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SIGNAL & SYSTEM
BY-SURAJ SIR

- Theory
- Explanation
- Derivation
- Example
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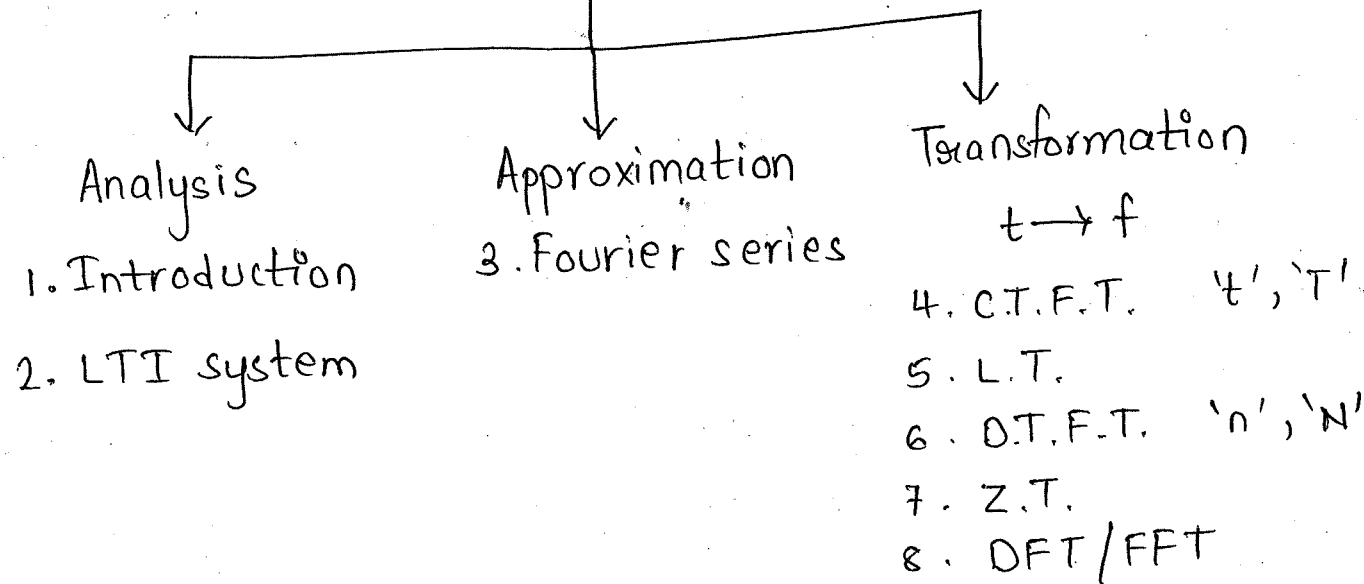
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Signals and Systems

GATE: (9 to 12 Marks)

Reference Book: S & S by Ranjan and HSU

<u>Mentor</u>: Sujal sir

Signals and Systems

Analysis	Approximation	Transformation
1. Introduction	3. Fourier series	$t \rightarrow f$
2. LTI system		4. C.T.F.T. 't', 'T'
		5. L.T.
		6. D.T.F.T. 'n', 'N'
		7. Z.T.
		8. DFT/FFT

1] Introduction to Signals and Systems

→ What is signal?

→ What is system?

→ Characteristics of signals.

→ Types of signals

→ Some standard signals

→ Transformation on signals $(x(t))$

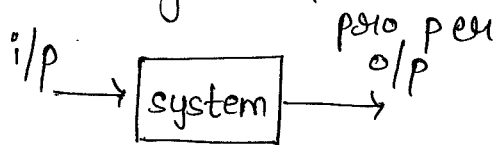 ① Time shifting $x(t \pm t_0)$

  ② Time scaling $x(\alpha t)$

  ③ Time reversal $x(-t)$

  ④ Amplitude scaling $k \cdot x(\alpha)$

→ Problems

→ Classification of signals

→ Classification of systems

→ Summary

→ Problems

What is signal?

- It is the indication from which some amount of information is to be conveyed from one place to another.

What is system?

$$i/p \longrightarrow \boxed{system} \longrightarrow o/p \quad \text{pro, per}$$

- System is nothing but group of elements/physical components arranged in such a way that it gives proper output to given input.

Eg:- A fan without blades: No air flow: not proper o/p: Not a system

A fan with blades: Air flow: proper o/p: It is system

If we add controller from controlling purpose then it is called CONTROL SYSTEM.

* Characteristics of signals

(1) Dimension

$1D \longrightarrow$ point ($\cdot$)   x-co-ordinate only

$2D \longrightarrow$ image ▦ (x,y)

$3D \longrightarrow$ TV (x,y,t)

(2) Bandwidth

Range of frequencies occupy by signals.

f_L f_H $f \rightarrow$

$\longleftarrow$ B.W. $\longrightarrow$
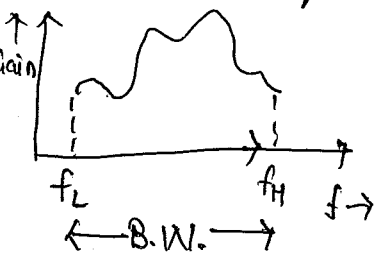
(3) Randomness

- More the randomness more the information

$$I = \log_2 \frac{1}{Pi} = -\log_2 Pi$$

$$Pi = \frac{1}{8} \implies I = 3 \text{ bits}$$

more random $\rightarrow Pi = \frac{1}{32} \implies I = 5 \text{ bits}$

* Types of Signals *

Based on
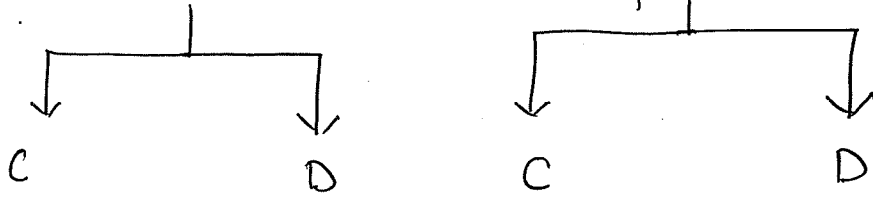
```
        Time        &        Amplitude
          |                      |
     ┌────┴────┐           ┌─────┴─────┐
     ↓         ↓           ↓           ↓
     C         D           C           D
(Continuous)  (discrete)
```

$t \rightarrow$ Continuous $\rightarrow t = 0.1$, $t = 0.01$, $t = 0.02$, $t = 2$

$n \rightarrow$ discrete $\rightarrow n = 0, 1, 2, 3, 4, -1, -2, -3, -4$
$$n = 1.5 \text{ X}$$

$A \rightarrow$ continuous $\rightarrow -\infty$ to $+\infty$

$A \rightarrow$ discrete $\rightarrow [-2, -1, 0, 0.5, 2]$

① Continuous signal

time $\rightarrow$ Continuous , amplitude $\rightarrow$ Continuous

For eg:- $x(t) = e^{-3t} \cdot u(t)$
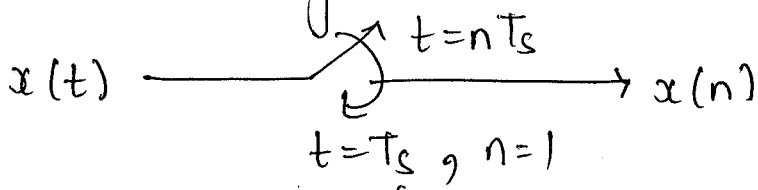
$\qquad = e^{-3t} \cdot 1$, $t \geq 0$

$\qquad = 0$, $t < 0$

$$\boxed{\begin{aligned} u(t) &= 1 \text{ , } t > 0 \\ &= 0 \text{ , } t < 0 \\ &= \text{not defined} \text{, } t = 0 \end{aligned}}$$
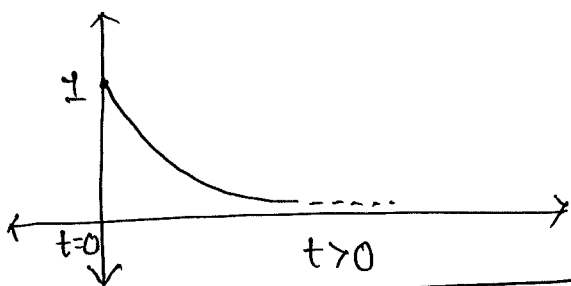
$$x(t)\Big|_{t \to \infty} = e^{-\infty} = \frac{1}{e^{\infty}} = \frac{1}{\infty} = 0$$

A signal which is continuous in both amplitude and time at any instant amplitude and time is known as continuous signal.

② Discrete signal

$x(t)$ ——— $t = nT_s$ ——→ $x(n)$

$t = T_s$, $n = 1$

↳ sampling period

$f_s = \dfrac{1}{T_s}$ = sampling frequency

$$x(t) = e^{-3t} \cdot u(t)$$

$\Big\downarrow \; t = nT_s$
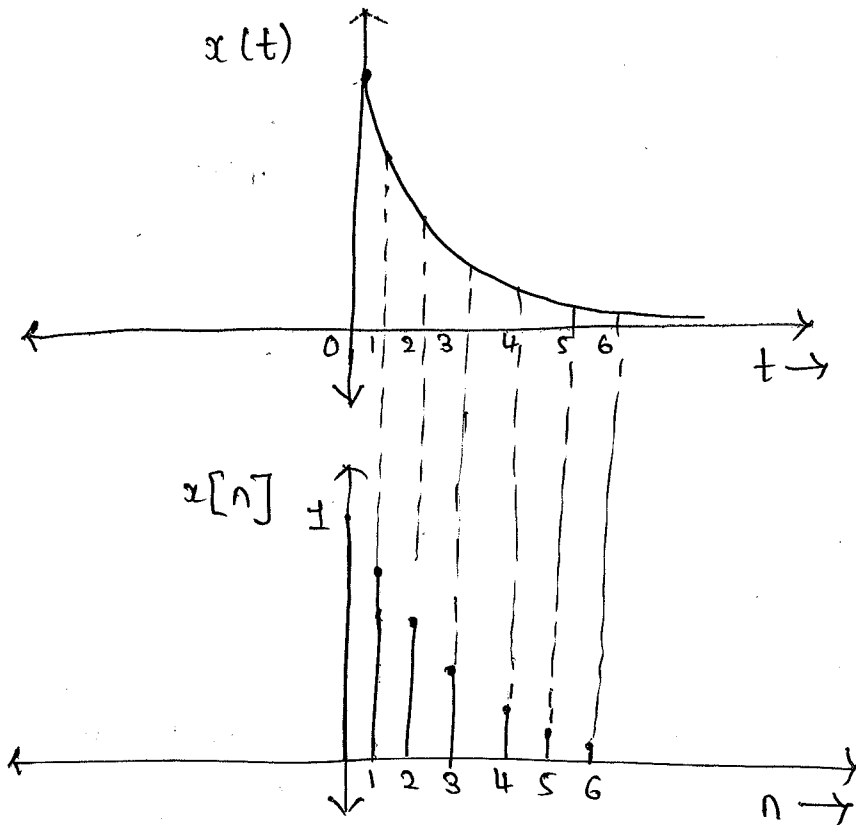
$$x(nT_s) = e^{-3nT_s} \cdot u[nT_s]$$

Let $T_s = 1$

$$x[n] = e^{-3n} u[n] \quad , n = 0, \pm1, \pm2, \pm3, \ldots \ldots$$

$$x[n] = e^{-3n} \quad , n \geq 0 \quad , n = 0, \pm1, +2, +3, \ldots$$

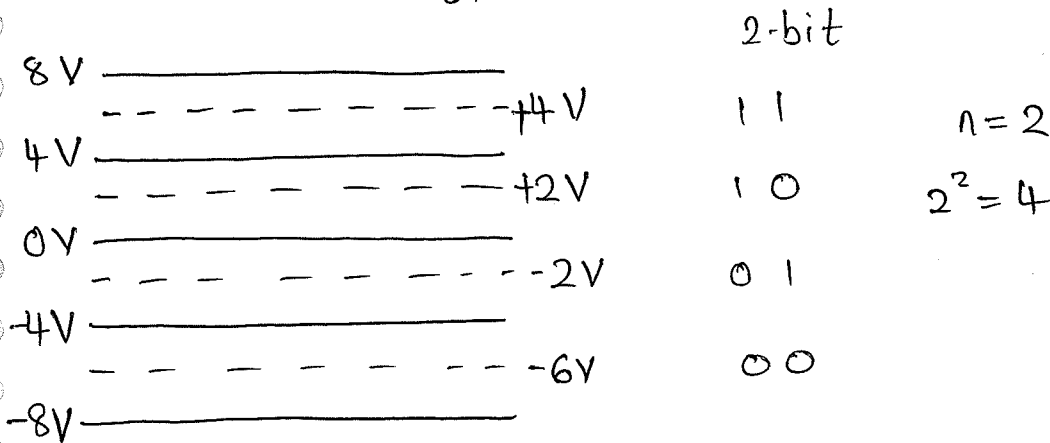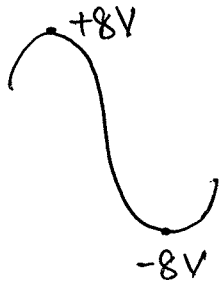$$ = 0 \quad\quad , n < 0$$

If $t = 10\,sec$

$t = 0, 2, 4, 6, 8$

$n = 5$

$T_s = 2$

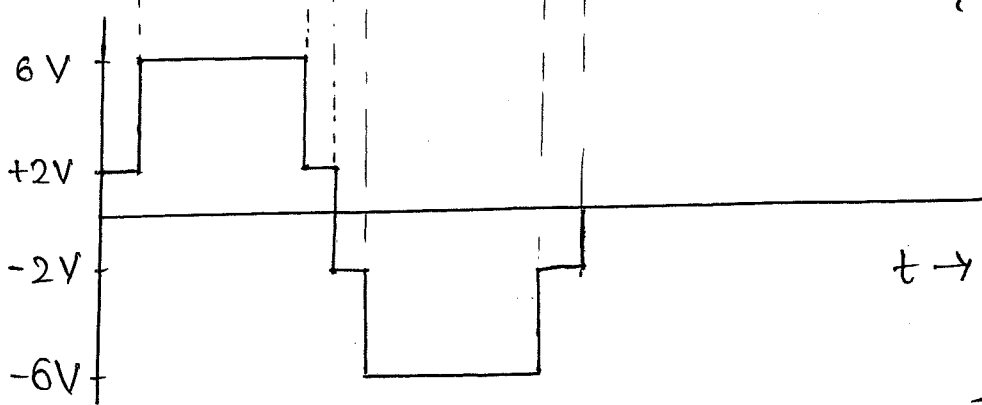$\boxed{t = nT_s}$

③ Quantized Signal

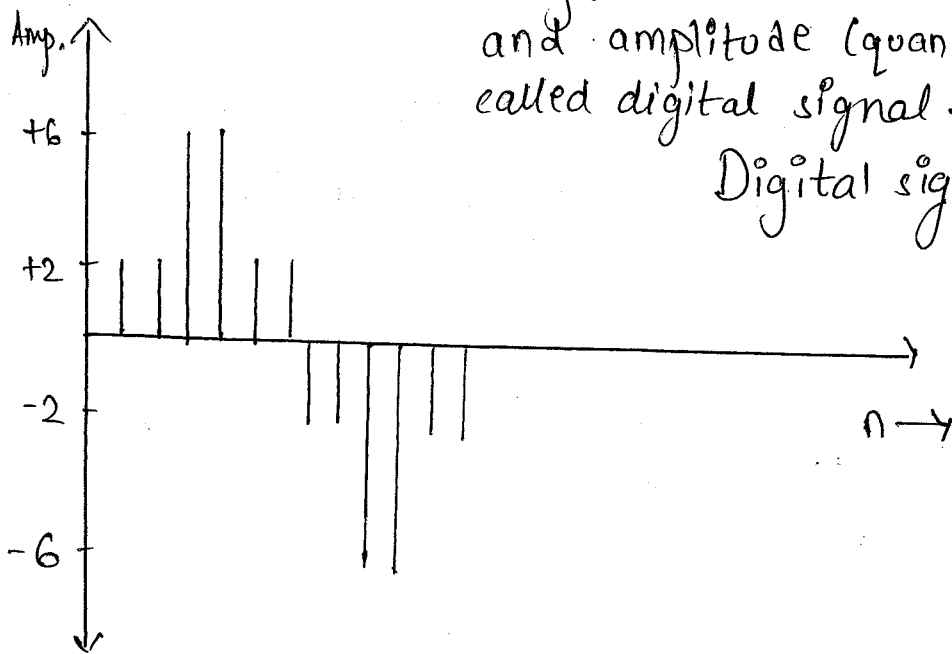-A signal which is continuous in time and discrete in amplitude is called quantized signal.

+8V

-8V

8 V		2-bit	
	+4 V	1 1	$n=2$
4 V			
	+2V	1 0	$2^2 = 4$
0V			
	-2V	0 1	
-4V			
	-6V	0 0	
-8V			

+8V
+4V

-4V
-8 V

$t \rightarrow$

Range: $[-6,-2,2,6]$

6 V

+2V

-2V $t \rightarrow$

-6V
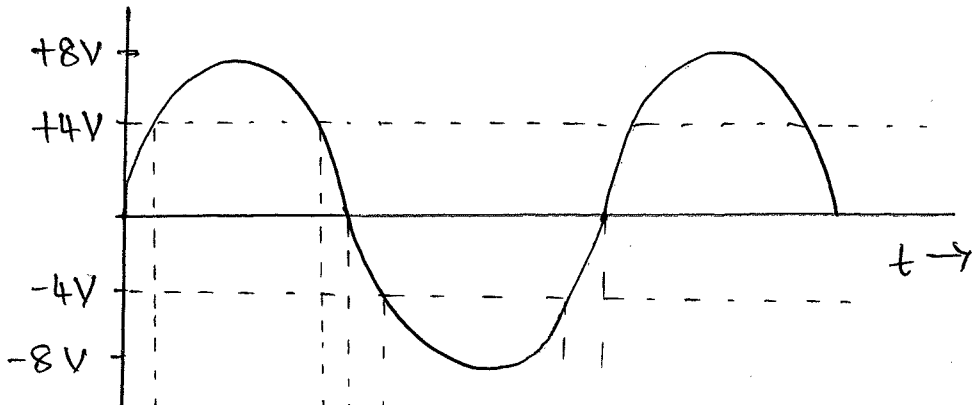
$t \Rightarrow$ continuous

$A \rightarrow$ discrete

A signal which is discrete in time and amplitude (quantized amp.) is called digital signal.

Digital signal.

Types of signals	Amplitude	Time
Continuous time signal	C	C
Discrete time signal	C	D
Quatised signal	D	C
Digital signal	D	D

The arrow from Continuous time signal (Time) to Discrete time signal (Time) is labelled **Sampling**.
The arrow from Discrete time signal (Amplitude) to Quatised signal (Amplitude) is labelled **Quantization**.

NOTE:
Amplitude conversion from C→D ⇒ Quantizer

Time conversion from C→D ⇒ Sampling

* Some standard signals *

[1] Continuous step signal

$$u(t) = A \quad, \quad t > 0$$
$$\quad\quad = 0 \quad, \quad t < 0$$

if $A = 1 \implies$ unit step signal

$$u(t) = 1 \quad, \quad t > 0$$
$$\quad\quad = 0 \quad, \quad t < 0$$
$$\quad\quad = \text{not defined} \quad, \quad t = 0$$

① $u(-t) = 1$

$$u(-t) = 0 \quad, \quad -t < 0$$
$$\quad\quad\quad = 1 \quad, \quad -t > 0$$

$$u(-t) = 1 \quad, \quad t < 0$$
$$\quad\quad\quad = 0 \quad, \quad t > 0$$

② $u(t) + u(-t) = x(t) = ? = 1 \quad, \forall t$

$u(t)$

$t < 0 \qquad 1 \qquad t > 0$

$t = 0$

$+$

$u(-t)$

$t < 0 \qquad 1 \qquad t > 0$

$t = 0$

$\|$

$x(t) \implies$

1

$t < 0 \qquad t = 0 \qquad t > 0$

u(t)

$t > 0$

1

$t < 0 \qquad t = 0$

$t \rightarrow$
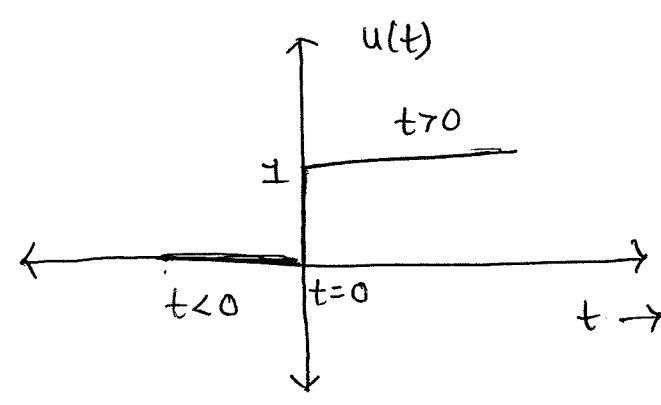
Practically $u(t)\big|_{t=0} = \frac{1}{2}$

$u(-t)$

$1 \qquad t > 0$

$t < 0 \qquad t = 0$
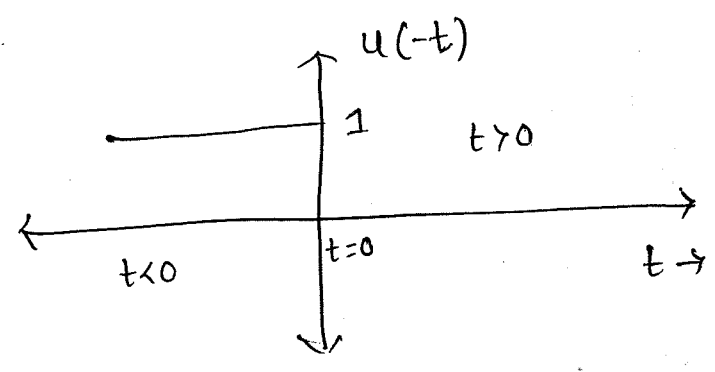
$t \rightarrow$
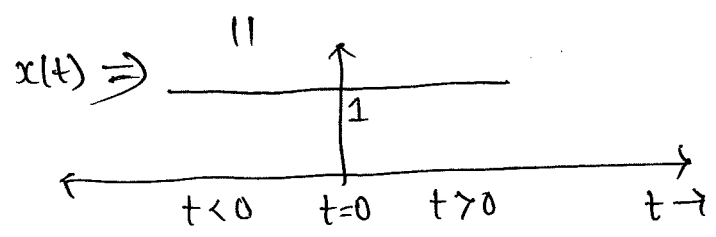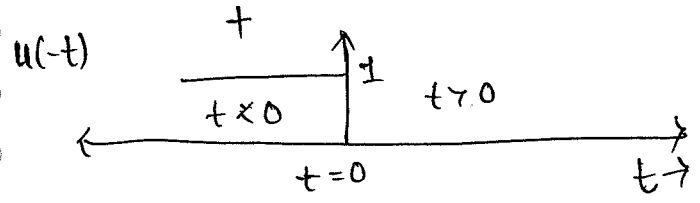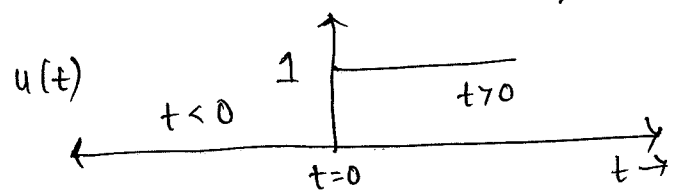
$$u(t) + u(-t) = 1$$

$$u(0) + u(0) = 1$$

$$2u(0) = 1$$

$$u(0) = 1/2$$

$$\boxed{u(t)\bigg|_{t=0} = 1/2}$$
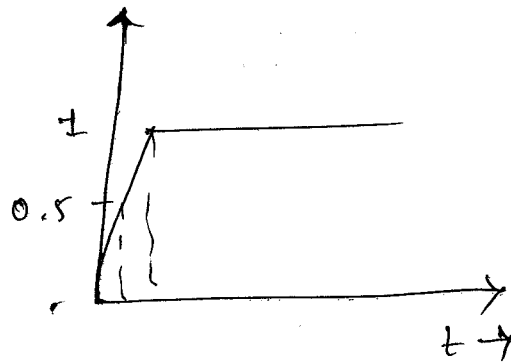
④ $u(t+1)$

$$u(t+1) = 1 \quad , \quad t+1 > 0$$
$$= 0 \quad , \quad t+1 < 0$$

$$u(t+1) = 1 \quad , \quad t > -1$$
$$= 0 \quad , \quad t < -1$$
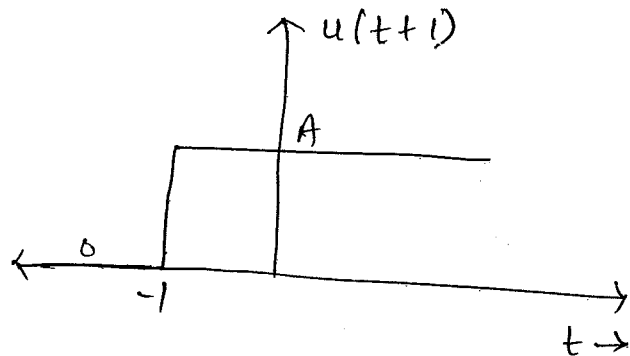
⑤ $u(t-1)$

$$u(t-1) = 1 \quad , \quad t-1 > 0$$
$$= 0 \quad , \quad t-1 < 0$$

$$u(t-1) = 1 \quad , \quad t > 1$$
$$= 0 \quad , \quad t < 1$$
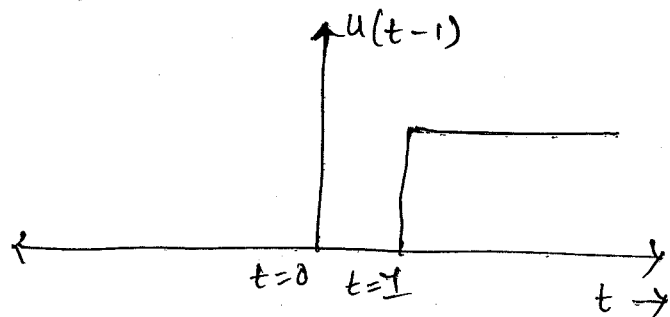
⑥ $u(2t-1)$

$$u(2t-1) = 1 \quad , \quad 2t-1 > 0$$
$$= 0 \quad , \quad 2t-1 < 0$$

$$u(2t-1) = 1 \quad , \quad t > 1/2$$
$$= 0 \quad , \quad t < 1/2$$
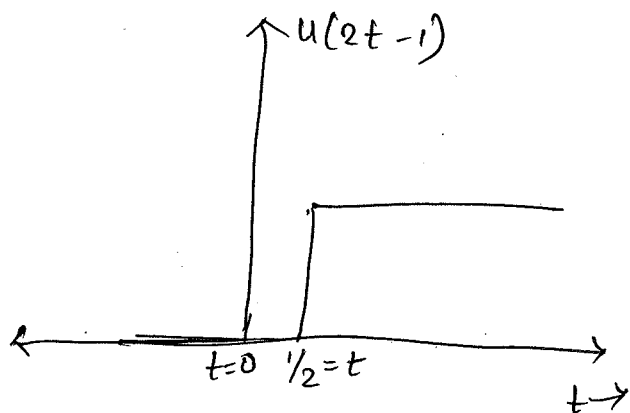
Examples

(1) $x(t) = 2u(t+1) - u(t) + u(t-1)$

$\uparrow 2u(t+1)$

$2u(t+1)$ graph, level 2 starting at $t=-1$

$-u(t)$

$u(t-1)$

$x(t)$

$\uparrow x(t)$

$x(t)$ graph with levels 2 (from $t=-1$), 1 (from $t=0$), 2 (from $t=1$)
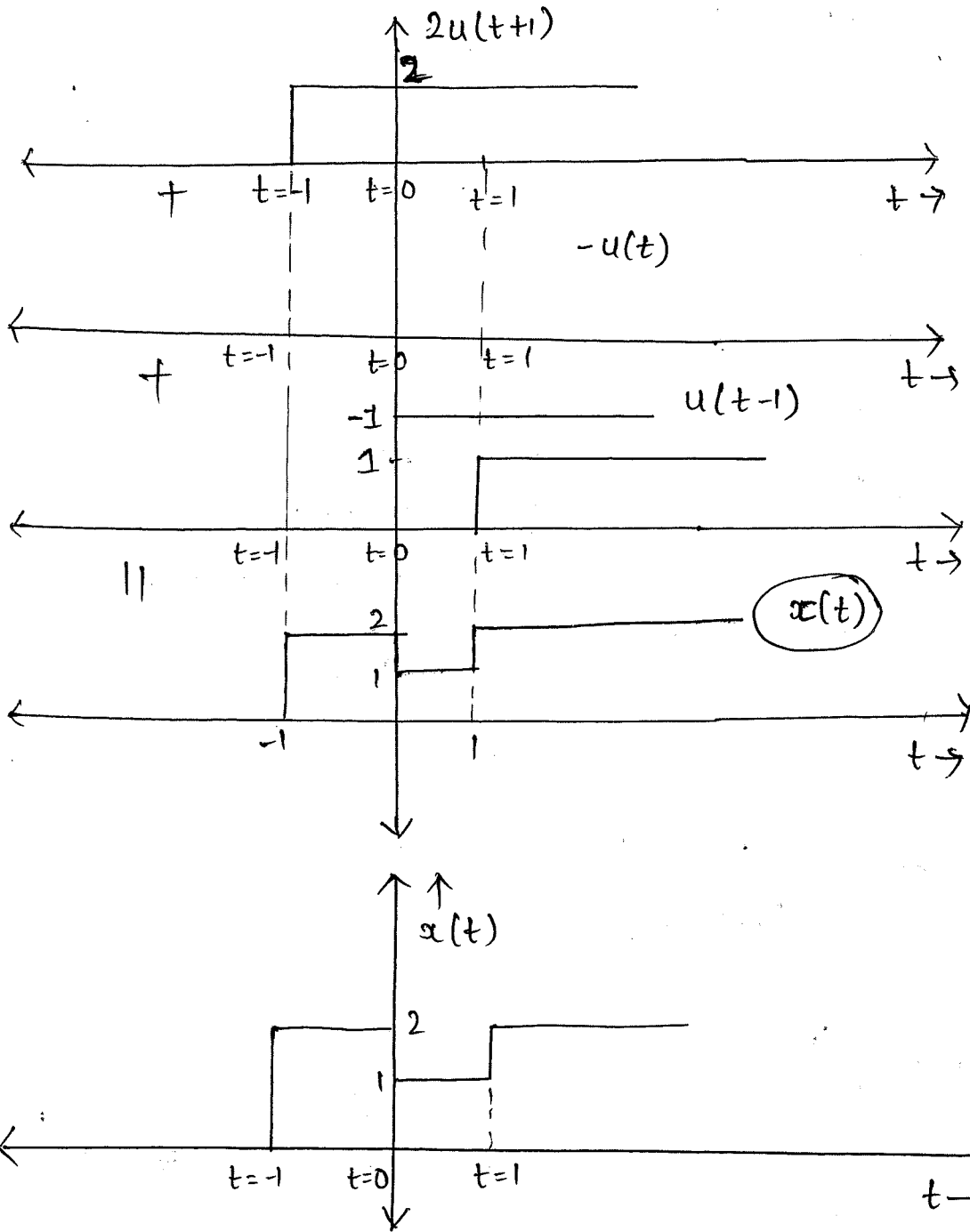
(2) $x(t) = u(t-2) + u(t) + 3u(t+2) - 2u(t+1) - 3u(t-5)$

$\quad\quad\quad t=2 \quad\quad t=0 \quad\quad\quad t=-2 \quad\quad\quad t=-1 \quad\quad\quad t=5$

Arrange in ascending order

$= 3u(t+2) - 2u(t+1) + u(t) + u(t-2) - 3u(t-5)$
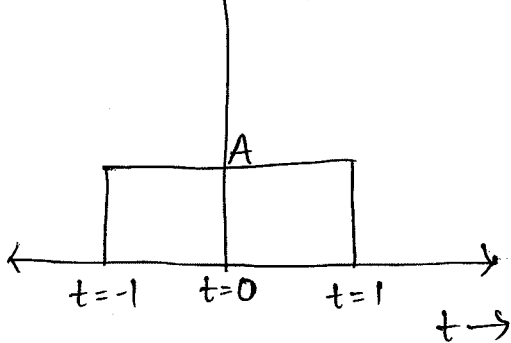
$\uparrow x(t)$
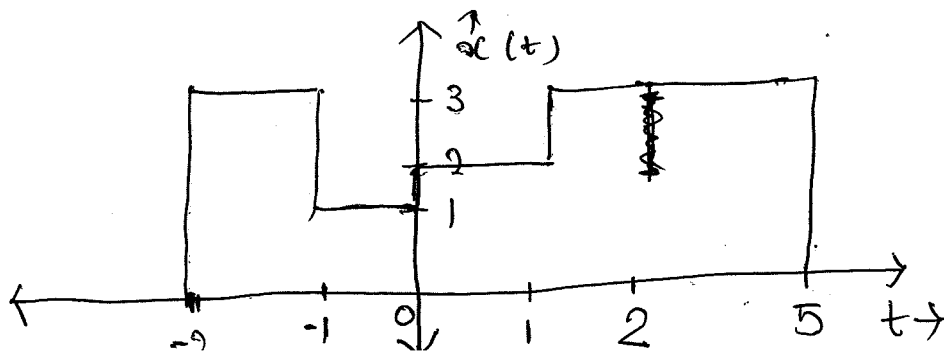
From graph to equation :-

①:- Write eq^n of following signal?
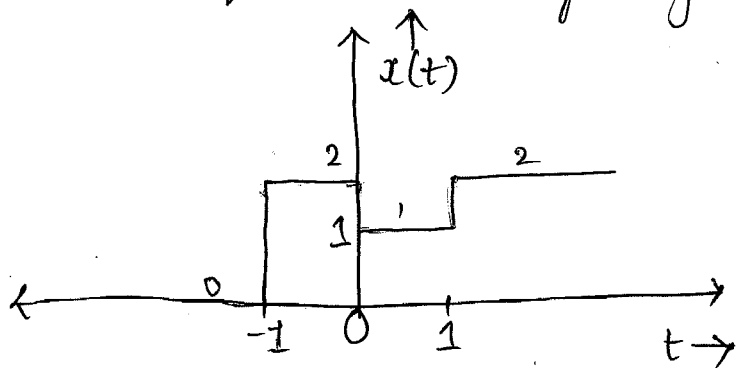
① First mark sudden change points
② Amplitude check
③ Write individual signal eq^n.

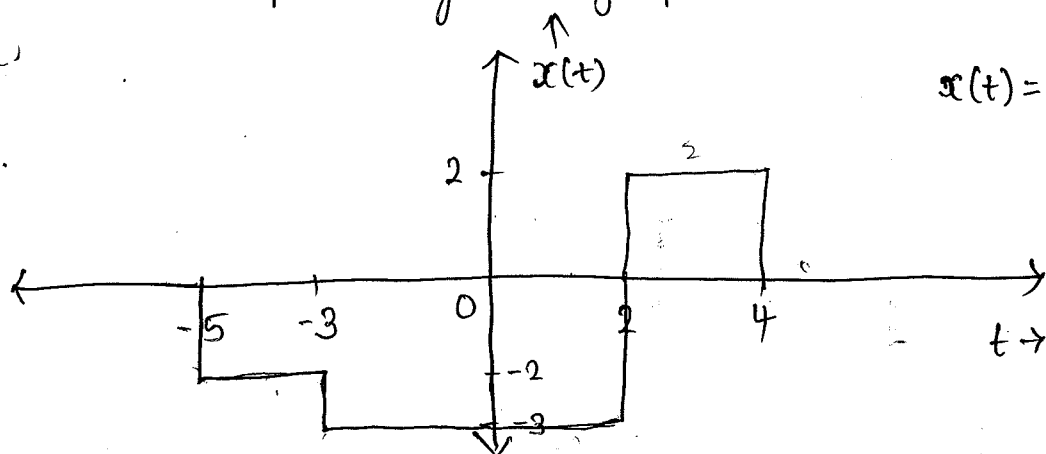Sol^n: $2u(t+1) - u(t) + 1 \cdot u(t-1)$

$$x(t) = A \cdot u(t+1) - A u(t-1)$$

$$\boxed{x(t) = A \left(u(t+1) - u(t-1) \right)}$$

NOTE: Whenever there is sudden change in signal ⟹ step signal exists.

①:- Write eq^n for given graph :- (in terms of step signal)

$x(t) = -2u(t+5) - 1 \cdot u(t+3)$
$\qquad + 5u(t-2)$
$\qquad\qquad - 2u(t-4)$.