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Basics of Signals

Comprehensive Course on Signals and Systems

Aditya Kanwal • Lesson 1 • Apr 15, 2024

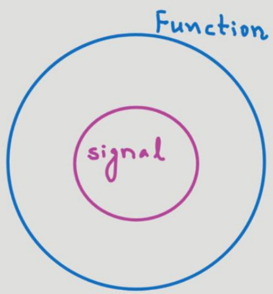
Signals and Systems :-

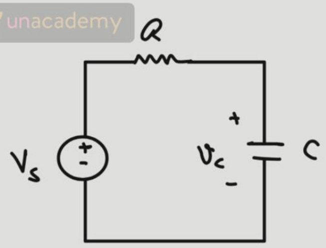
1) Continuous signals.
2) Continous systems.
3) CTFS
4) CTFT
5) Laplace transform.
6) Sampling theorem.
7) Discrete signals & systems.
8) Z - transform.
9) DTFT
10) DFT & FFT.
11) DTFS.
12) Miscellaneous.

1) Attend classes live.
2) Make class notes.
3) $\boxed{\text{Revision.}}$ ***
4) PYQs

1 → 2 → 3 → 4 → 5

Signal:- It is a mathematical representation of a physical phenomena which contains some information.





$v_c(0) = 0$

$v_c(t) = V_s\left[1 - e^{-t/RC}\right]$

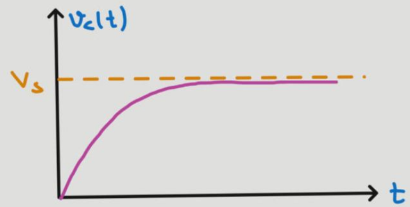


Image = $f(x, y)$

Video = $f(x, y, t)$

1 dimensional signals.

$\Downarrow$

time (t)

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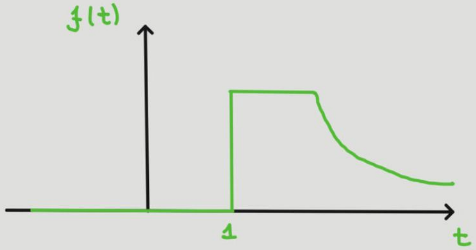
$f(t)$ → dependent variable.

t → independent variable

$f(t) = 3t^2 + 5t + 6$

1) Continuous and discrete time signals:-

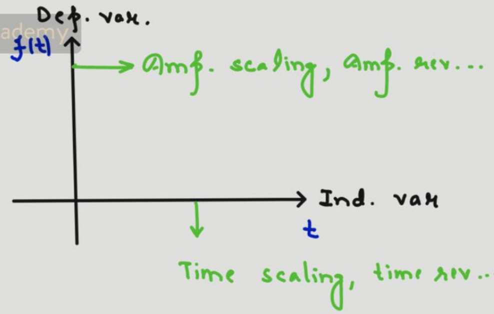
In the case of continuous time signals the independent variable is continuous and thus these signals are defined for a continuum of values of the independent variable in a considered interval however small the interval is.



signal which is defined for each and every instant of time in a considered interval, however small the interval is, is called as continuous time signal.

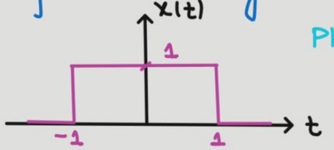
Operations → Dependent var.

Operations → Independent var.

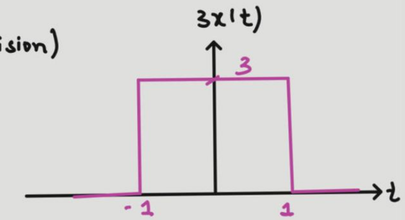


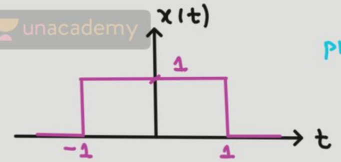
i) Operations on dependent variable :-

1) Amplitude scaling :- (Multiplication/Division)

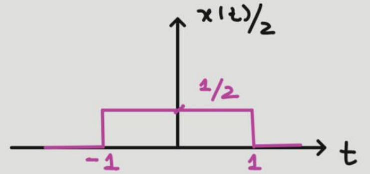


Plot → $3x(t)$

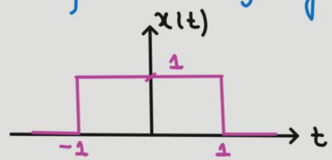




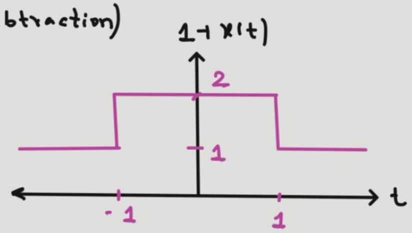
Plot → $\frac{1}{2}x(t) = \frac{x(t)}{2}$

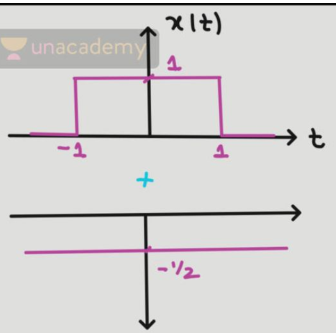


2) Amplitude shifting :- (Addition or Subtraction)



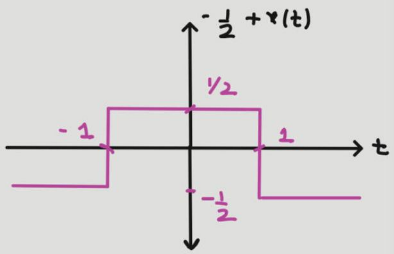
Plot $1 + x(t)$



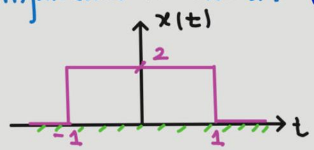


Plot $x(t) - \frac{1}{2}$

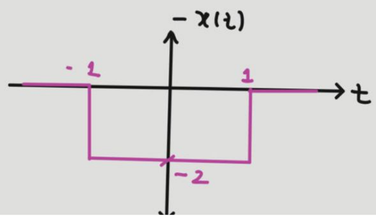
$= -\frac{1}{2} + x(t)$



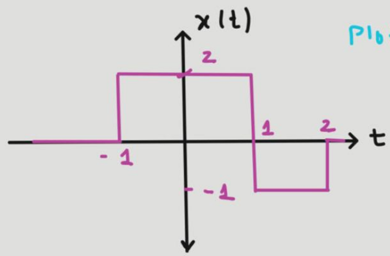
3) Amplitude reversal :- (mirror image about x-axis).



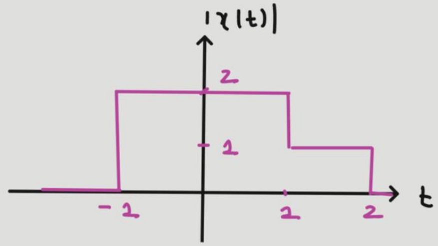
Plot → $-x(t)$



4) Modulus :-



Plot → $|x(t)|$



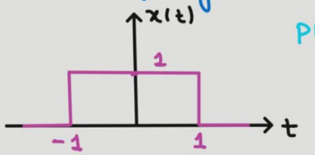
Continuous And Discrete Time Signals - Part I

Comprehensive Course on Signals and Systems

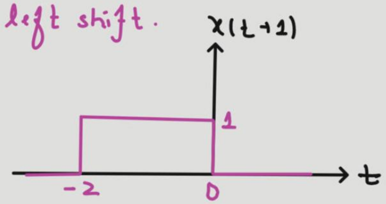
Aditya Kanwal • Lesson 2 • Apr 16, 2024

- Operations on independent variable :-

i) Time shifting :-



Plot $x(t+1)$ → Advance or left shift.



$x(t) = 1 \quad -1 \le t \le 1$

$\quad\ 0 \quad$ Otherwise

$x(\ ) = 1 \quad -1 \le (\ ) \le 1$

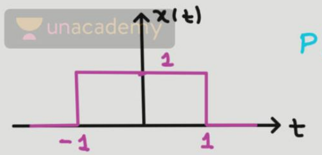
$\quad\ 0 \quad$ Otherwise

$x(t+1) = 1 \quad -1 \le t+1 \le 1$

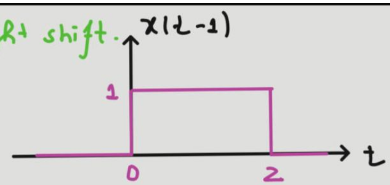
$\quad\ 0 \quad$ Otherwise

$x(t+1) = 1 \quad -2 \le t \le 0$

$\quad\ 0 \quad$ Otherwise



Plot $x(t-1)$ → delay or right shift.



$x(\ ) = 1 \quad -1 \le (\ ) \le 1$

$\quad\ 0 \quad$ elsewhere

$x(t \pm t_0)$

$x(t-1) = 1 \quad -1 \le t-1 \le 1$

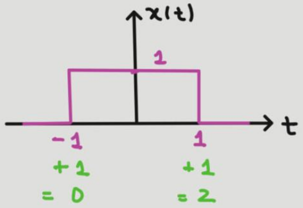
$\quad\ 0 \quad$ elsewhere

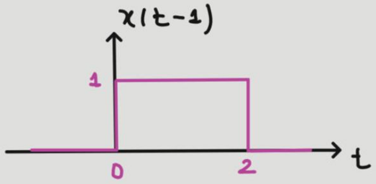
$x(t-1) = 1 \quad 0 \le t \le 2$

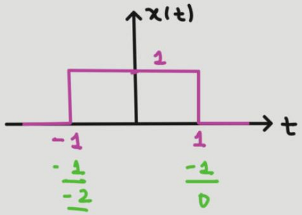
$\quad\ 0 \quad$ elsewhere

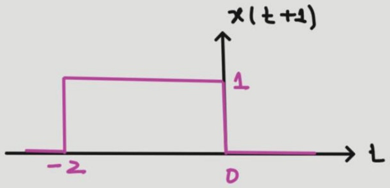
$x(t-t_0) \Rightarrow$ At every instant add t_0.

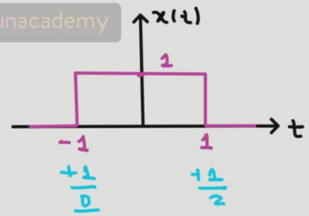
$x(t+t_0) = x(t-(-t_0)) \Rightarrow$ add $-t_0$.

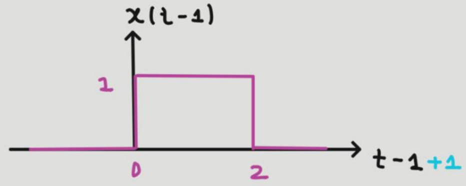


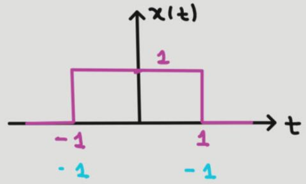


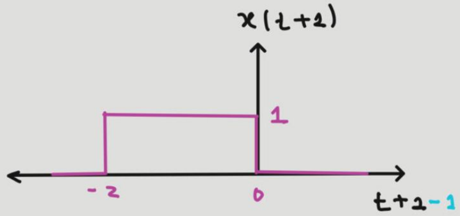




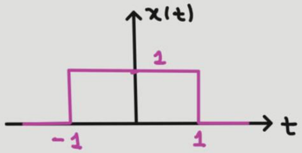




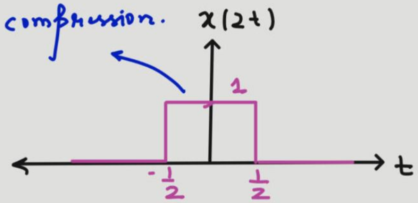




(ii) Time scaling :-



Plot $x(2t)$



$x(t) = 1 \quad -1 \leq t \leq 1$

$\quad\quad 0 \quad$ otherwise

$x(\ ) = 1 \quad -1 \leq (\ ) \leq 1$

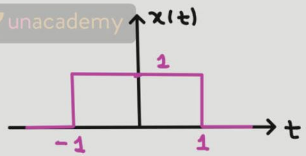
$\quad\quad 0 \quad$ otherwise

$x(2t) = 1 \quad -1 \leq 2t \leq 1$

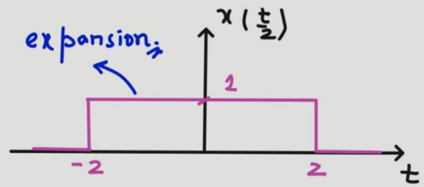
$\quad\quad 0 \quad$ otherwise

$x(2t) = 1 \quad -\frac{1}{2} \leq t \leq \frac{1}{2}$

$\quad\quad 0 \quad$ otherwise



Plot $x(\frac{1}{2}t)$



$x(t) = 1 \quad -1 \leq t \leq 1$

$\quad\quad 0 \quad$ otherwise

$x(\frac{t}{2}) = 1 \quad -1 \leq \frac{t}{2} \leq 1$

$\quad\quad 0 \quad$ otherwise

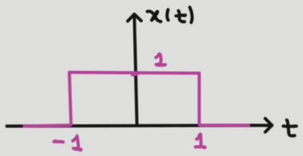
$x(\frac{t}{2}) = 1 \quad -2 \leq t \leq 2$

$\quad\quad 0 \quad$ otherwise

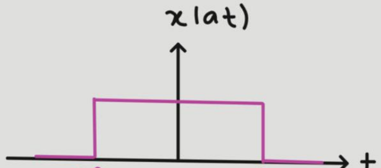
$$x(t) \xrightarrow{t \to at} x(at)$$

$a > 1 \Rightarrow$ Compression.

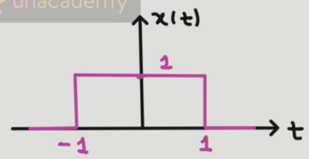
$a < 1 \Rightarrow$ Expansion.

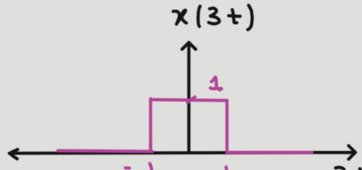


$t \to at$

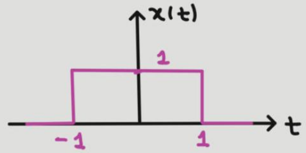


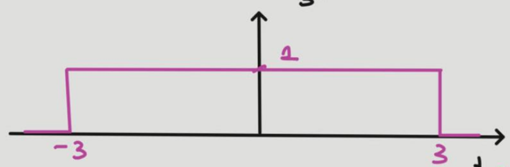
$-\frac{1}{a}$ $\quad$ $\frac{1}{a}$





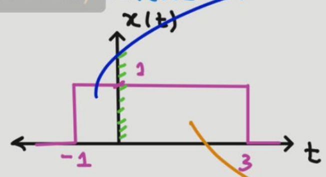
$-\frac{1}{3}$ $\quad$ $\frac{1}{3}$ $\quad$ $\frac{3t}{3}$





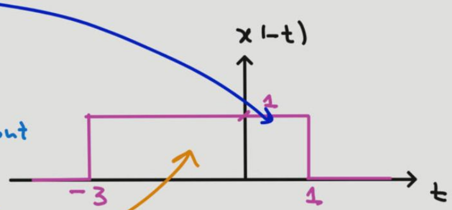
$x\left(\frac{t}{3}\right)$ $\quad$ $\frac{t}{3} \times 3$

iii) Time reversal :-



Plot $x(-t)$

mirror image about y on vertical axis.



$x(t) = 1 \quad -1 \leq t \leq 3$

$\quad\quad\; 0 \quad$ otherwise

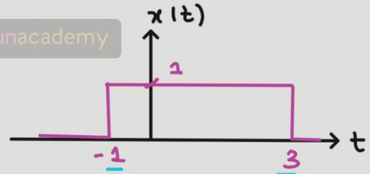
$x(-t) = 1 \quad -1 \leq -t \leq 3$

$\quad\quad\;\; 0 \quad$ otherwise

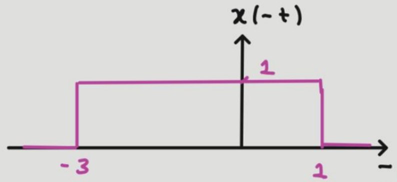
$x(-t) = 1 \quad 1 \geq t \geq -3$

$\quad\quad\quad\quad\;\; -3 \leq t \leq 1$

$\quad\quad\;\; 0 \quad$ otherwise

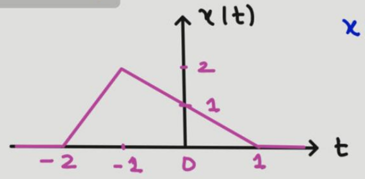


$\frac{-1}{-1} = 1 \quad\quad \frac{3}{-1} = -3$

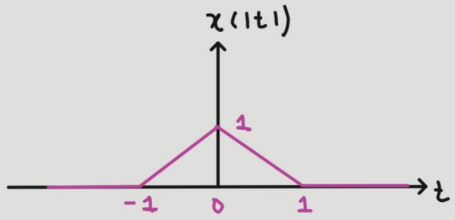


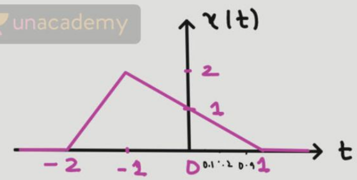
$\frac{-t}{-1}$

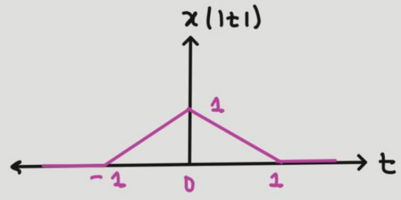
iv) Modulus :-



$x(|t|)$ Vs t

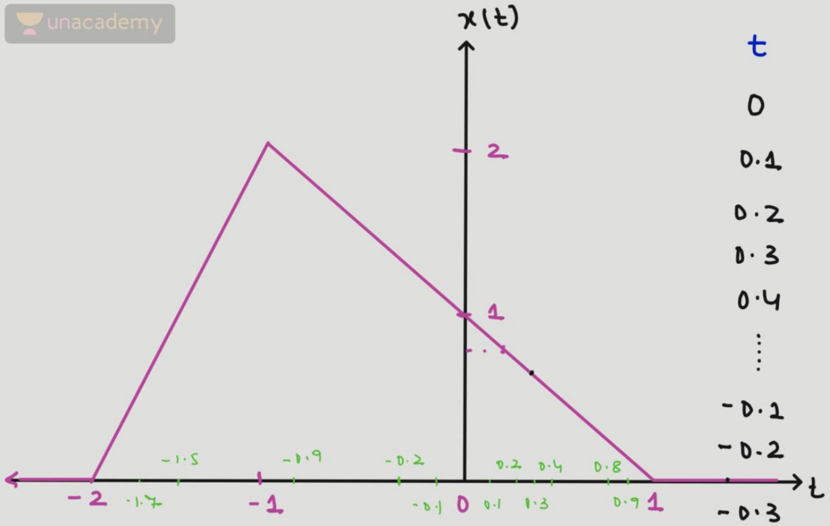






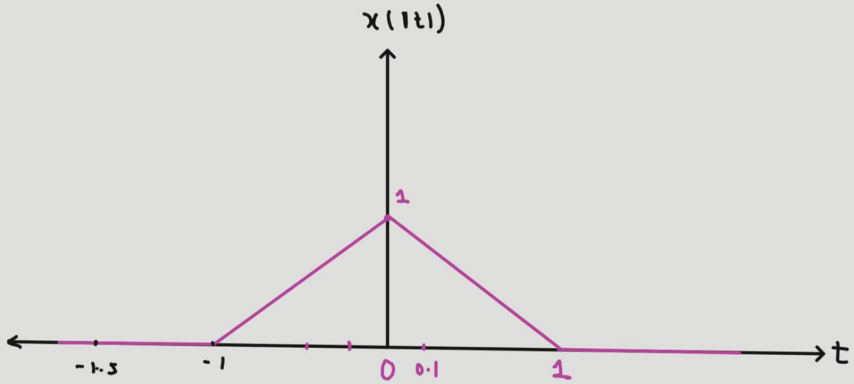
t	$x(\|t\|)$
0.1	$x(0.1)$
0.2	$x(0.2)$
⋮	⋮
1	$x(1)$

t	$x(\|t\|)$
-0.1	$x(\|-0.1\|) = x(0.1)$
-0.2	$x(\|-0.2\|) = x(0.2)$
⋮	
-1.5	$x(\|-1.5\|) = x(1.5)$

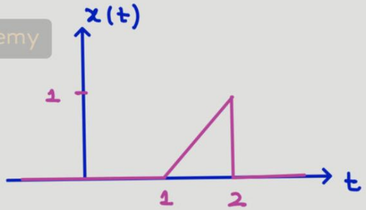


t	$x(\|t\|)$
0	$x(0)$
0.1	$x(0.1)$
0.2	$x(0.2)$
0.3	$x(0.3)$
0.4	$x(0.4)$
⋮	⋮
-0.1	$x(0.1)$
-0.2	$x(0.2)$
-0.3	$x(0.3)$
-0.4	$x(0.4)$
-1.5	$x(1.5)$

when t is +ve $x(|t|) = x(t)$

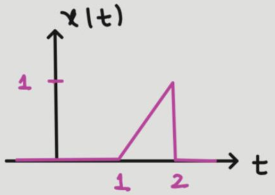


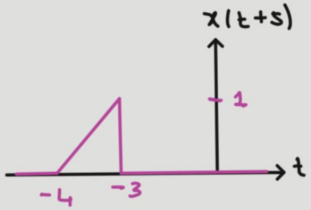
Ex:-

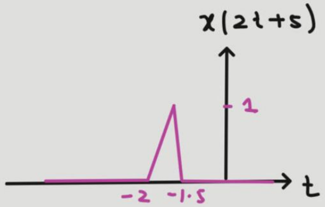


Develop $x(2t+5)$

Sol: I :- $x(t) \xrightarrow{t \to t+5} x(t+5) \xrightarrow{t \to 2t} x(2t+5)$





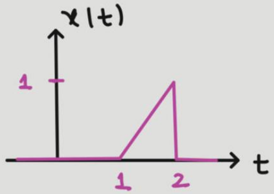


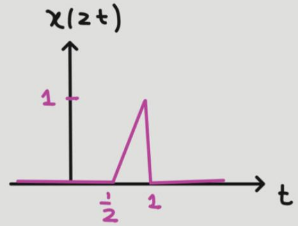
Shifting Scaling

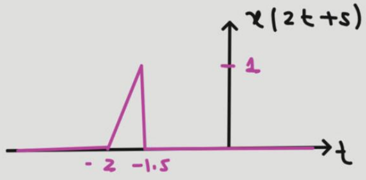
II :- $x(t) \xrightarrow{t \to 2t} x(2t) \xrightarrow{t \to t+5} x(2(t+5)) = \cancel{x(2t+10)}$

$x(t) \xrightarrow{t \to 2t} x(2t) \xrightarrow{t \to t+\frac{5}{2}} x\left(2\left(t+\frac{5}{2}\right)\right)$

$= x(2t+5)$



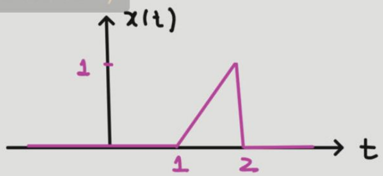




Scaling Shifting.

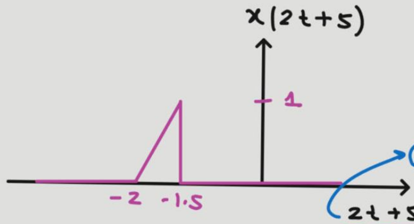
$x(2t+5) = x\left(2\left(t+\frac{5}{2}\right)\right)$ ① ②

III :- Shortcut :-

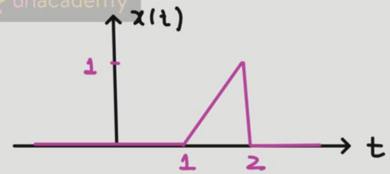


1)

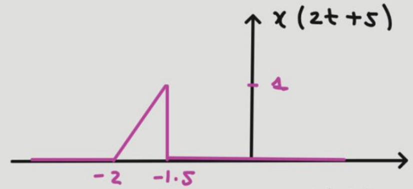
-5	-5
-4	-3
$\div 2$	$\div 2$
-2	-1.5



$\frac{2t+5-5}{2}$ ① (i) (ii)



$\div 2$	$\div 2$
$\frac{1}{2}$	1
-2.5	-2.5
-2	-1.5



$\frac{2t+5}{2} - \frac{5}{2}$

$\frac{2t+5}{2} = t + \frac{5}{2} - \frac{5}{2}$

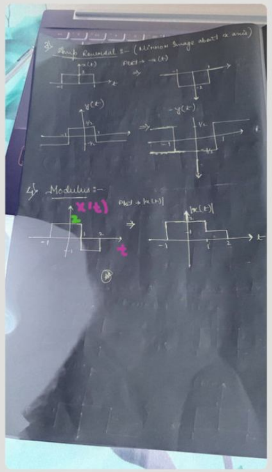
1) Shifting $\longrightarrow$ Scaling $\quad x(at+b)$

2) Scaling $\longrightarrow$ Shifting $\quad x\left(a\left(t+\frac{b}{a}\right)\right)$

- If shifting is performed after scaling then the care should be taken to divide the shift amount by the scaling factor.

1 • Asked by Shouryadee...

sir yeh wala ekbr btaiye



$|x(t)|$

$x(t) = -5 \quad |x(t)| = 5$

$x(t) = 6 \quad |x(t)| = 6$

Continuous And Discrete Time Signals - Part II

Comprehensive Course on Signals and Systems

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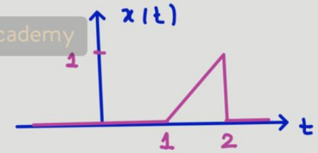
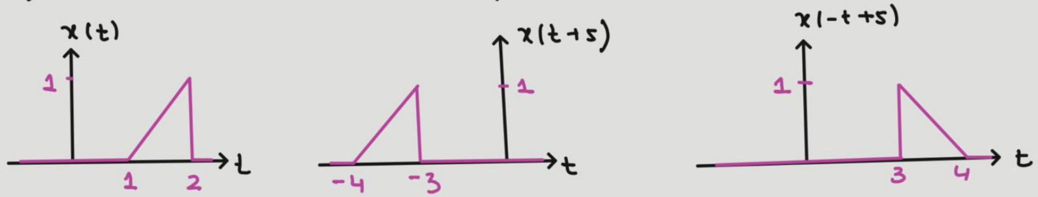
Ex:-



Develop $x(-t+s)$

Sol: I:- $x(t) \xrightarrow{t \to t+s} x(t+s) \xrightarrow{t \to -t} x(-t+s)$

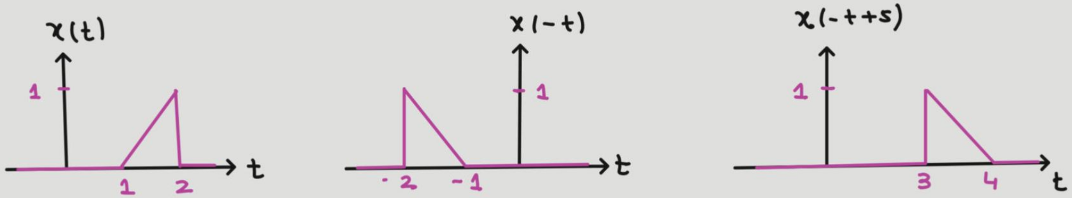


Shifting

Reversal

II:- $x(t) \xrightarrow{t \to -t} x(-t) \xrightarrow{t \to t+s} x(-(t+s)) = \cancel{x(-t-s)}$

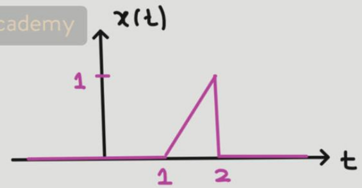
$x(t) \xrightarrow{t \to -t} x(-t) \xrightarrow{t \to t-s} x(-(t-s)) = x(-t+s)$

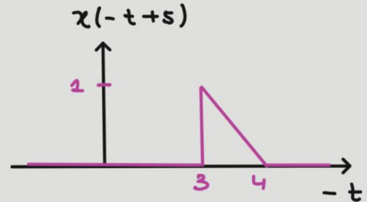


Reversal

Shifting

III





①	-4	-3
②	4	3

①	-1	-2
②	4	3

$-t+s-s$ → ①

-1 → ②

$-t+s$ $+s$ → ②

-1 → ②

$t-s$