SIGNALS & SYSTEMS

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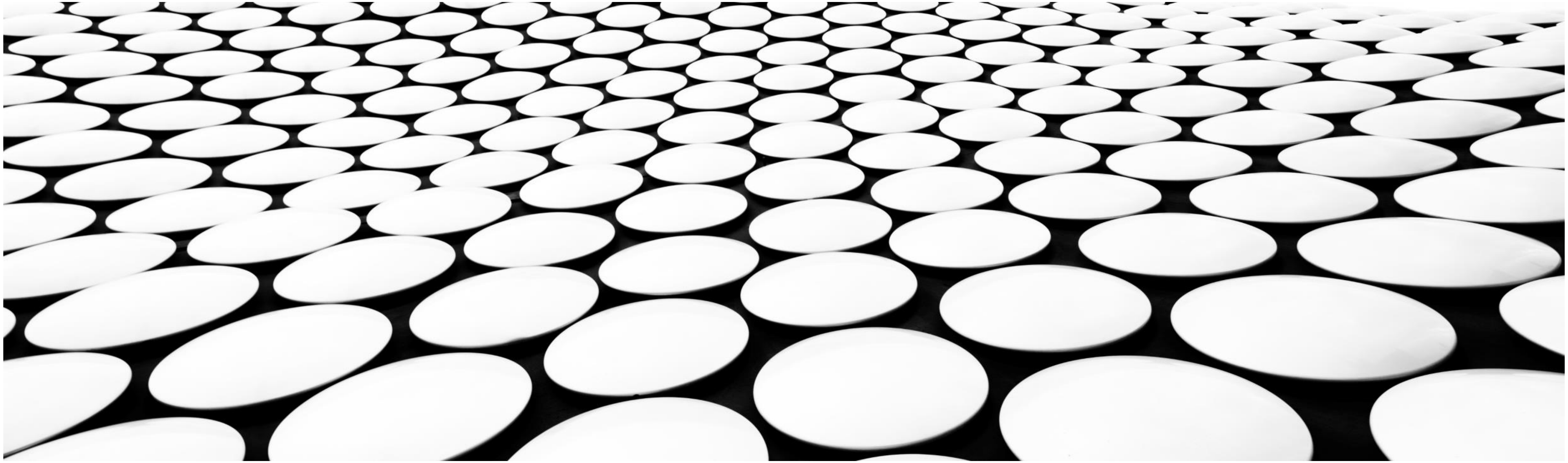


Short-cut Tips:- A system is said to be time invariant —

1) No time scaling.

2) coefficient should be constant

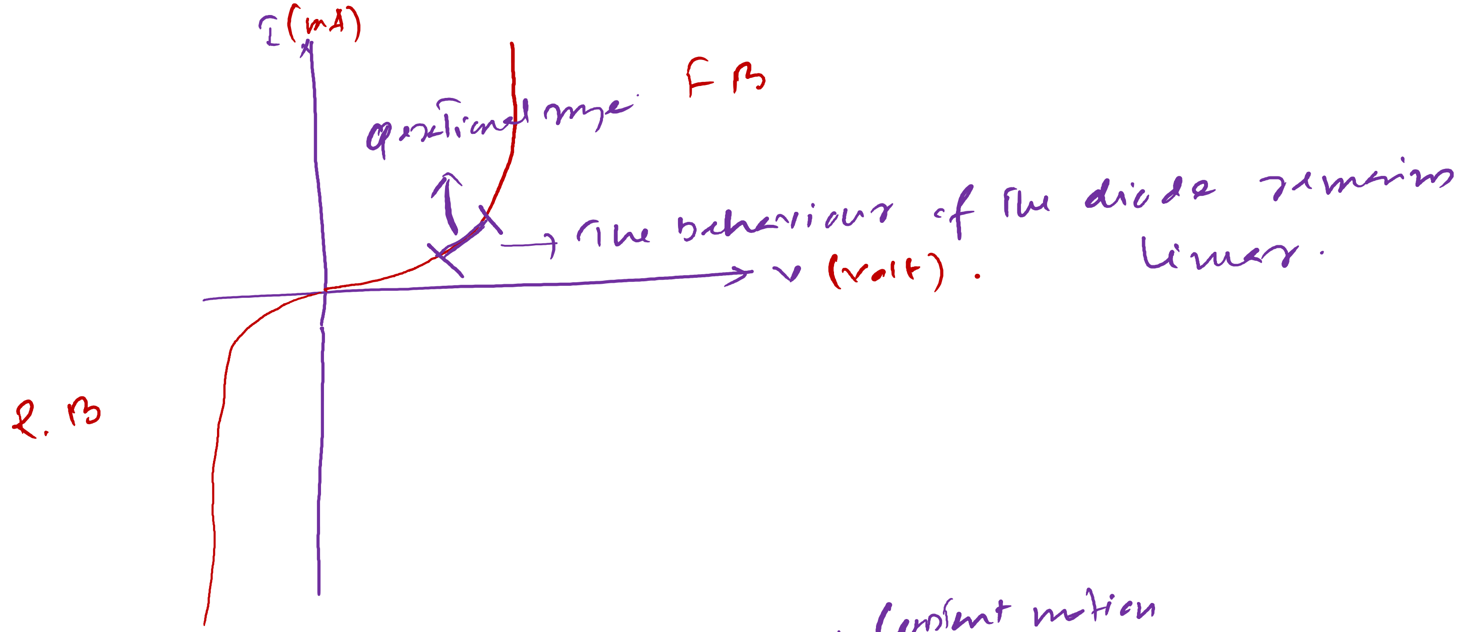
3) Any added/ subtracted Term in the system relationship (except i/p or o/p) must be constant or zero.

$y(t) = 1x(t+1) + 1x(t-1)$ → No time scaling. → coefficient is constant

Delay the o/p by t_0 and delay the i/p by t_0

-: Linear and Non-Linear Systems: -

Forward biased ckt:-

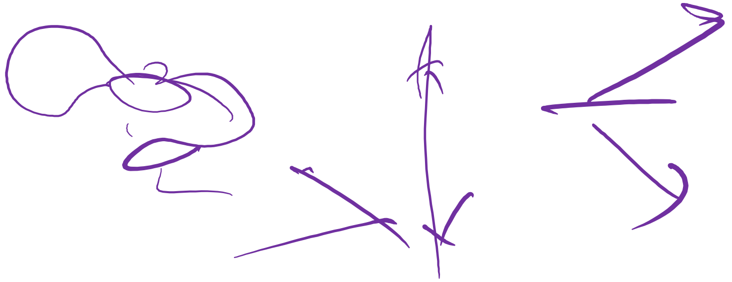


The civil Aircraft } Boeing 737

Fighter aircraft } Rafael, F-35

Random motion

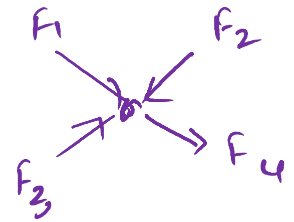
Constant motion



Principle of superposition :-

$\Downarrow$

Law of additivity $\Rightarrow$ law of homogeneity.



$y_1 = A_1 \sin\omega t$

$y_2 = A_2 \sin\omega t$

$y = y_1 + y_2$

$= (A_1 + A_2)\sin\omega t$

$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4$

Case1:-

$x_1(t) \longrightarrow$ system $\longrightarrow y_1(t)$ (a, +)

$\Sigma \longrightarrow y_1(t) + y_2(t)$

$x_2(t) \longrightarrow$ system $\longrightarrow y_2(t)$ (a, +)

$a(y_1(t) + y_2(t))$

We have added two O/ps. [$y_1(t)$ and $y_2(t)$]

Case2:-

$x_1(t)$ (a, +) $\rightarrow \Sigma \longrightarrow$ system $\longrightarrow y'(t)$

$x_2(t)$ (a)

$a(x_1(t) + x_2(t))$

We added two i/ps

If $y'(t) = y_1(t) + y_2(t) \rightarrow$ follows the law of additivity

$\Downarrow$

Linear.

$y'(t) \neq y_1(t) + y_2(t)$

$\Downarrow$

Non-Linear

Law of homogeneity :-

$x(t) \longrightarrow \boxed{\text{system}} \longrightarrow y(t) \longrightarrow \boxed{k} \longrightarrow k\,y(t)$

constant k is multiplied with the o/p

$x(t) \longrightarrow \boxed{k} \longrightarrow \boxed{\text{system}} \longrightarrow y'(t)$

constant k is multiplied with the i/p

$y'(t) = k\,y(t)$ → homogeneous → linear

$y'(t) \neq k\,y(t)$ → non-homogeneous → non-linear

$y(t) = x(\sin t)$ → we need to determine whether this system is linear or non-linear.

Solⁿ:- Let us check for law of additivity.

$$\left.\begin{array}{l} x_1(t) \longrightarrow y_1(t) \\ x_2(t) \longrightarrow y_2(t) \end{array}\right\} \quad \begin{array}{l} y_1(t) = x_1(\sin t) \\ y_2(t) = x_2(\sin t) \end{array}$$

$$y_1(t) + y_2(t) = x_1(\sin t) + x_2(\sin t) \quad \text{--- (1)}$$

$x_1(t) + x_2(t)$

$$y'(t) = x_1(\sin t) + x_2(\sin t) \quad \text{--- (2)}$$

$$y'(t) = y_1(t) + y_2(t)$$

Check for homogeneity :-

$y(t) = x(\sin t)$

$y(t) = ky(t) = kx(\sin t)$. ✓

LOH is satisfied

$kx(t) \longrightarrow$ system $\longrightarrow y'(t)$

$kx(\sin t) \longrightarrow$ system $\longrightarrow y'(t) = kx(\sin t)$ ✓

$y(t) = x(t^2) \rightarrow$ linear in nature

Sol^n:

$$x(t) \longrightarrow \boxed{H(t)} \longrightarrow y(t)$$

Assume two diff. i/ps $\rightarrow x_1(t)$ and $x_2(t)$

$$x_1(t) \xrightarrow{o/p} y_1(t) \qquad x_2(t) \xrightarrow{o/p} y_2(t)$$

$y_1(t) = x_1(t^2)$

$y_2(t) = x_2(t^2)$

$y_1(t) + y_2(t) = x_1(t^2) + x_2(t^2)$.

let us consider $x_3(t)$ = linear combination of $x_1(t)$ and $x_2(t)$

$\rightarrow x_3(t) = a_1 x_1(t) + a_2 x_2(t)$

$x_3(t) \rightarrow y_3(t)$

$y_3(t) = a_1 x_1(t^2) + a_2 x_2(t^2)$

$\boxed{y_3(t) = a_1 y_1(t) + a_2 y_2(t)}$ $\rightarrow$ linear comb^n of o/ps $y_1(t)$ and $y_2(t)$

LOA :-

$x_1(t) \rightarrow y_1(t) = x_1(t^2)$

$x_2(t) \rightarrow y_2(t) = x_2(t^2)$

$y_1(t) + y_2(t) = x_1(t^2) + x_2(t^2)$

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

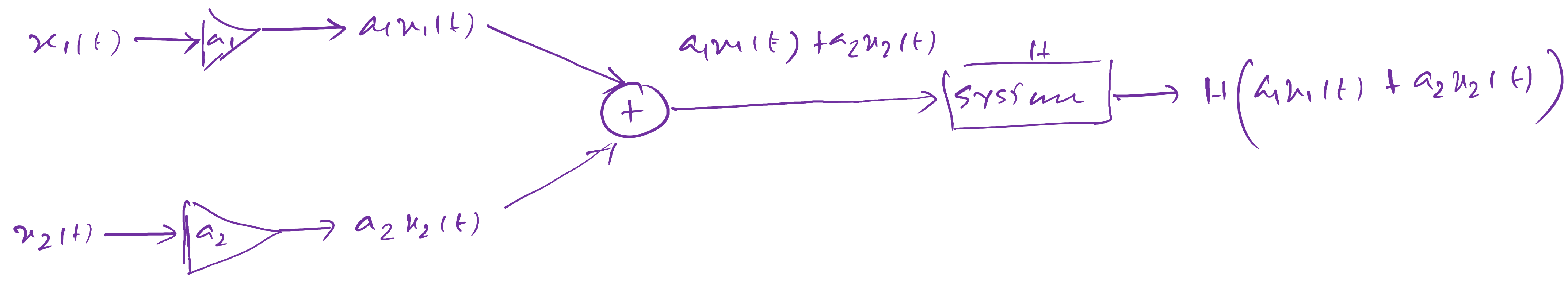
$x_1(t) + x_2(t) \longrightarrow \text{system} \rightarrow y'(t) = x_1(t^2) + x_2(t^2)$

LOH :-

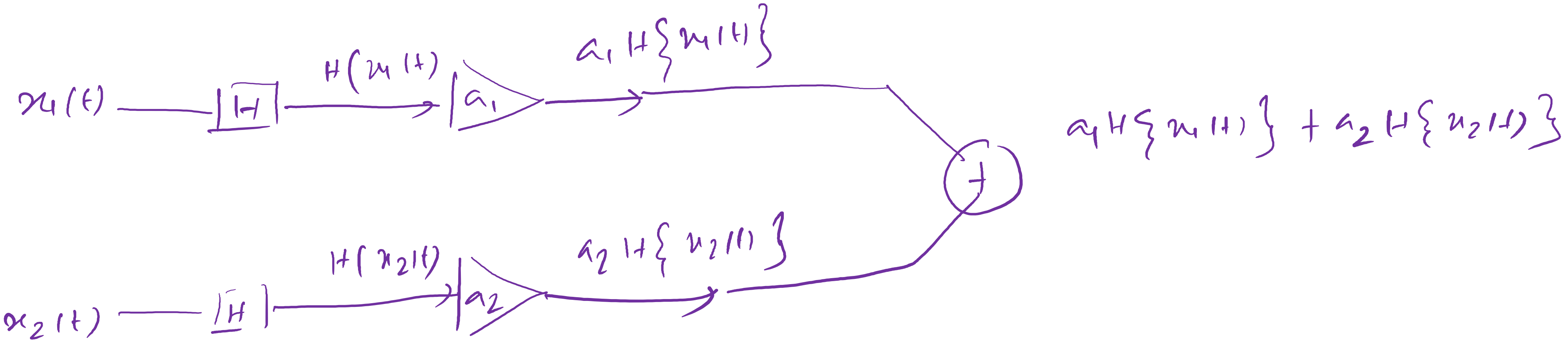
$x(t) \rightarrow \text{sys} \rightarrow y(t) \longrightarrow k \rightarrow ky(t) = k\,x(t^2) \Rightarrow y(t) = kx(t^2)$

$x(t) \rightarrow k \rightarrow kx(t) \longrightarrow \text{system} \longrightarrow y'(t) = kx(t^2)$

Linear in nature.



x1(t)
a1
a1x1(t)
x2(t)
a2
a2x2(t)
+
a1x1(t) + a2x2(t)
H
system
H(a1x1(t) + a2x2(t))



x1(t)
H
H(x1(t))
a1
a1 H{x1(t)}
x2(t)
H
H(x2(t))
a2
a2 H{x2(t)}
+
a1H{x1(t)} + a2 H{x2(t)}

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

$x^2(t) = \underline{(x(t))}^2$

$x_1(t) \longrightarrow \text{system} \longrightarrow y_1(t) = x_1^2(t)$

$x_2(t) \longrightarrow \text{system} \longrightarrow y_2(t) = x_2^2(t)$

$y_1(t) + y_2(t) = x_1^2(t) + x_2^2(t)$ ✓

$x_1(t) + x_2(t) \longrightarrow \text{system} \longrightarrow y'(t) = (x_1(t) + x_2(t))^2$ ✓

<u>LOA</u> is not satisfied $\Rightarrow$ Non-Linear <u>system</u>.