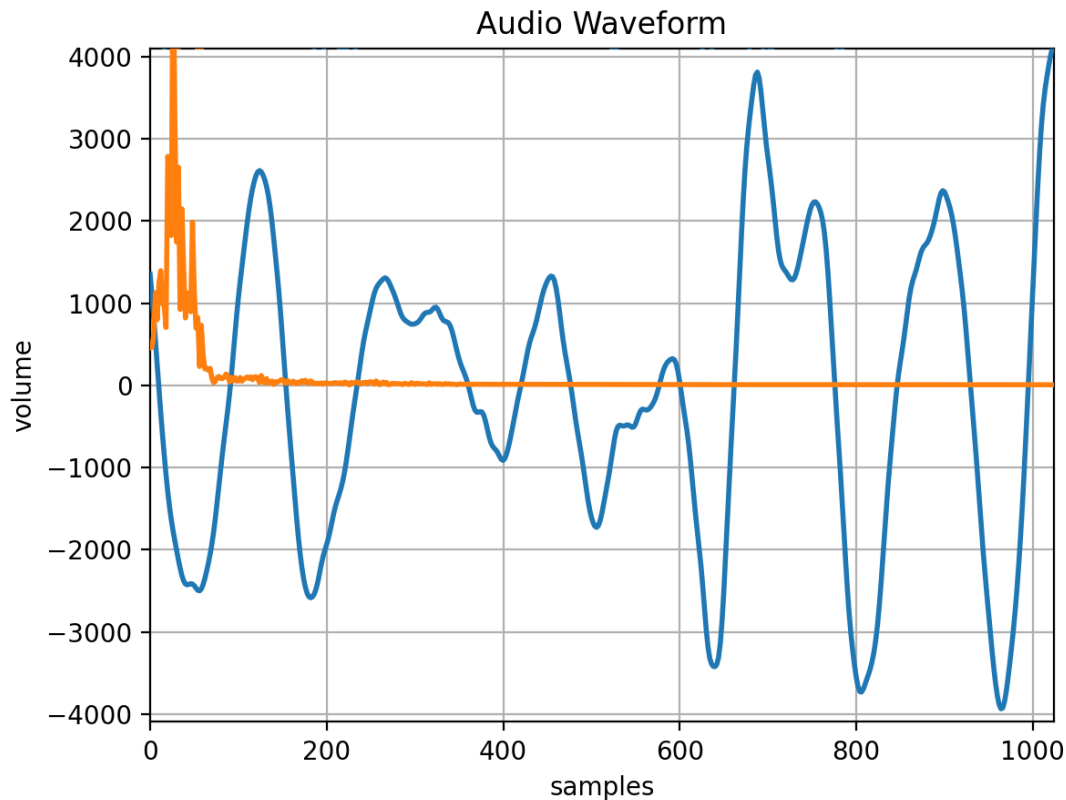
- What are Signals?

- 시간에 따라 변화하는 (Time-varying) Δ
- 물리적 현상 (Physical quantity) $\checkmark$
- 함수 (Function) $\checkmark$



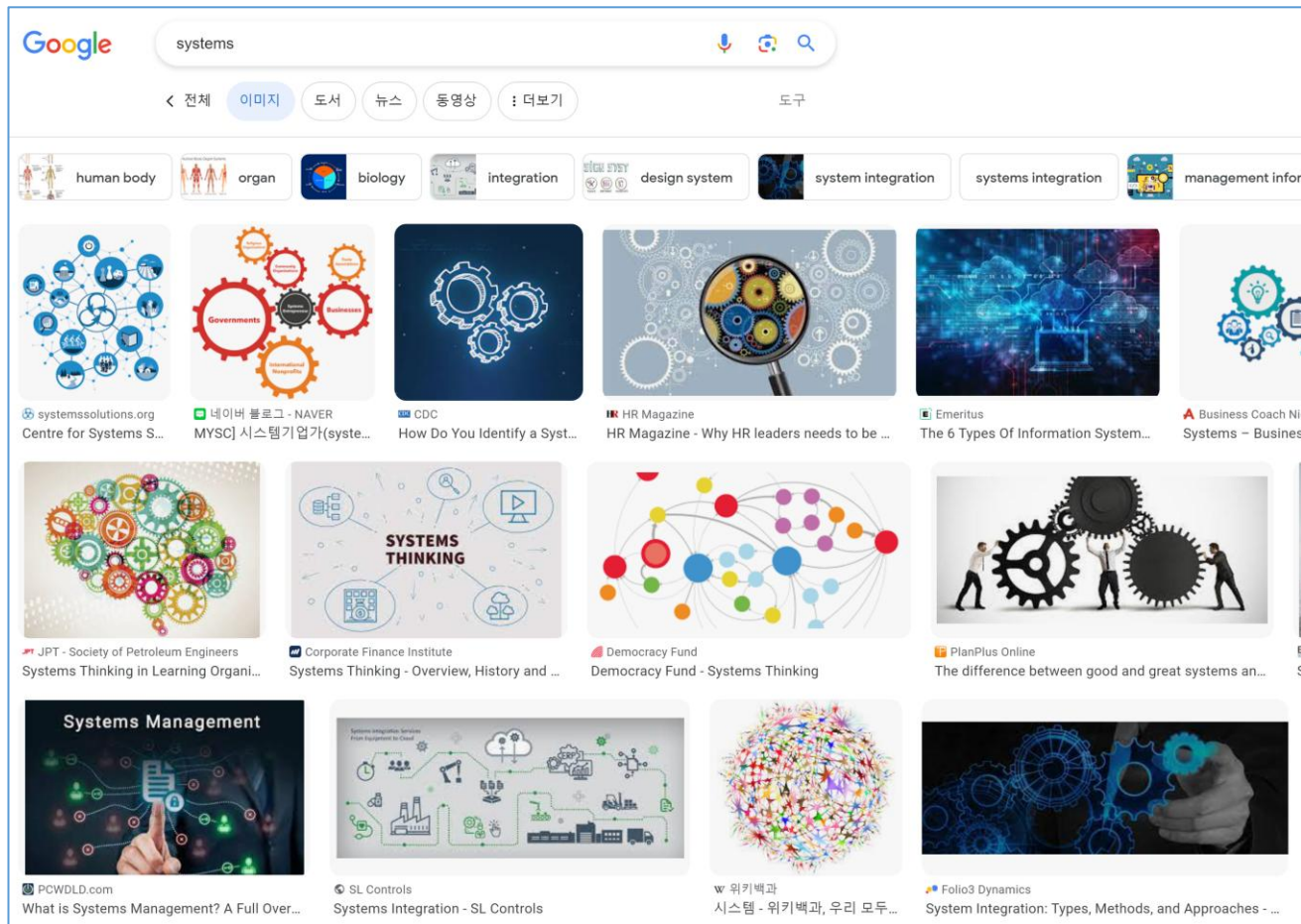
Representing Signals

- What are Signals?
 - Demo: Python Audio Waveform and its Frequency



Representing Signals

- What are Systems?



Representing Signals

• What are Systems?

 시스템은 무엇인가?



다른 답안 보기 



 시스템은 서로 관련된 요소들이 상호작용하여 하나의 목적을 달성하는 유기적인 집합체입니다. 시스템은 자연계에도 존재하고, 인위적으로 만들어지기도 합니다.

시스템은 크게 자연적 시스템과 인위적 시스템으로 나눌 수 있습니다. 자연적 시스템은 인간의 개입 없이 자연적으로 발생하는 시스템입니다. 예를 들어, 생태계, 기후 시스템, 지구 물리 시스템 등이 자연적 시스템에 속합니다.

인위적 시스템은 인간에 의해 만들어진 시스템입니다. 예를 들어, 자동차, 컴퓨터, 공장, 사회, 경제 시스템 등이 인위적 시스템에 속합니다.

시스템은 다음과 같은 특징을 가지고 있습니다.

- 상호작용: 시스템의 구성 요소들은 서로 영향을 미치며 상호작용합니다.
- 목적성: 시스템은 하나의 목적을 달성하기 위해 존재합니다.
- 복잡성: 시스템은 구성 요소의 수와 상호작용의 복잡성으로 인해 복잡합니다.

시스템은 다양한 분야에서 사용됩니다. 공학, 과학, 경영, 경제, 사회학, 정치학, 심리학 등 다양한 분야에서 시스템의 개념과 원리가 적용됩니다.

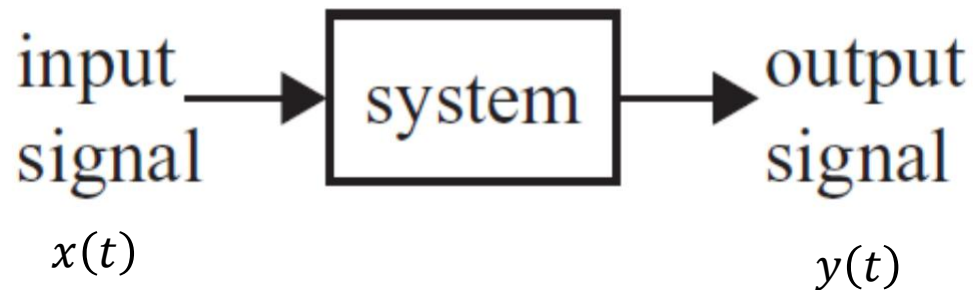
시스템은 다양한 방식으로 분석할 수 있습니다. 시스템 분석은 시스템의 구성 요소, 상호작용, 목적 등을 파악하여 시스템을 이해하는 과정입니다. 시스템 분석에는 다양한 도구와 방법이 사용됩니다.

시스템은 다양한 목적으로 사용됩니다. 시스템은 문제를 해결하고, 효율성을 높이고, 새로운 것을 창조하는 데 사용됩니다.

시스템은 우리 삶의 모든 영역에 존재합니다. 시스템을 이해하고 활용함으로써 우리는 세상을 더 잘 이해하고, 더 나은 삶을 만들어 갈 수 있습니다.

Representing Signals

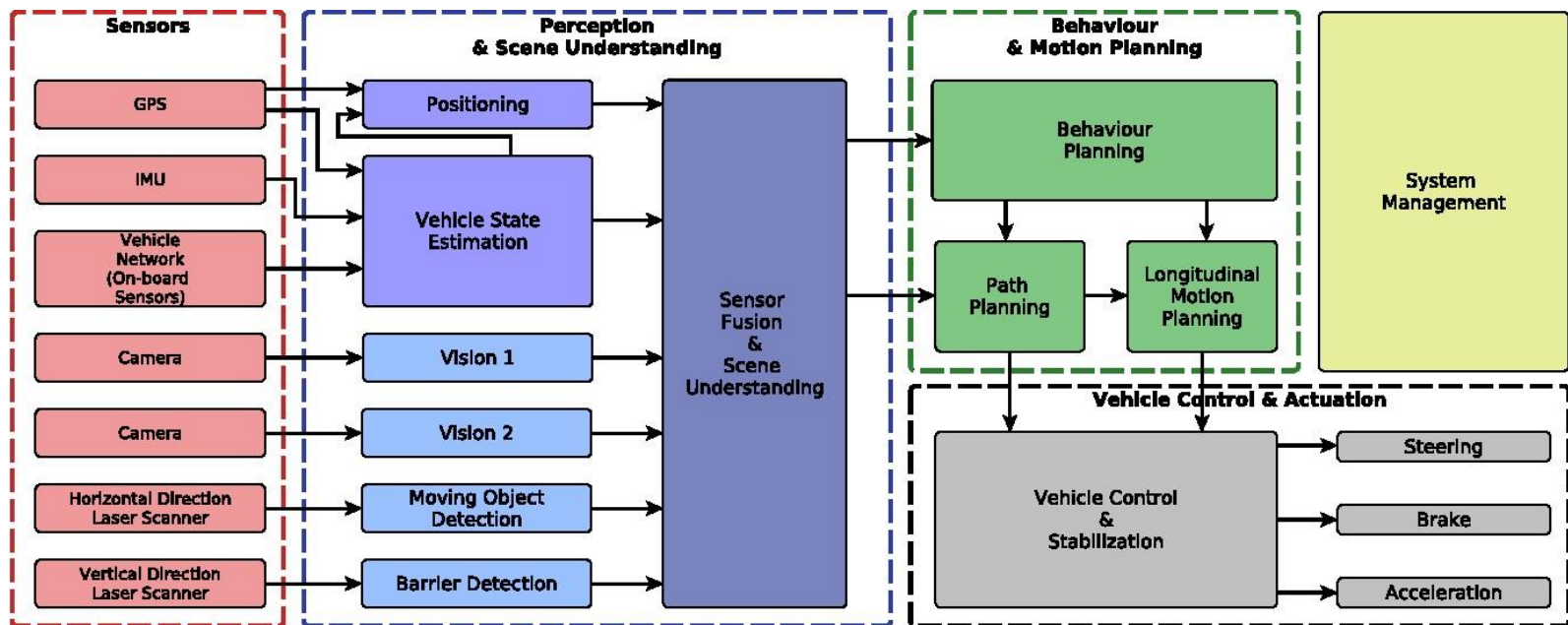
- What are Systems?
 - An entity that processes and produces a set of signals.
 - A function of signal?



- A simple linear function $y = ax + b$
- A linear system $y(t) = ax(t) + b$

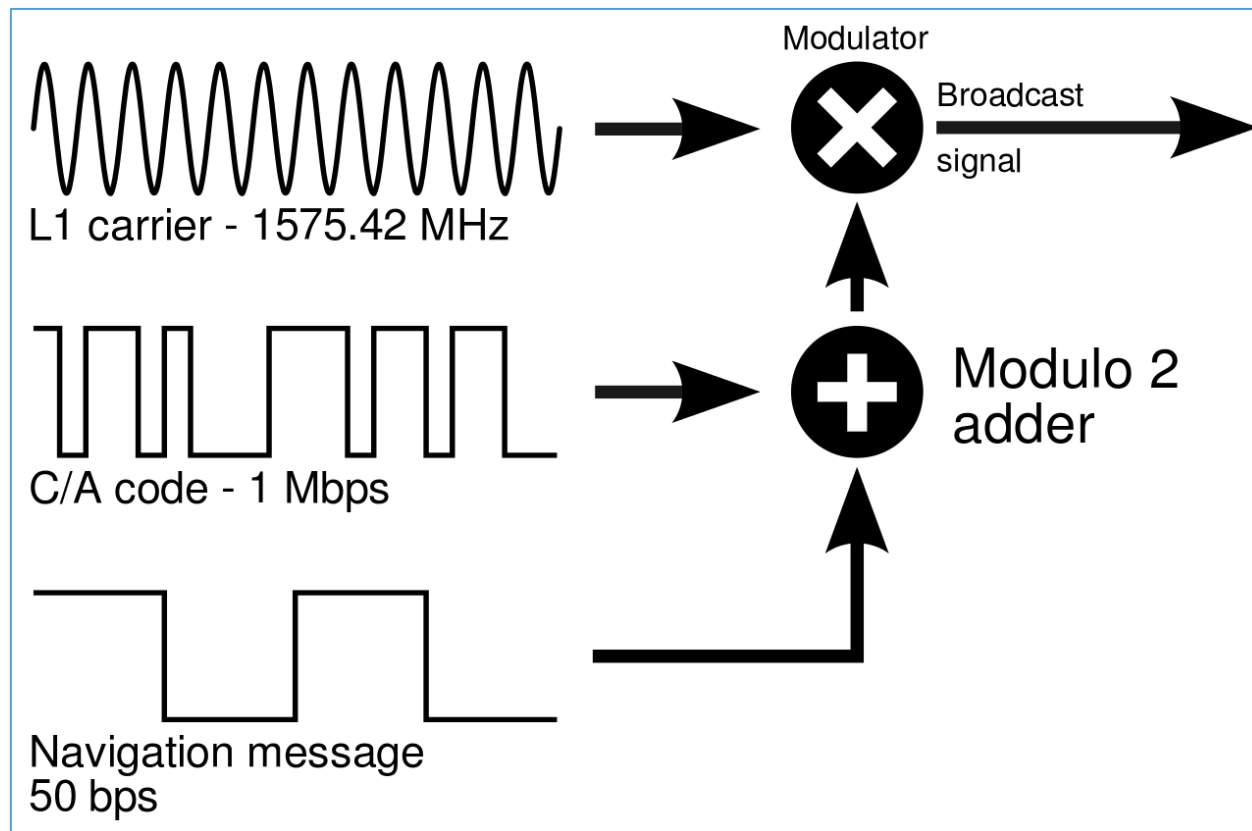
Representing Signals

- What are Systems?
 - Example: Autonomous Driving System
 - Input: A set of **signals** from sensor
 - Output: A control **signal set**



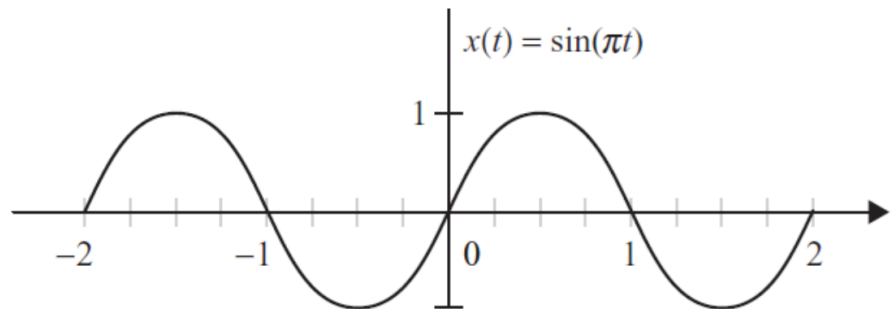
Representing Signals

- Classification of signals
 - GPS Signal: Analog & Digital Signals

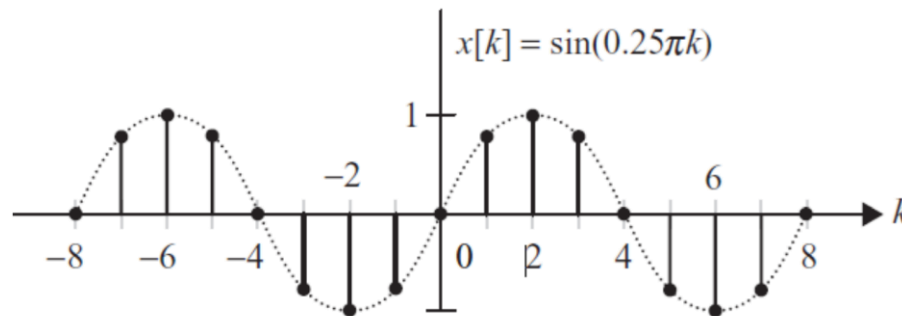


Representing Signals

- Classification of signals
 - Continuous Signals : in real world & mathematical

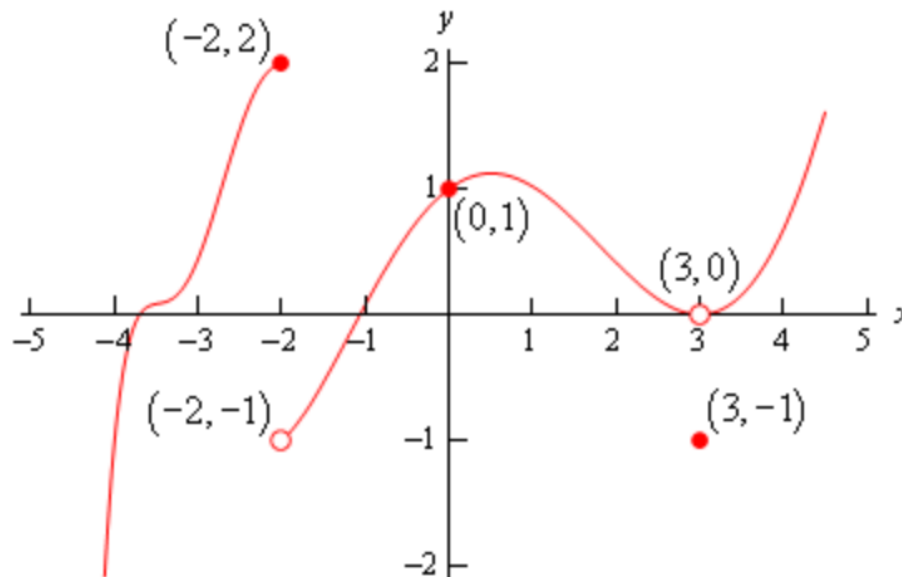


- Discrete Signals : in digital domain (computer)



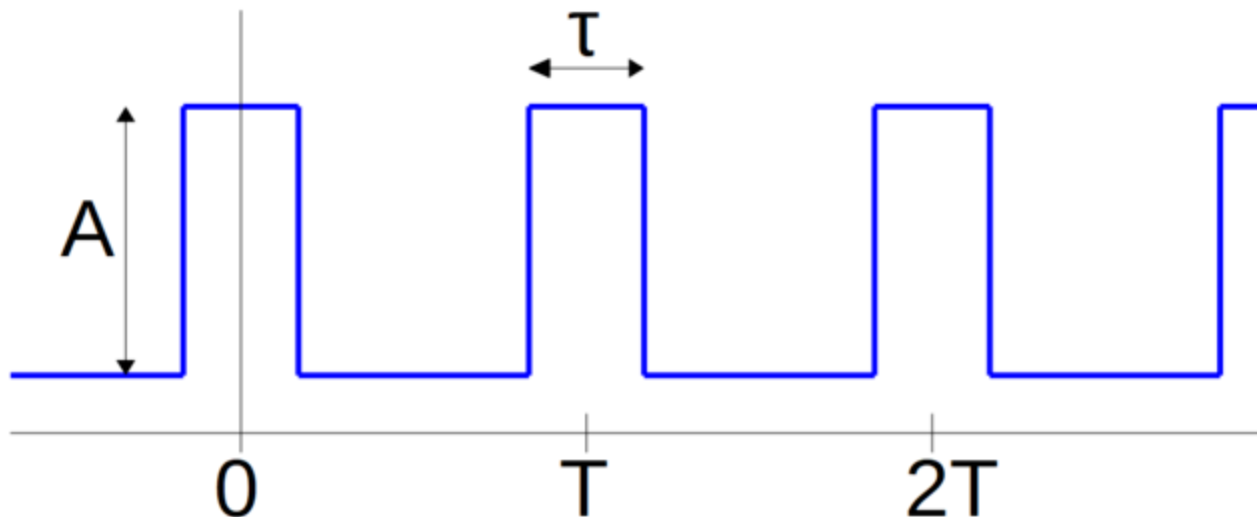
Representing Signals

- Classification of signals
 - Continuous Signals : **Continuity (연속성)**
 - $f(a)$ **is defined**
 - $\lim_{x \rightarrow a} f(x)$ **exists.**
 - $\lim_{x \rightarrow a} f(x) = f(a)$



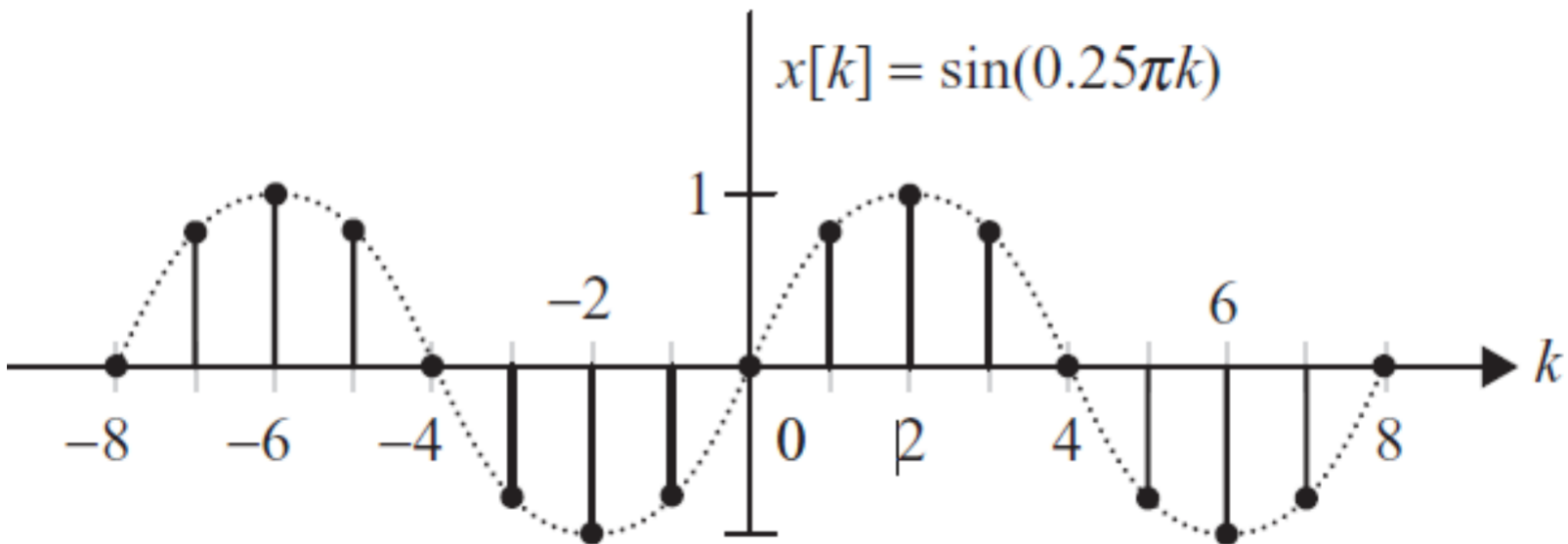
Representing Signals

- Classification of signals
 - Example: A pulse train
 - Rectangular function **rect(t)**
 - Piecewise Continuous



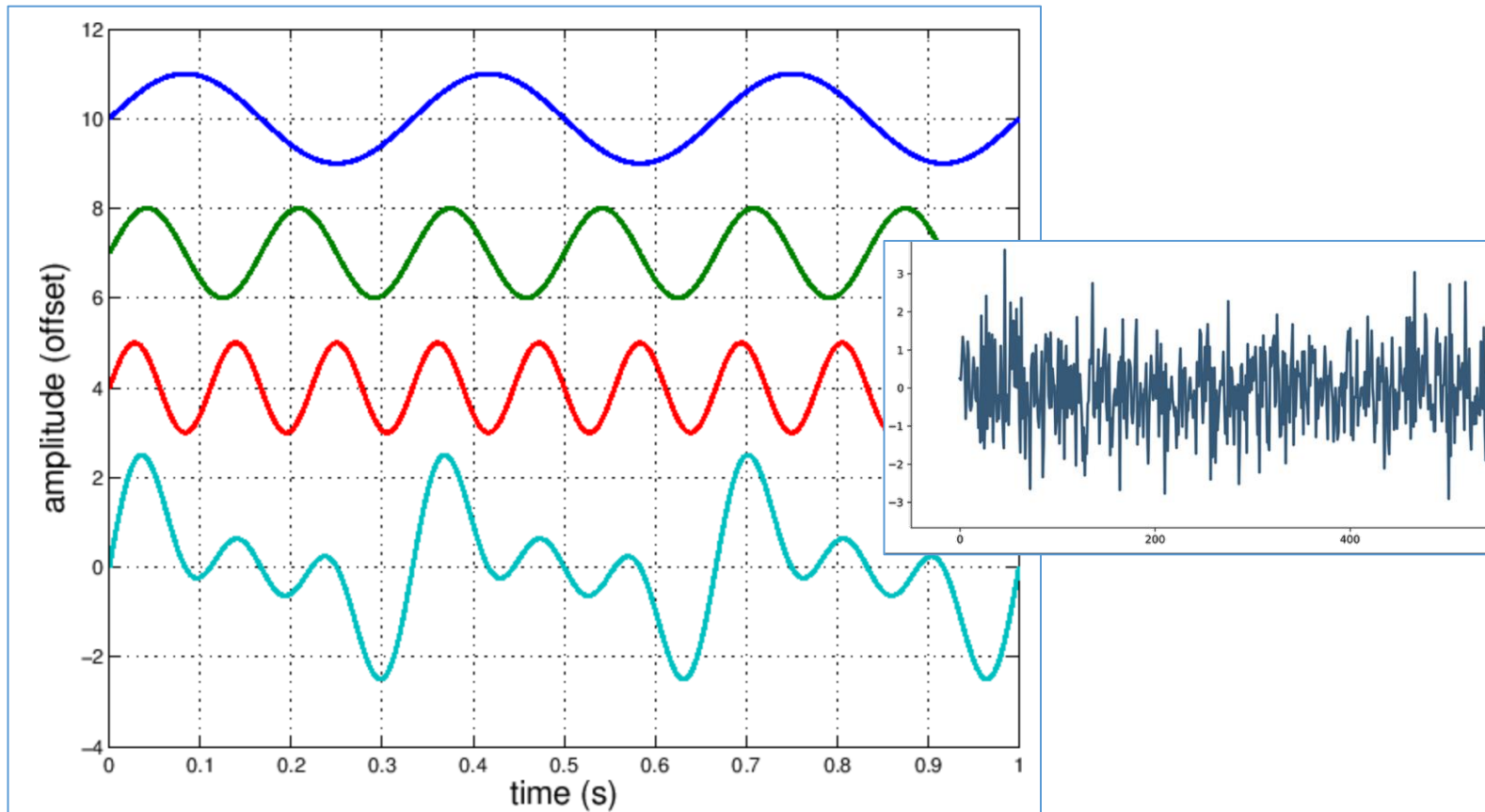
Representing Signals

- Classification of signals
 - Discrete-Time Signals
 - The signal exists only when $t = kT_s$
 - What is T_s for below signal?



Representing Signals

- Classification of signals
 - Periodic Signals : $x(t) = x(t + nT)$



Representing Signals

- Classification of signals

- Q. The sum of two periodic signals will be periodic?

- $x(t) = x_1(t) + x_2(t)$

- $x_1(t) = x_1(t + kT_1)$

- $x_2(t) = x_2(t + lT_2)$

- If the summed signal is periodic with T , $x(t) = x(t + T)$

- $x(t + T) = x_1(t + T) + x_2(t + T) = x_1(t + kT_1) + x_2(t + lT_2)$

 $T = kT_1 = lT_2 \quad T_1/T_2 = (\text{rational number})$

1. The new period will be LCM(Least Common Multiple) of T_1 and T_2
2. If the ratio is irrational number, then not periodic.

Representing Signals

- Classification of signals
 - Q1. The sum of two periodic signals will be periodic?
 - $x(t) = x_1(t) + x_2(t)$
 - $x_1(t) = \cos(t)$
 - $x_2(t) = \sin(2.5t)$

Representing Signals

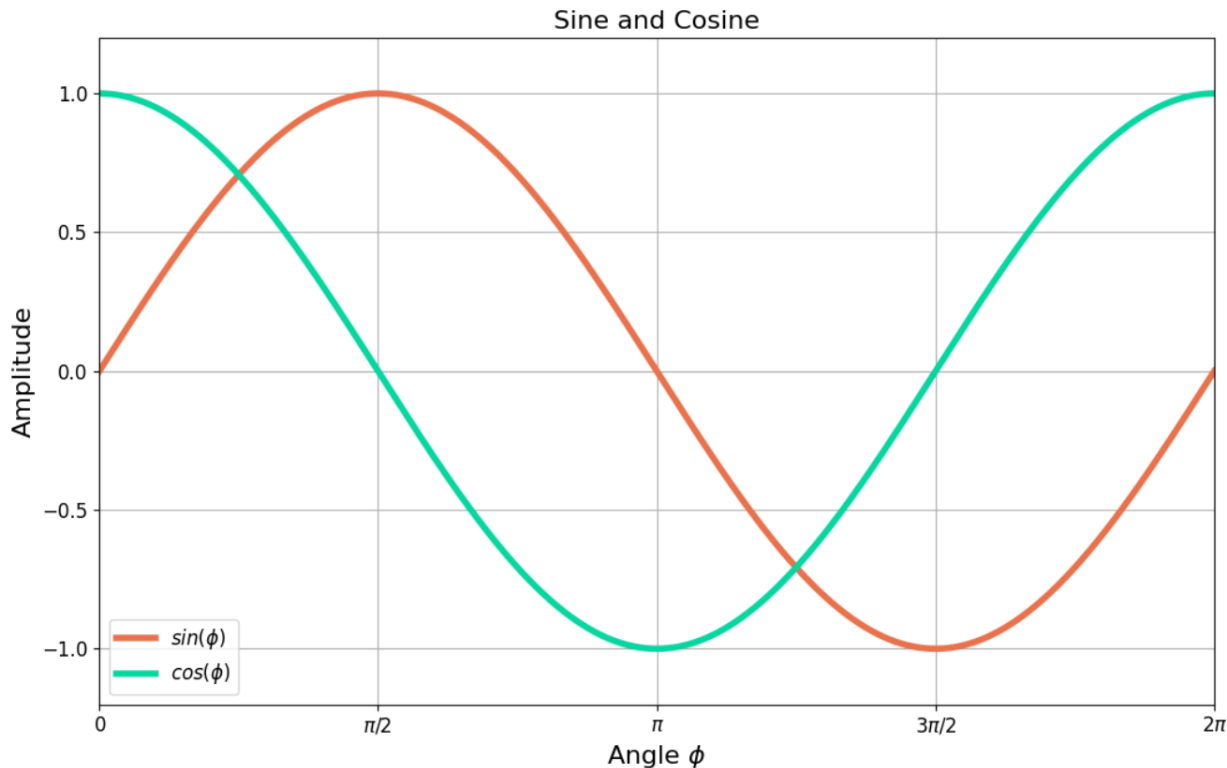
- Classification of signals
 - Q2. The sum of two periodic signals will be periodic?
 - $x(t) = x_1(t) + x_2(t)$
 - $x_1(t) = \cos(t)$
 - $x_2(t) = \sin(\sqrt{3} \cdot t)$

Representing Signals

- Classification of signals
 - Q3. The sum of two periodic signals will be periodic?
 - $x(t) = x_1(t) + x_2(t)$
 - $x_1(t) = \cos(\sqrt{12} \cdot t)$
 - $x_2(t) = \sin(\sqrt{3} \cdot t)$

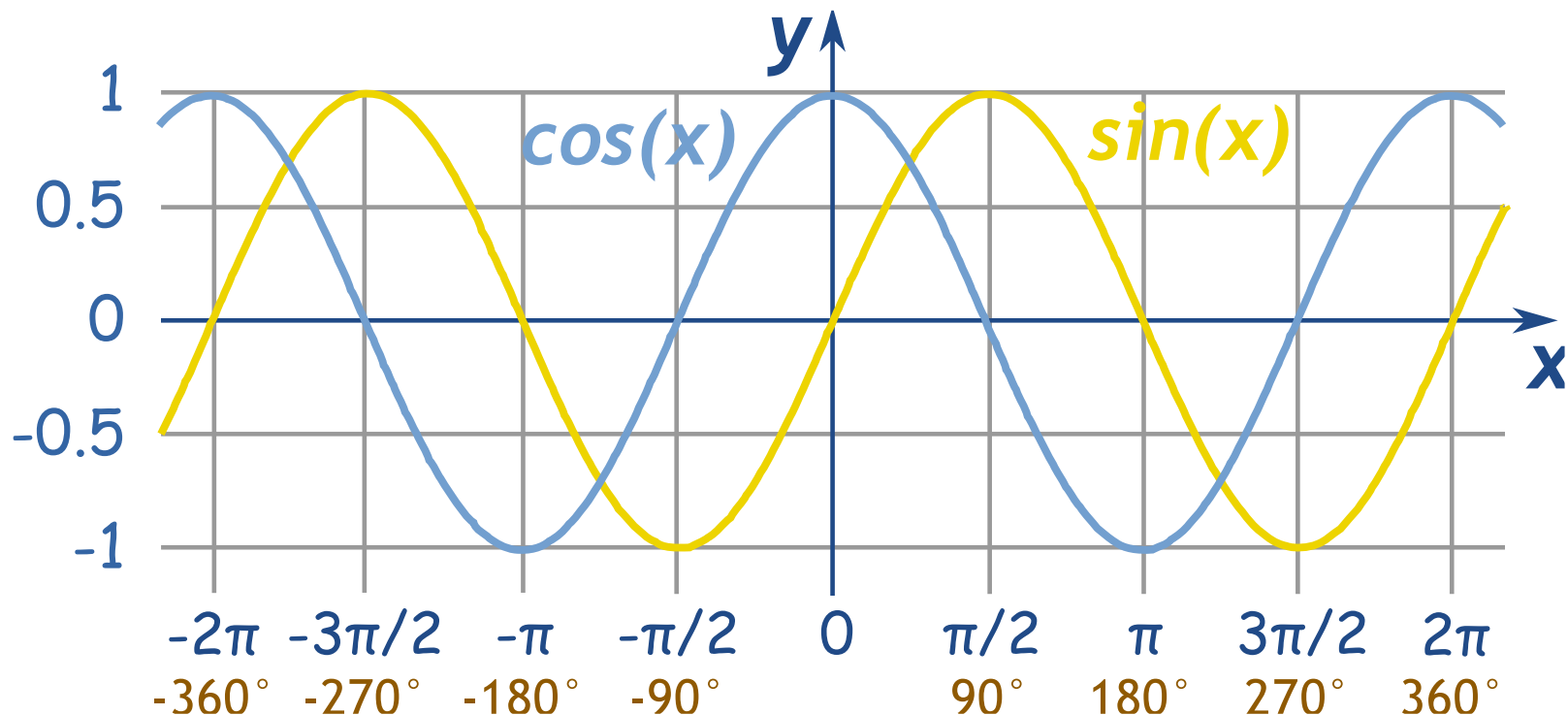
Representing Signals

- Classification of signals
 - A sinusoidal signal : Amplitude, Phase, Frequency



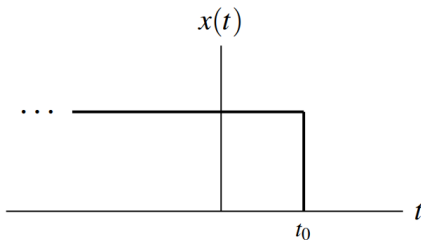
Representing Signals

- Classification of signals
 - Symmetrical functions : odd and even

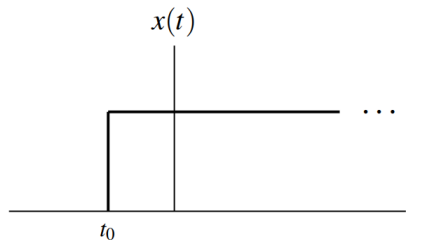


Representing Signals

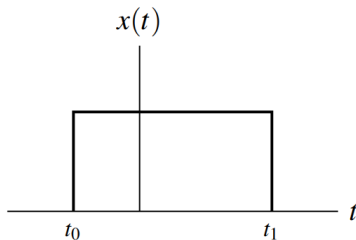
- Classification of signals
 - Misc. Properties
 - Left-sided/Right-sided/time limited
 - Causality ($x(t) = 0$ for all $t < 0$)
 - Bounded



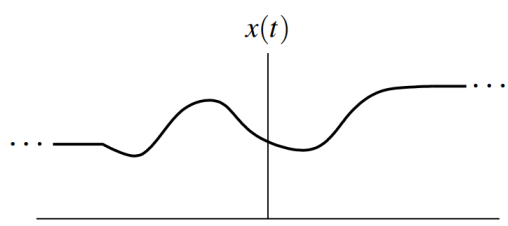
(a)



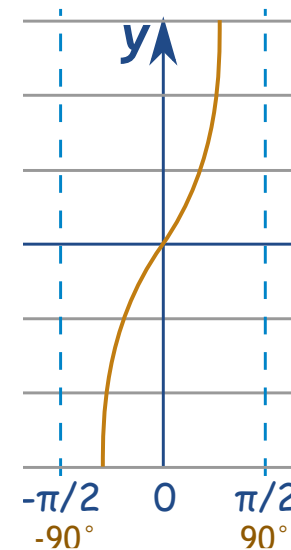
(b)



(c)

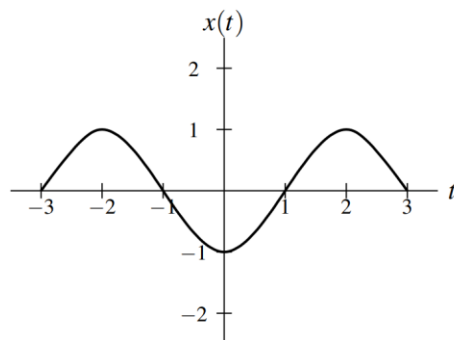


(d)

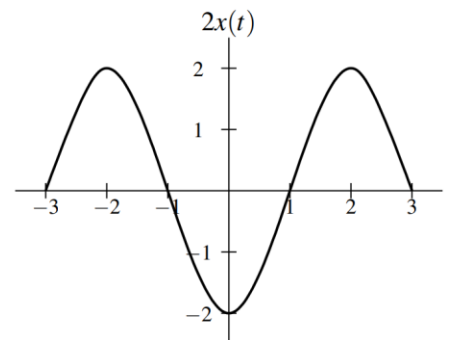


Representing Signals

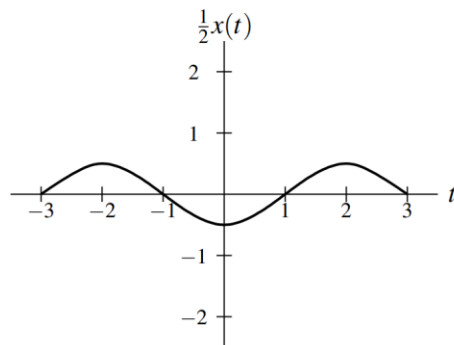
- Transformations of Independent Variable
 - The scaling operation (in amplitude)



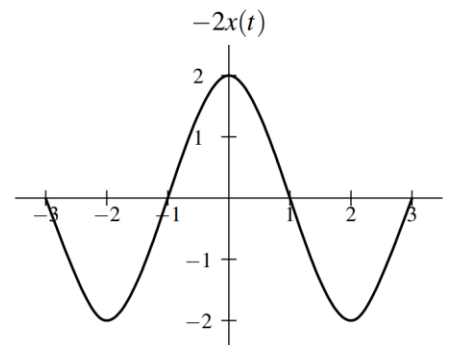
(a)



(b)



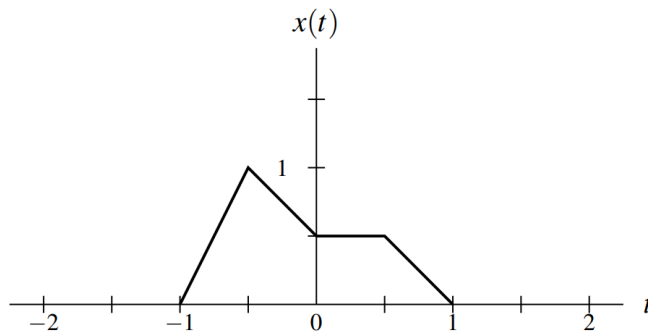
(c)



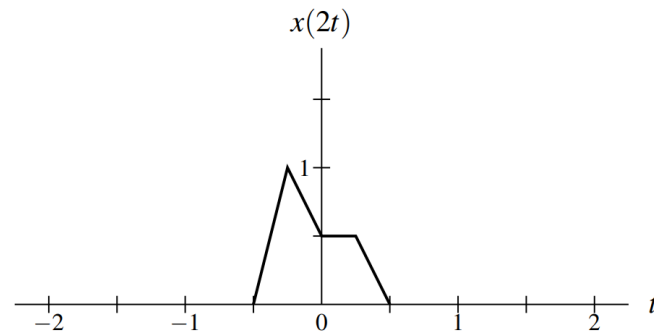
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Representing Signals

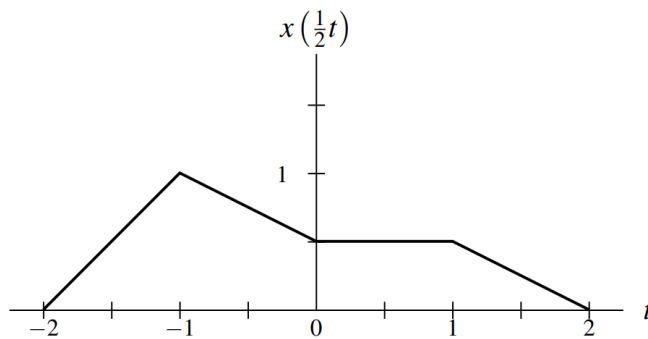
- Transformations of Independent Variable
 - The scaling operation (in time)



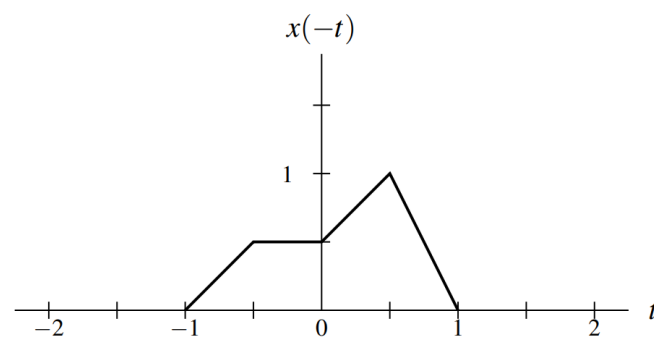
(a)



(b)



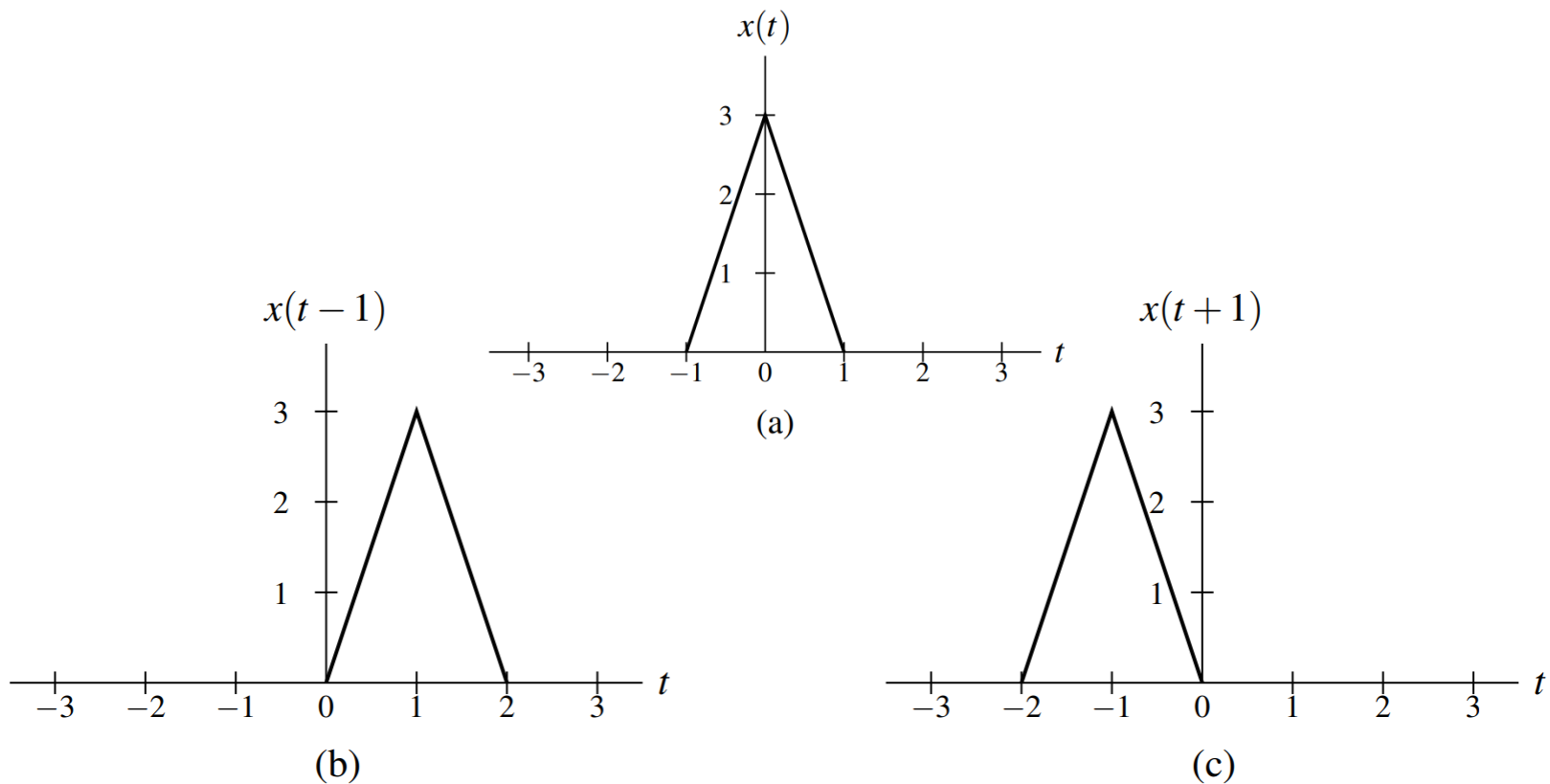
(c)



(d)

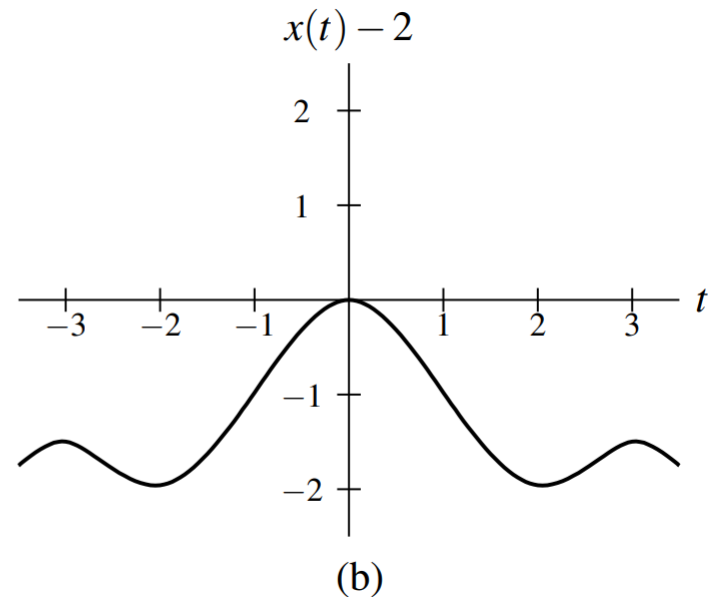
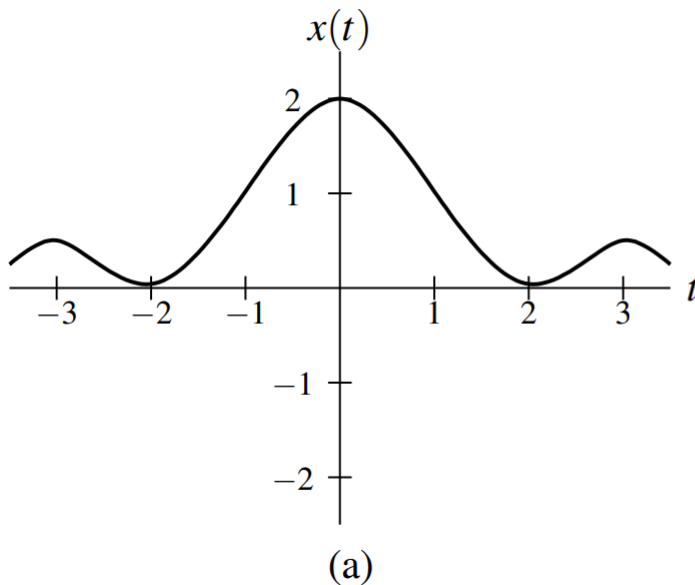
Representing Signals

- Transformations of Independent Variable
 - The shifting operation (in time)



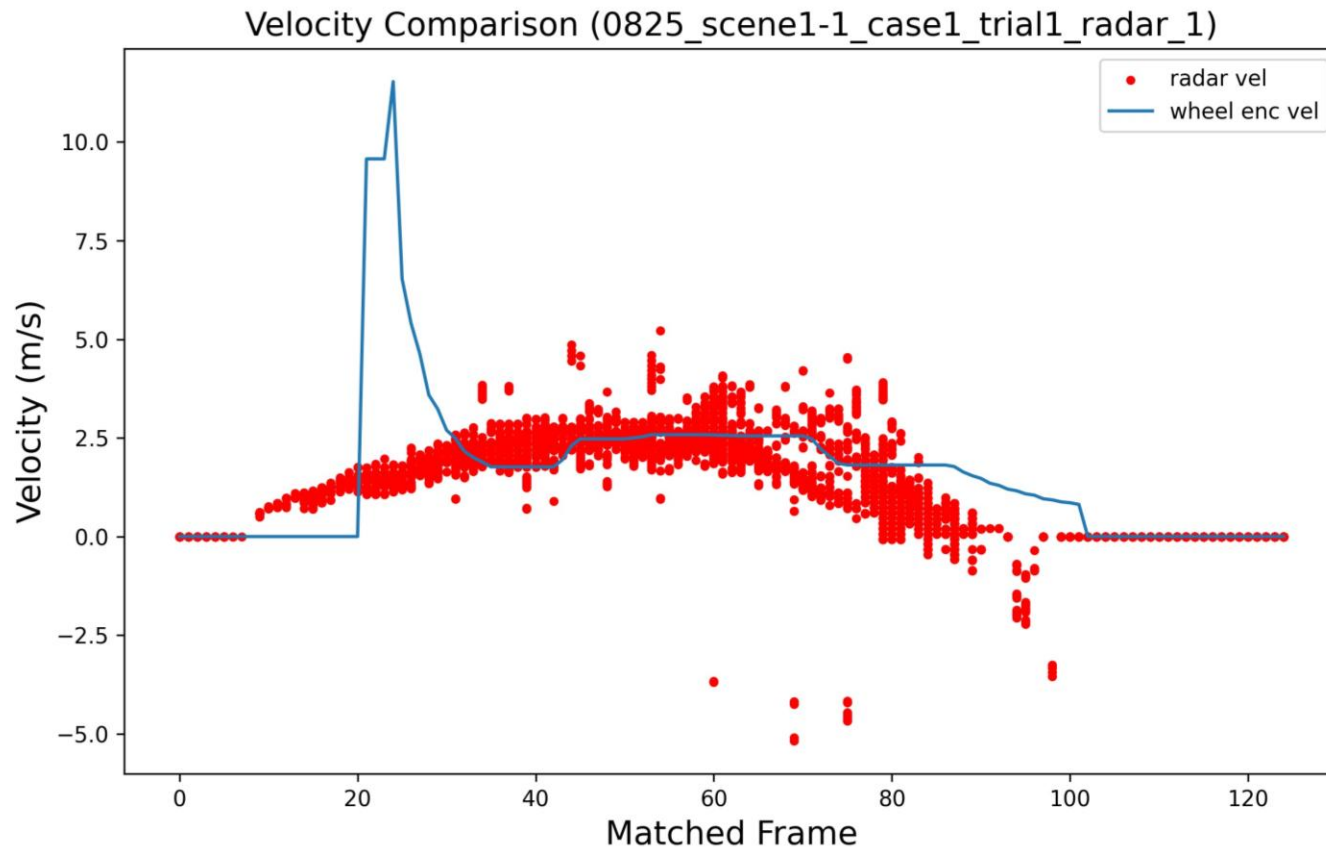
Representing Signals

- Transformations of Independent Variable
 - The shifting operation (in amplitude)



Representing Signals

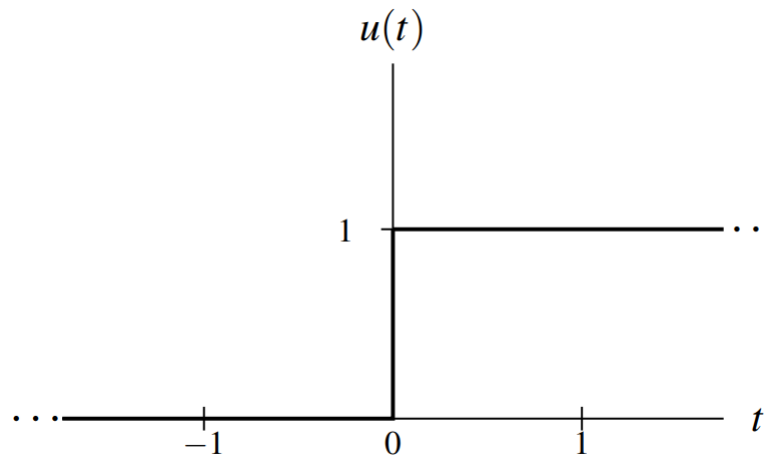
- Transformations of Independent Variable
 - An example: signal from two different sensors



Representing Signals

- Elementary Signals
 - Unit Step Function, $u(t)$
 - Heaviside function

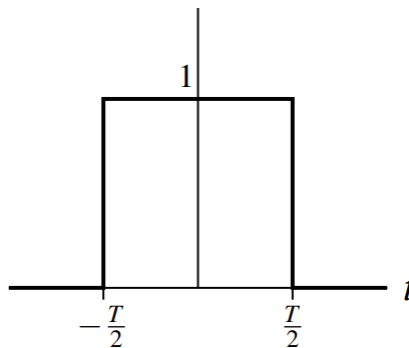
$$u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & \text{otherwise.} \end{cases}$$



Representing Signals

- Elementary Signals
 - Rectangular Function, $\text{rect}(t)$
 - Also called as a pulse signal

$$\text{rect } t = \begin{cases} 1 & -\frac{1}{2} \leq t < \frac{1}{2} \\ 0 & \text{otherwise.} \end{cases}$$

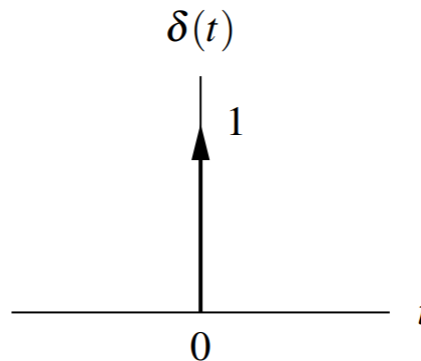


Representing Signals

- Elementary Signals

- Dirac Delta function, $\delta(t)$
- Also called as a (unit-)impulse function.
- *Is it function?*

$$\begin{aligned}\delta(0) &\rightarrow \infty \\ \delta(t) &= 0 \quad \text{for } t \neq 0 \quad \text{and} \\ \int_{-\infty}^{\infty} \delta(t) dt &= 1.\end{aligned}$$

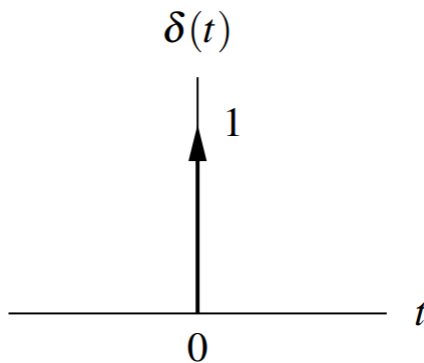


Representing Signals

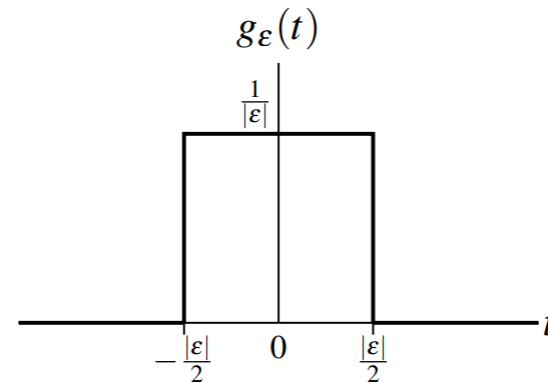
- Elementary Signals

- Dirac Delta function, $\delta(t)$ and pulse function g_ϵ
- *Any similarity?*

$$\delta(t) = 0 \quad \text{for } t \neq 0 \quad \text{and} \\ \int_{-\infty}^{\infty} \delta(t) dt = 1.$$



$$g_\epsilon(t) = \begin{cases} \frac{1}{|\epsilon|} & |t| < \frac{|\epsilon|}{2} \\ 0 & \text{otherwise,} \end{cases}$$

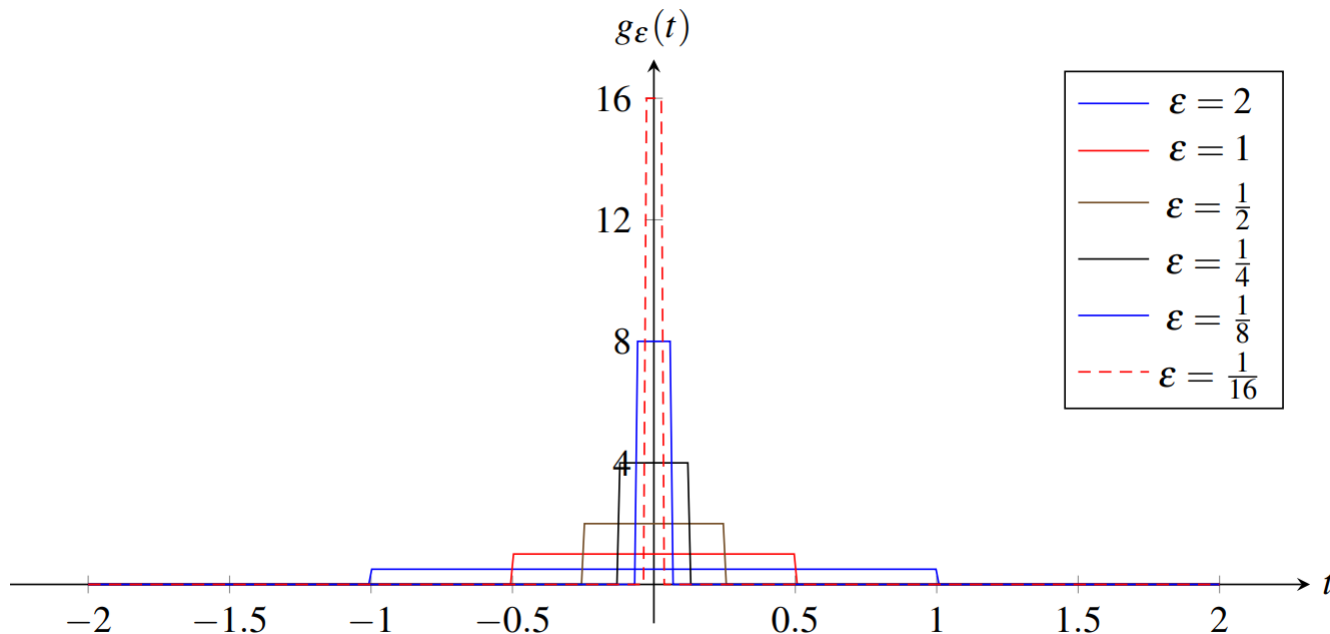


Representing Signals

- Elementary Signals

- Dirac Delta function, $\delta(t)$ and pulse function g_ϵ

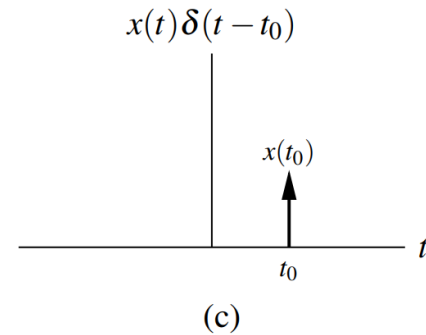
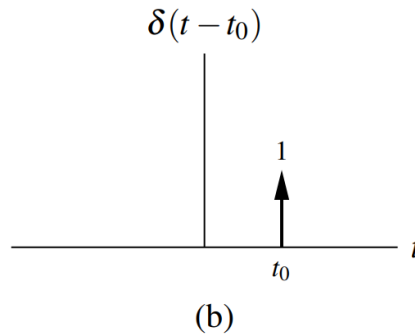
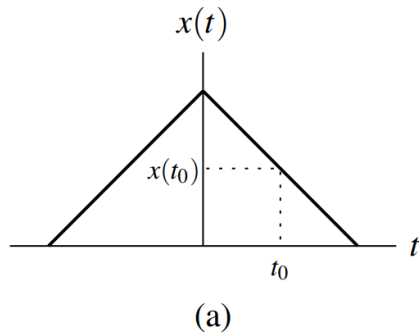
$$\delta(t) = \lim_{\epsilon \rightarrow 0} g_\epsilon(t).$$



Representing Signals

- Elementary Signals
 - Properties of the Dirac Delta function, $\delta(t)$

$$x(t)\delta(t - t_0) = x(t_0)\delta(t - t_0)$$



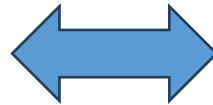
- Sifting (not shifting) property

$$\int_{-\infty}^{\infty} x(t)\delta(t - t_0)dt = x(t_0).$$

Representing Signals

- Elementary Signals
 - Sifting (not shifting) property

$$\int_{-\infty}^{\infty} x(t) \delta(t - t_0) dt = x(t_0).$$



$$x(t) = \int_{-\infty}^{\infty} x(\tau) \delta(t - \tau) d\tau$$

A sum of weighted impulse

$$\int_{-2}^1 (t + t^2) \cdot \delta(t - 3) dt =$$

$$\int_{-2}^4 (t + t^2) \cdot \delta(t - 3) dt =$$

$$\int_0^3 e^{t-2} \cdot \delta(2t - 4) dt =$$

$$\int_{-\infty}^t \delta(\tau) d\tau =$$

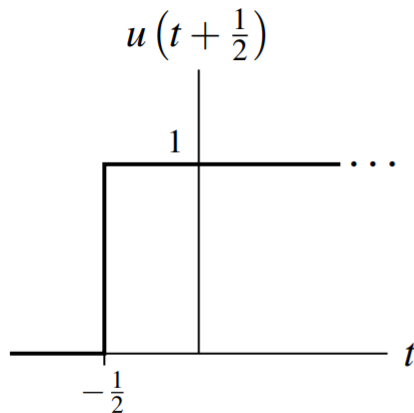
Representing Signals

- Representation of Arbitrary Functions
 - Show that following is true.

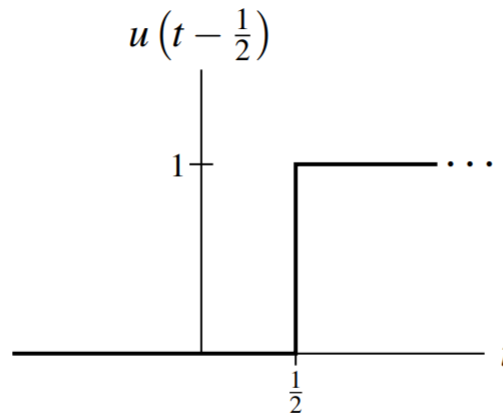
$$\text{rect}t = u\left(t + \frac{1}{2}\right) - u\left(t - \frac{1}{2}\right).$$

$$\text{rect}t = \begin{cases} 1 & -\frac{1}{2} \leq t < \frac{1}{2} \\ 0 & \text{otherwise.} \end{cases}$$

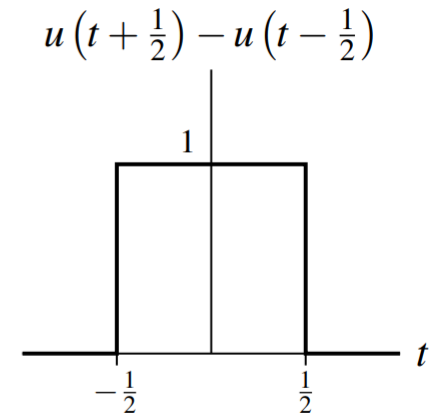
$$u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & \text{otherwise.} \end{cases}$$



(a)



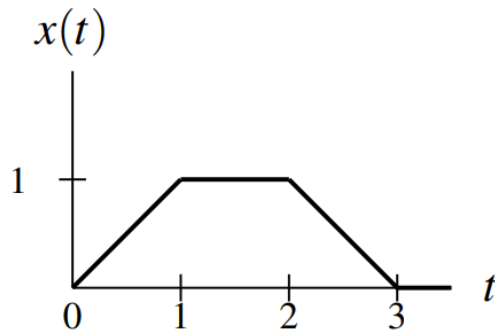
(b)



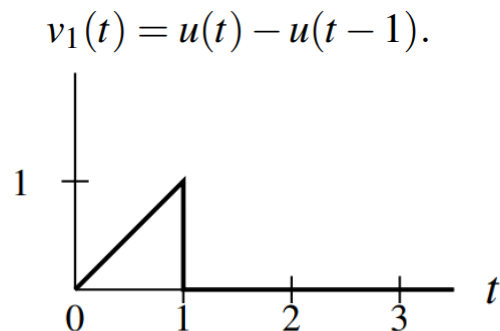
(c)

Representing Signals

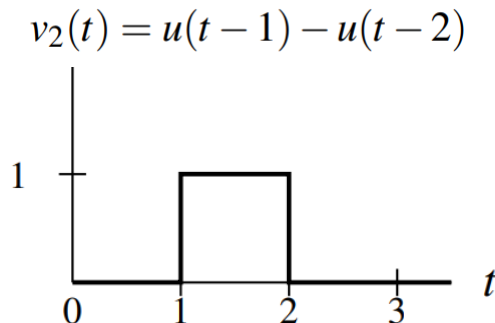
- Representation of Arbitrary Functions



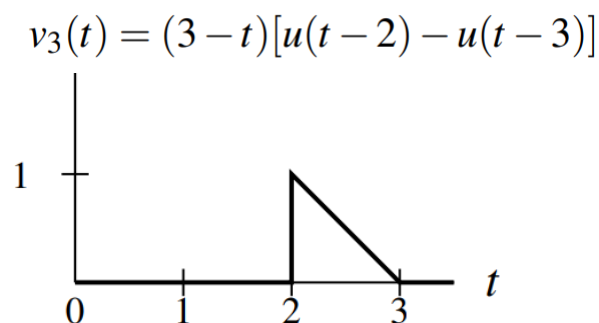
(a)



(b)



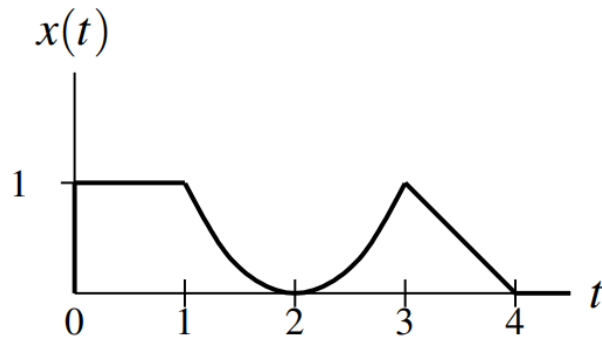
(c)



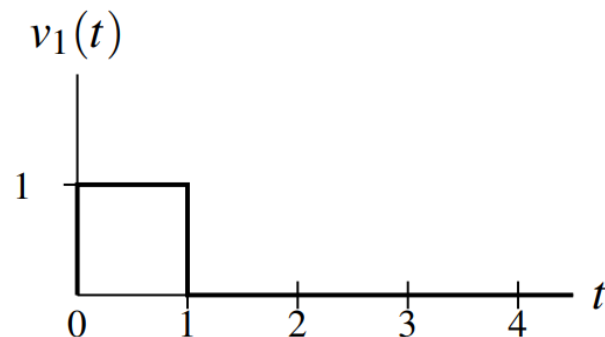
(d)

Representing Signals

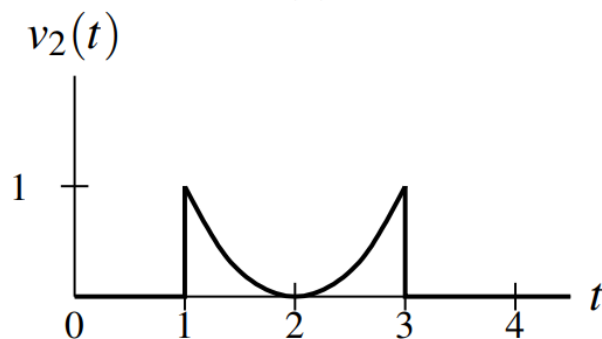
- Representation of Arbitrary Functions



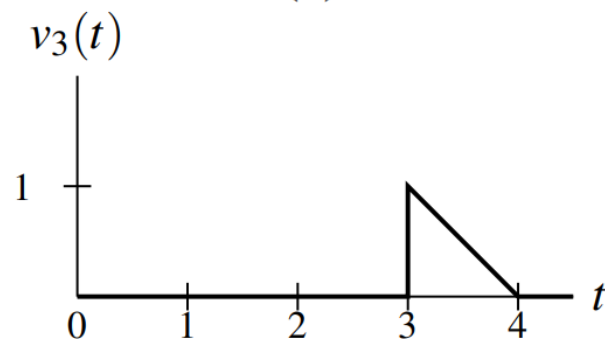
(a)



(b)



(c)



(d)

Thank you

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