Mechatronics Lab: (CB-1034)
No tutorial this week.

→ Matlab used for assignments (15%)
↳ 5 assignments total

→ 3 lab sessions
↳ 1 lab report

↳ Wang using course website on Flash, not D2L

Chapter 1 - Introduction

(1.1) - overview
→ Signal process: to extract representative Features for advanced analysis

→ pattern classification (diagnostics)

→ modeling (Forecasting)

→ control

(1.2) - maintenance strategies
→ run-to-break

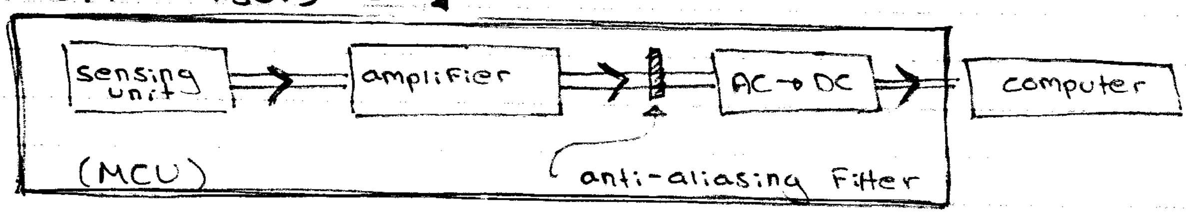
→ preventative maintenance ($\gtrsim$ 25%)
↳ periodically shut down machine for maintenance
↳ unnecessary downtimes

→ predictive maintenance (research state)
↳ condition monitoring → recognize defects
↳ predict the remaining useful life of the faulty component
↳ schedule maintenance operations

- literature review, discuss the maintenance strategies

Condition monitoring
- recognize the defects at its earliest stage
- Prevent machinery performance degradation, malfunction, failure.

Smart sensors



micro controller unit (?)

(1.3) - approaches to Fault detection

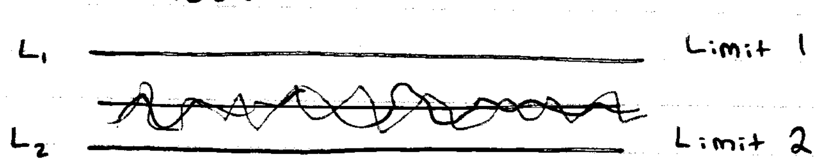
1. classical approaches ~ biological sense
   - looking
   - listening
   - touching
   - Smelling

2. Automatic diagnosis
   - Analytical model

diff. equations

   - Signal processing - based

3. Monitoring
   - limit checking
   - index



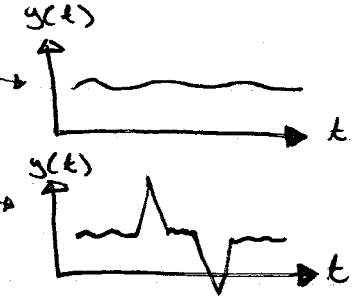
Chapter 2 - Introduction to Signals & Systems

(2.1) - Signal Classification

- deterministic (inputs, outputs)
- random (statistical quantities, mean, std.)

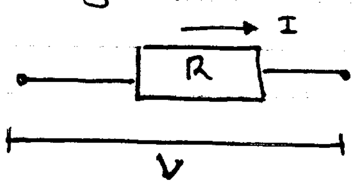
e.g. $y(t) = 28^{32(t)}$

Signals
- continuous
- transient



Signals
- stationary (statistical quantities don't change w/ time)
- non-stationary (change w.r.t. time)

Enough power



$\text{Energy} = I^2R = \frac{V^2}{R=1}$

(if $R=1$, then) $= I^2 = V^2$

$\text{Energy} = \int x^2(t)\,dt$

I^2

V^2

$\boxed{\text{Sensor}} \rightarrow x(t)$

(2.2) - System Properties

1) Causality

@ any time t_1, $y(t_1) \sim x(t_1)$

$x(t) \longleftrightarrow y(t)$ $\qquad t \le t_1$

$\xrightarrow{x(t)} \boxed{\text{System}} \longrightarrow y(t)$

Output $y(t_1)$ depends on $x(t)\big|_{t \le t_1}$

Not depending on its future input $x(t)\big|_{t > t_1}$

System $\longrightarrow$ Causal

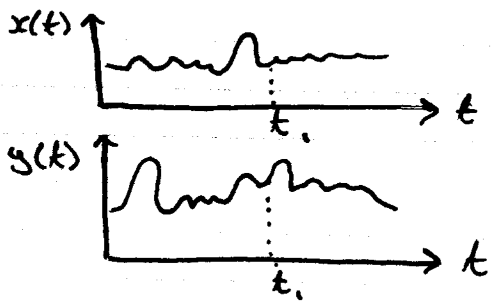
Real systems are causal

- Assume <u>no</u> initial energy

$y(t) = x^2(t) + \cancel{1}$ initial energy

when $x(t) = \emptyset$, $y(t) = \emptyset$

$y(t) = x^2(t)$



EX1 $y(t) = 3x(t+1)$

$t = 1$

$y(t)\big|_{t=1} = 3x(t+1)$

$\hookrightarrow$ non-causal

offline processing

diagnostics

2) Linearity:

- Additive $\quad \xrightarrow{x(t)} \boxed{\text{System}} \xrightarrow{y(t)}$

	Input	Output
	$x_1(t)$	$y_1(t)$
	$x_2(t)$	$y_2(t)$
Additive:	$x_1 + x_2$	$y_1 + y_2$

If the output is a sum, the system can be considered additive

- Homogeneous

	Input	output
	$x_1(t)$	$y_1(t)$
homogeneous:	$a\,x_1(t)$	$a\,y_1(t)$

output is . . . scaled by same amount as input

- linear ~ additive + homogeneous

	Input	Output
linear:	$ax_1(t) + bx_2(t)$	$ay_1 + by_2$

EX2 $\quad y(t) = t\,x(t)$

Input	Output
$x_1(t) = u$	$y_1 = tu$
$x_2 = 3u$	$3y_2 = 3tu$
$x_3 = x_1 + x_2 = 4u$	$y_3 = 4tu$

$y_3 = 4tu = y_1 + y_2$ = linear $\rightarrow (y_1 + y_2 = y_3)$

EX3 $\quad y(t) = x^2(t)$

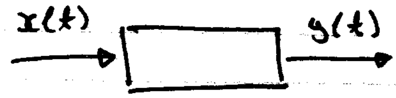
Input	Output
$x_1 = u$	$y_1 = u^2$
$x_2 = 3u$	$y_2 = 9u^2$
$x_3 = 4u$	$y_3 = 16u^2$

$y_1 + y_2 = 10u^2 \neq y_3$ non-linear

Linear System
↳ Superposition depends on this

3) Time Invariance

Input $x(t)$ Output $y(t)$



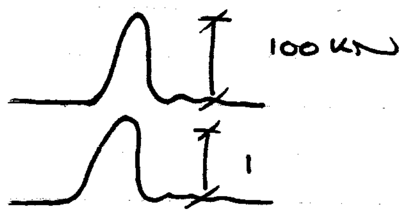
Shifted input $x(t-t_1)$, $y(t-t_1)$

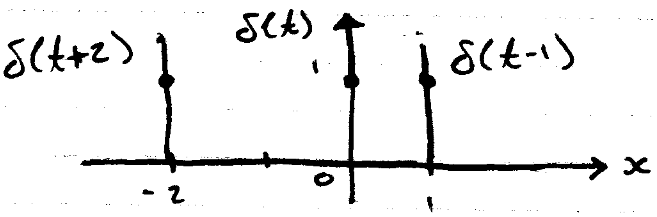
t_1 = number   time invariant

- System properties don't change with time

impulse f_n

$$\delta(t) = \begin{cases} 1, & t = 0 \\ 0, & \text{otherwise} \end{cases}$$





basically, input has shift, output has corresponding shift.

$t_1 = 1 > 0$

then $\delta(t-t_1) = \delta(t-1)$

$t_1 = -2 < 0$

then $\delta(t-t_1) = \delta(t+2)$

EX4 $y(t) = x^2(t) \cancel{+3}$

Input	output
$x_1(t) = x(t)$	$y_1 = x^2(t)$
$x_2(t) = x(t-t_1)$	$y_2 = x^2(t-t_1)$

Time Invariant

EX5 $\quad y(t) = t\,x(t)$

Input	Output
$x_1(t) = x(t)$	$y_1 = t\,x(t)$
$x_2 = x(t-t_1)$	$y_2 = t\,x(t-t_1)$

$$\#$$

$$y_s(t)|_{t = t - t_1}$$
$$= y(t-t_1) = (t-t_1)\,x(t-t_1)$$

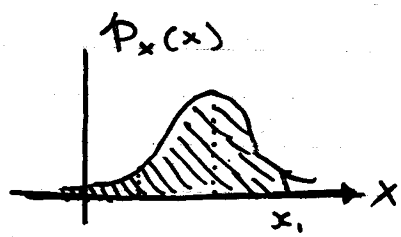
In Signal Processing,
Assume : casual, linear, time invariant

(2.3) - Review of Statistical Quantities

① Probability fn

Random variable X

Probability Distribution fn
$P_x(x)$

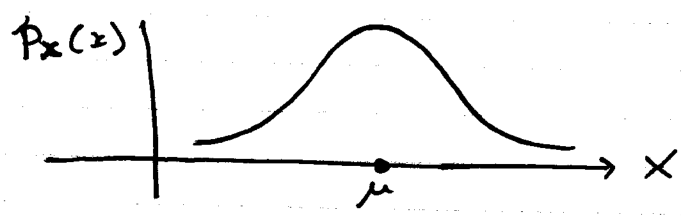


Probability of P_x = Prob $(x \le x_1)$

$$P_x = \int_{-\infty}^{x_1} P_x(x)\,dx$$

$$P_x(x) \ge 0$$
$$\int_{-\infty}^{\infty} P_x(x)\,dx = 1$$

Temp +



Gaussian probability density Function (pdf)

$$P_x = \frac{1}{2\pi\sigma}\, e^{\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)}$$

μ = mean
σ = st. d
σ = variance