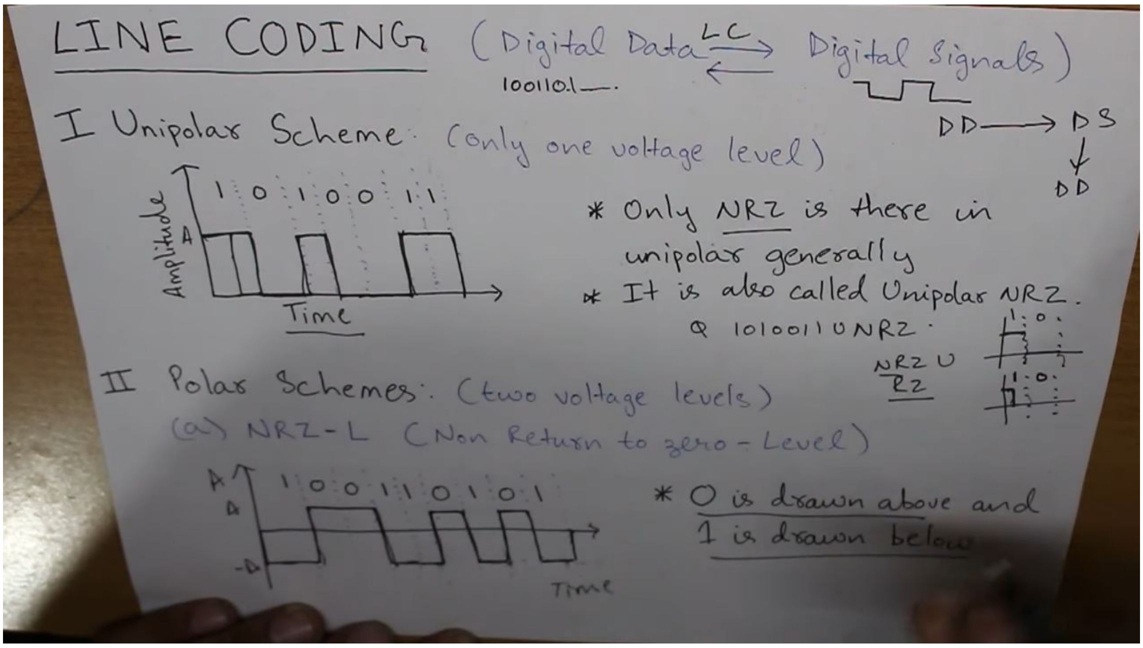
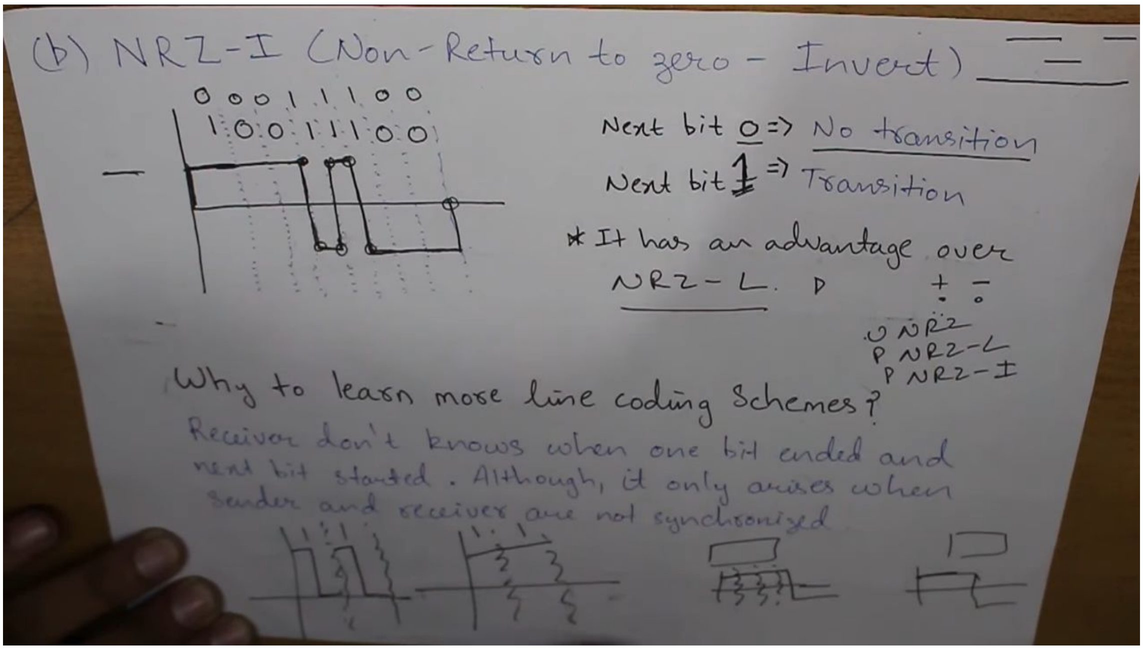
DC_Notes_Ip_Academy

Line Coding

05:14

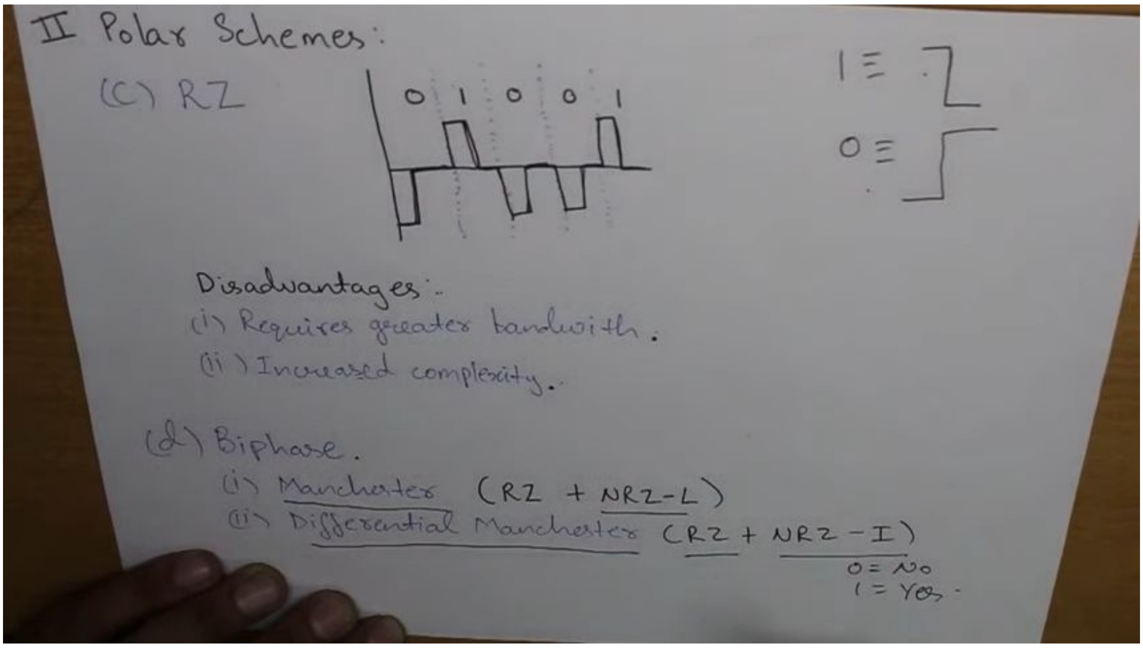


09:42



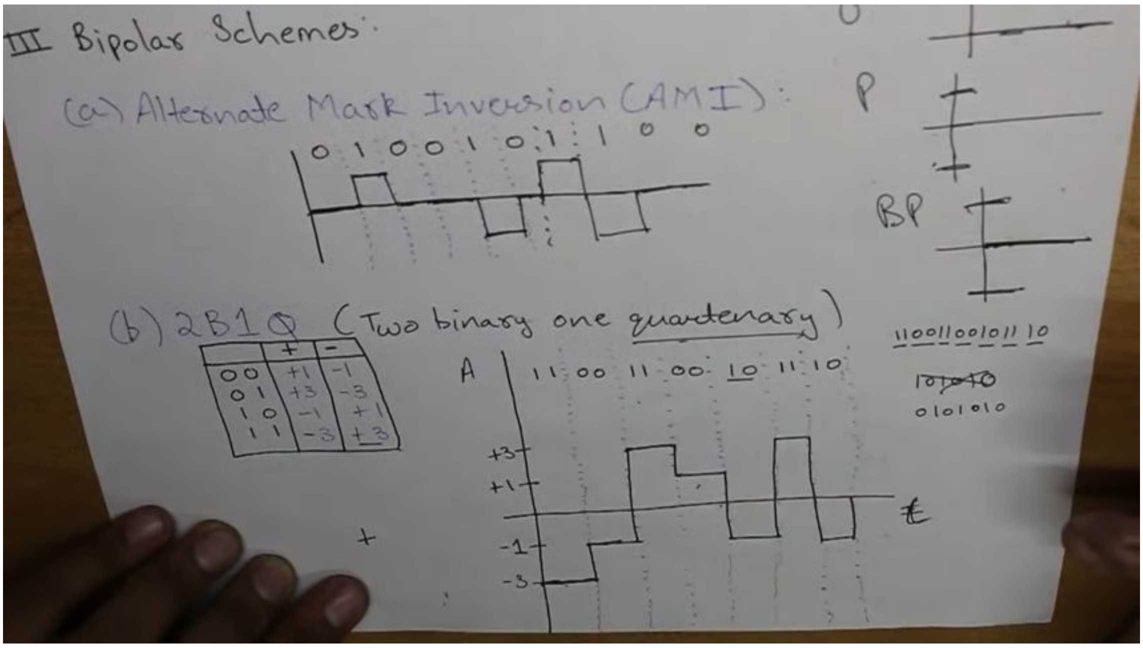
Polar (RZ & Manchester) and Bipolar

01:23



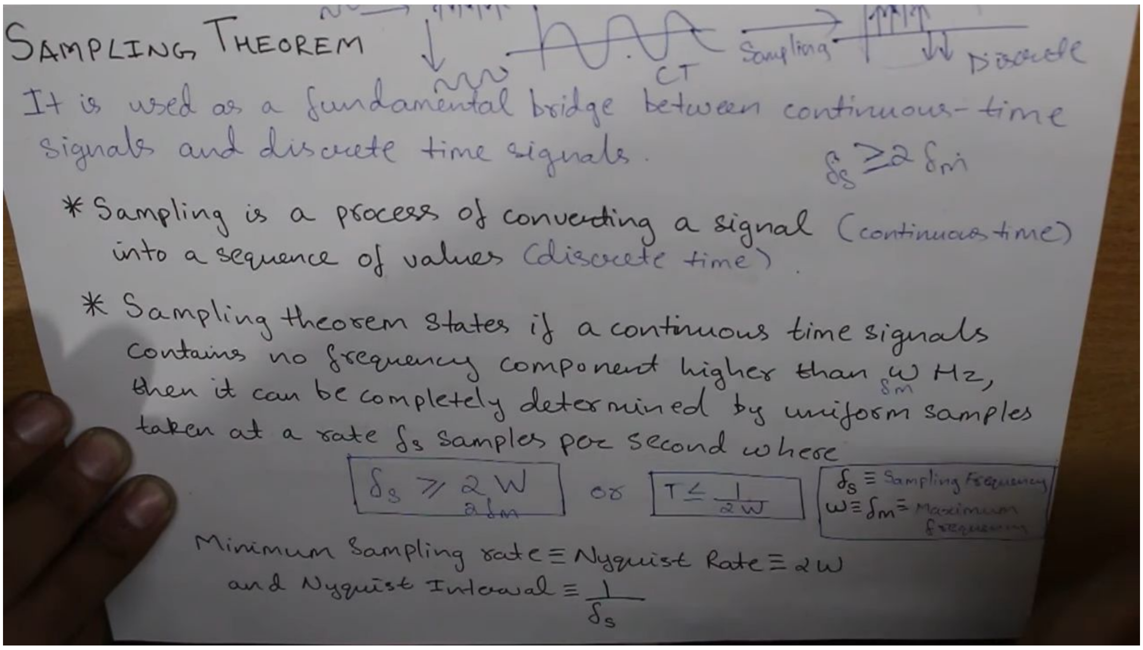
03:19

08:13

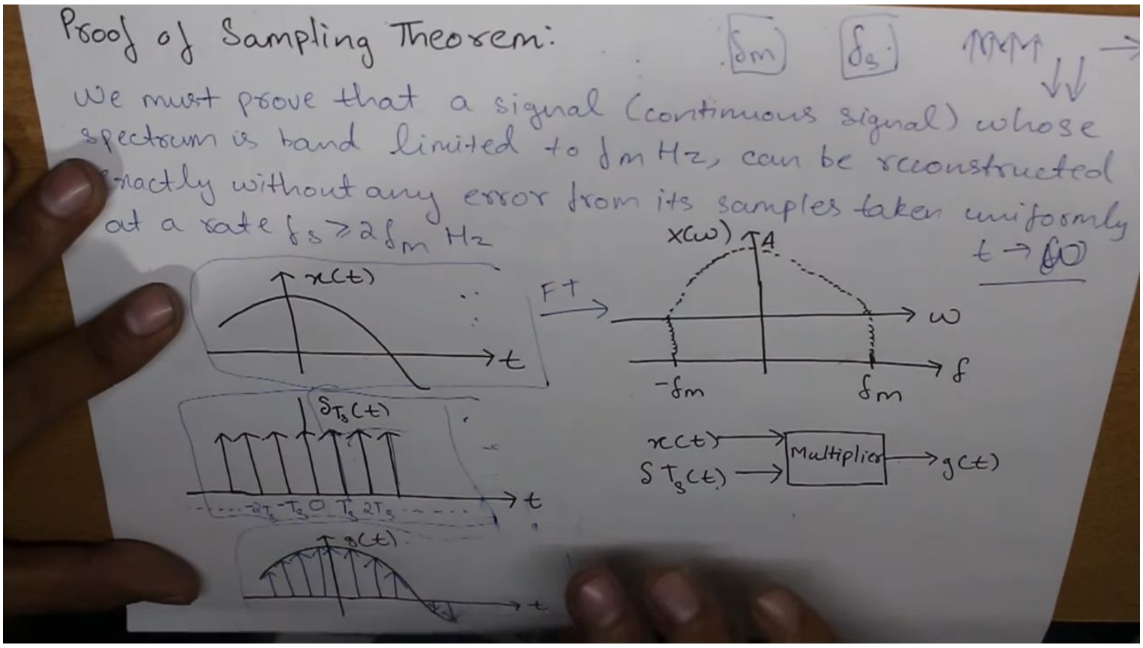


Sampling Theorem with proof

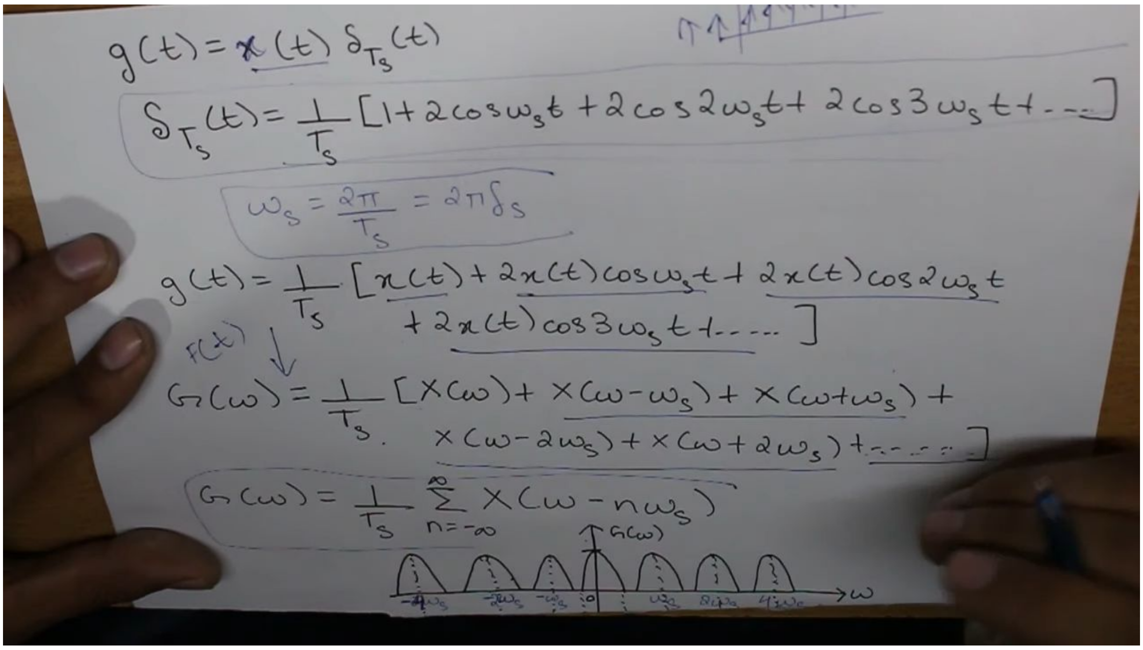
02:32



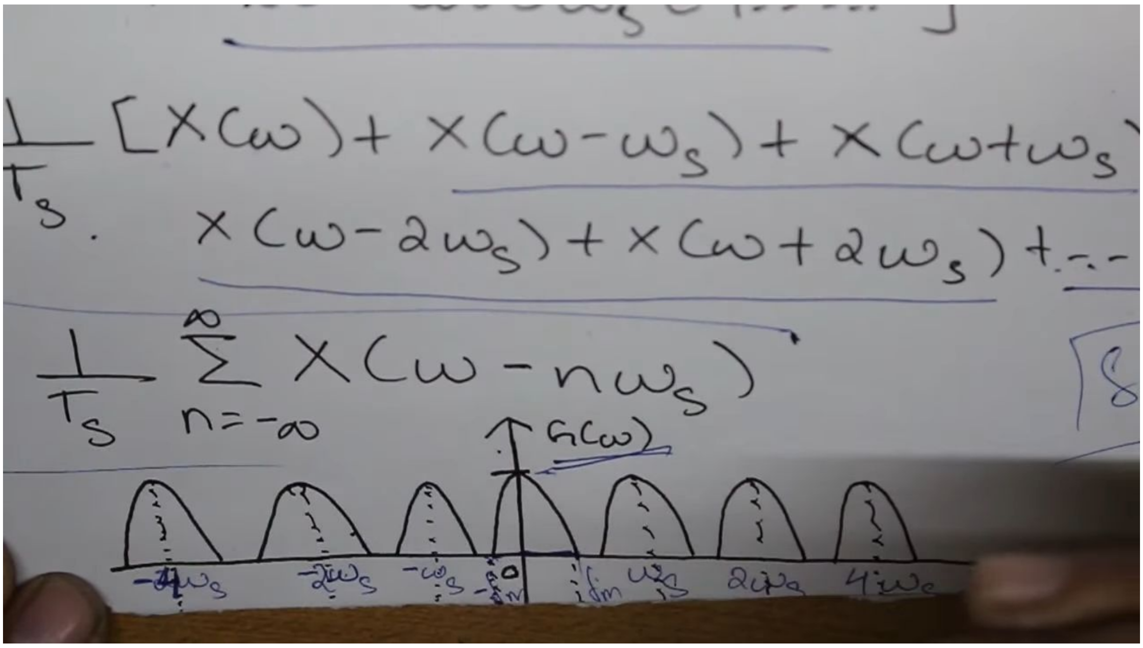
06:53



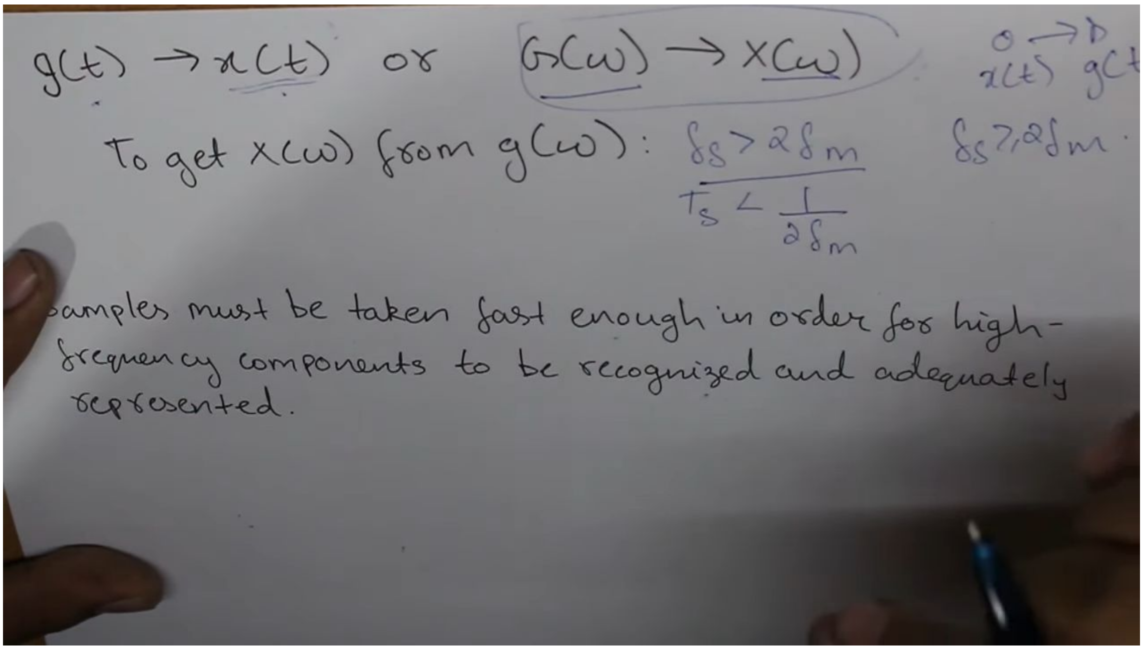
08:38


$g(t) = x(t)\,\delta_{T_s}(t)$
$\delta_{T_s}(t) = \frac{1}{T_s}[1 + 2\cos\omega_s t + 2\cos 2\omega_s t + 2\cos 3\omega_s t + \cdots]$
$\omega_s = \frac{2\pi}{T_s} = 2\pi f_s$
$g(t) = \frac{1}{T_s}[x(t) + 2x(t)\cos\omega_s t + 2x(t)\cos 2\omega_s t + 2x(t)\cos 3\omega_s t + \cdots]$
F(t)
$G(\omega) = \frac{1}{T_s}[X(\omega) + X(\omega-\omega_s) + X(\omega+\omega_s) + X(\omega-2\omega_s) + X(\omega+2\omega_s) + \cdots]$
$G(\omega) = \frac{1}{T_s}\sum_{n=-\infty}^{\infty} X(\omega - n\omega_s)$
$G(\omega)$
ω

09:53

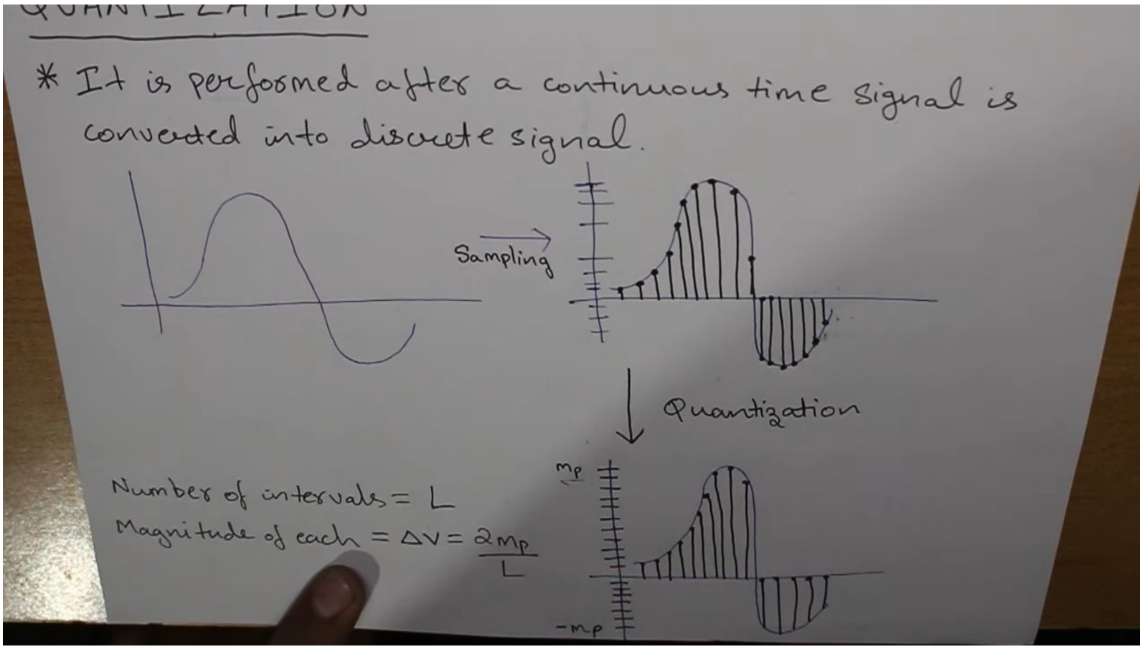

$\frac{1}{T_s}[X(\omega) + X(\omega-\omega_s) + X(\omega+\omega_s) + X(\omega-2\omega_s) + X(\omega+2\omega_s) + \cdots$
$\frac{1}{T_s}\sum_{n=-\infty}^{\infty} X(\omega - n\omega_s)$
$G(\omega)$
$-4\omega_s$
$-2\omega_s$
$-\omega_s$
0
f_m
ω_s
$2\omega_s$
$4\omega_s$

11:30



What is Quantization?

01:49



Companding

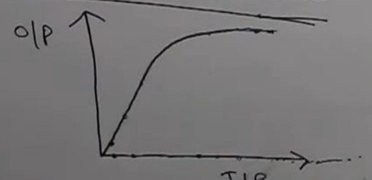
01:57

COMPANDING (Compressing + Expanding)

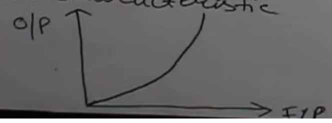
* Signal is compressed at transmitter end and expanded at receiver end.

I/P → Compressor → Uniform Quantizer → Expander → Output

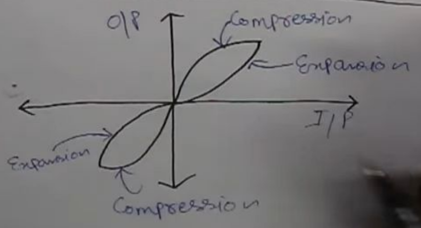
Compressor Characteristic



Expander characteristic



Compander Characteristic



03:42

Types:
(i) μ-law companding
(ii) A law companding.

I μ-law companding.

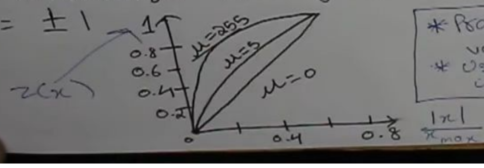
$$Z(x) = (\operatorname{sgn} x) \frac{\ln\left(1 + \frac{\mu |x|}{x_{max}}\right)}{\ln(1+\mu)}$$

x = Input

$\frac{|x|}{x_{max}}$

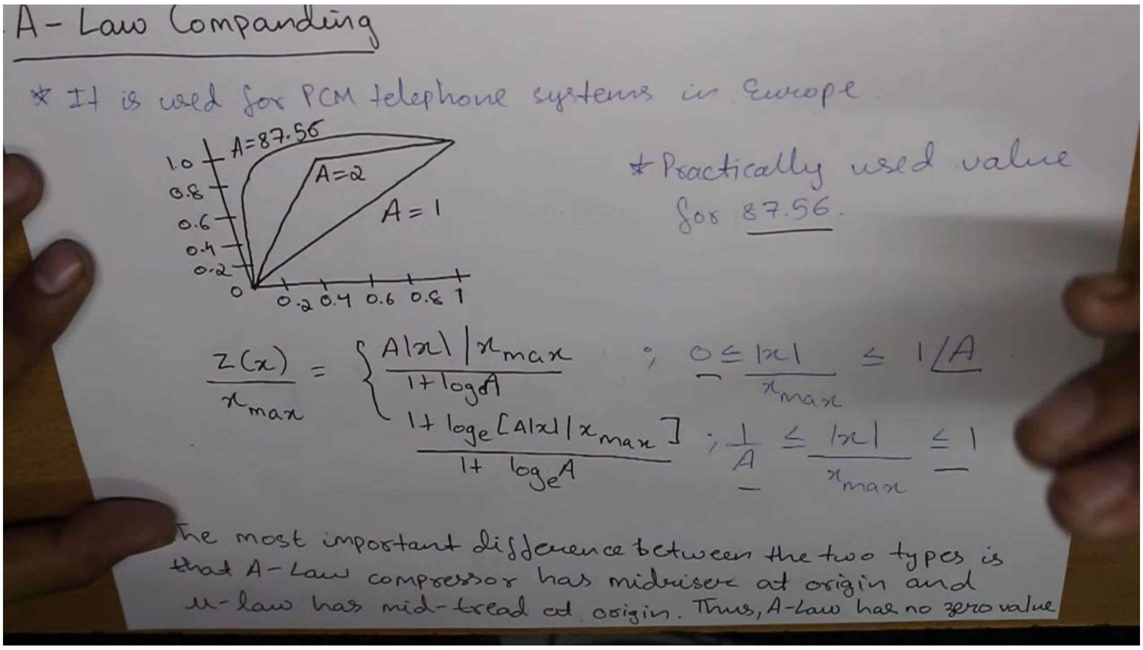
$\pm$

μ = extent of compression.
$Z(x)$ = Output or Normalized output.
x = Input.
$|x|/x_{max}$ = Normalized value of input w.r.t x_{max}.
$(\operatorname{sgn} x) = \pm 1$



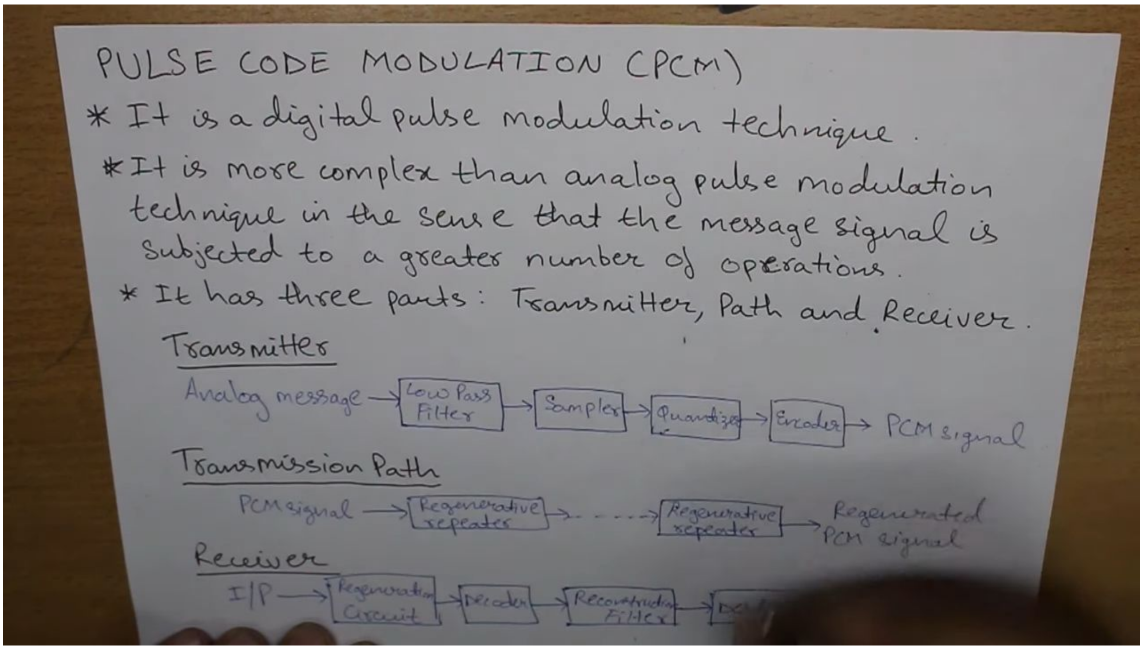
* Practically used value of μ is 255
* Used in PCM telephone in Canada & Japan
* Used for speech & music signals

05:45

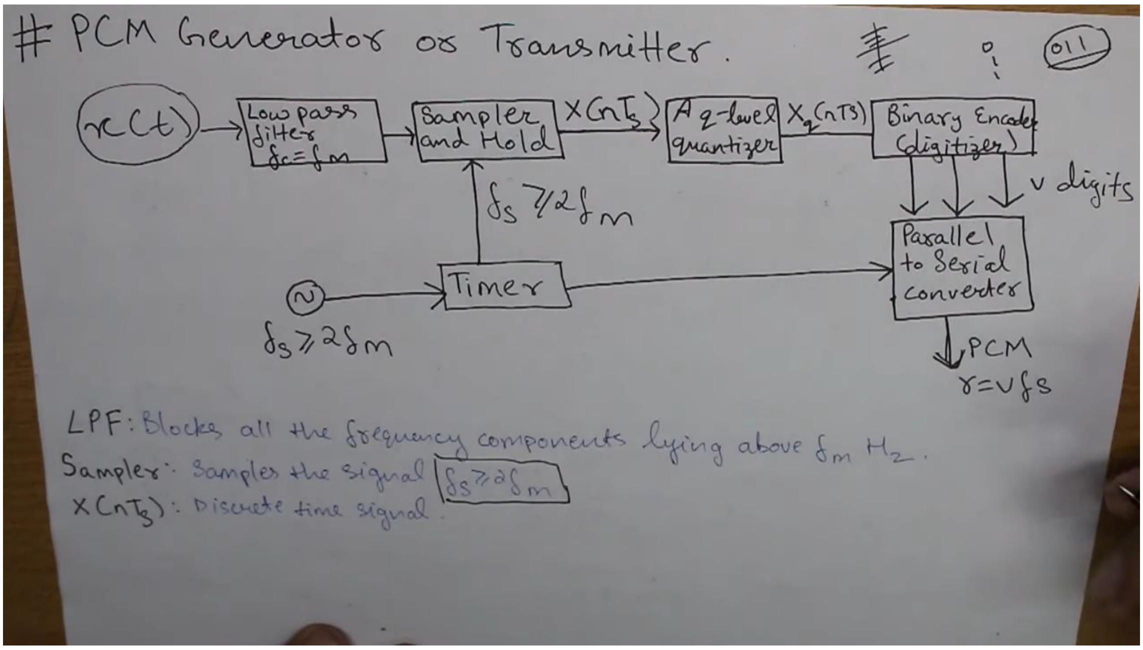


Pulse Code Modulation (PCM)

01:21

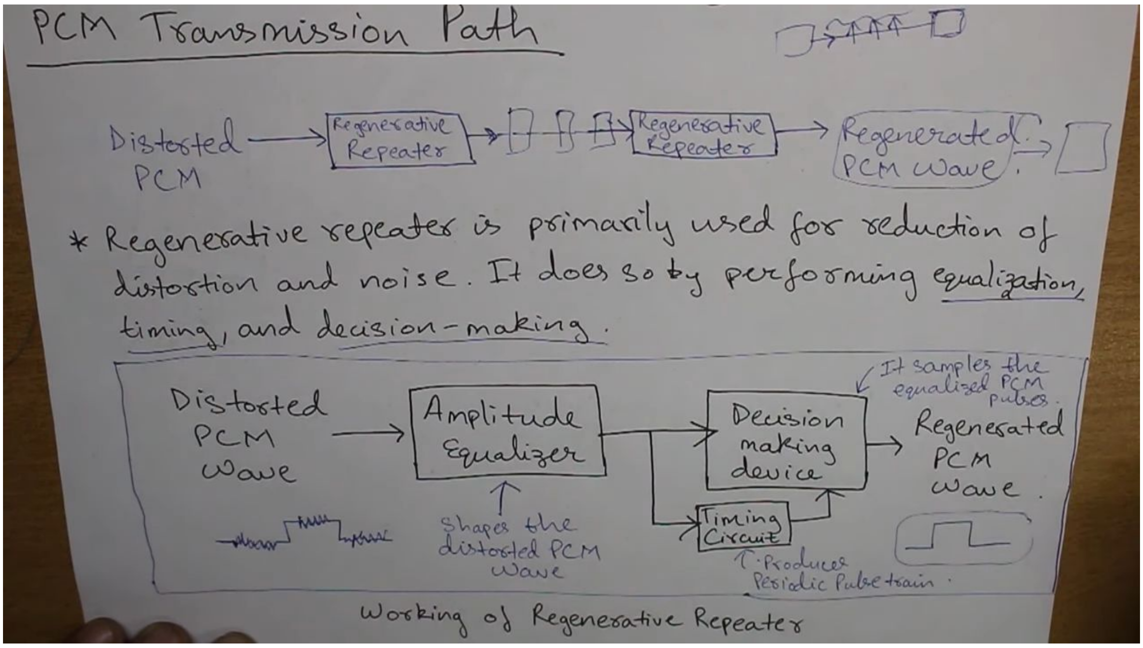


04:40



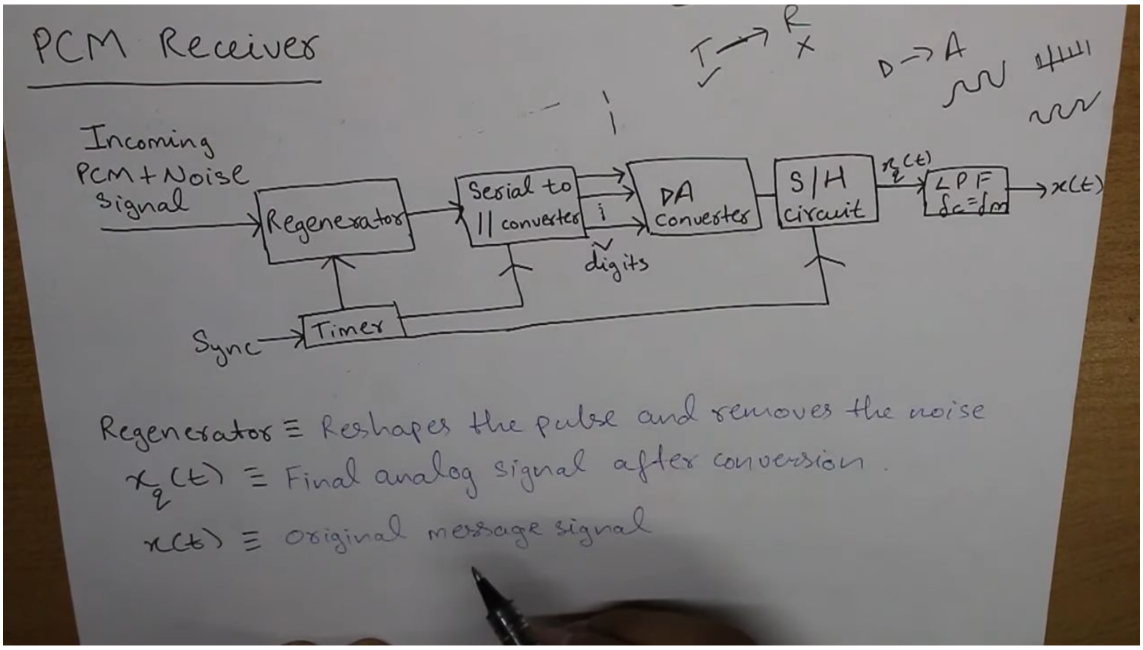
PCM Generator or Transmitter.
011
x(t)
Low pass filter fc=fm
Sampler and Hold
X(nTs)
A q-level quantizer
Xq(nTs)
Binary Encoder (digitizer)
v digits
fs ≥ 2fm
Parallel to Serial converter
Timer
fs ≥ 2fm
PCM
r=vfs
LPF: Blocks all the frequency components lying above fm Hz.
Sampler: Samples the signal fs ≥ 2fm
X(nTs): Discrete time signal.

07:49



PCM Transmission Path
Distorted PCM
Regenerative Repeater
Regenerative Repeater
Regenerated PCM Wave.
* Regenerative repeater is primarily used for reduction of distortion and noise. It does so by performing equalization, timing, and decision-making.
Distorted PCM Wave
Amplitude Equalizer
Decision making device
It samples the equalized PCM pulses.
Regenerated PCM wave.
Timing Circuit
Shapes the distorted PCM wave
Produces Periodic Pulse train.
Working of Regenerative Repeater

09:51



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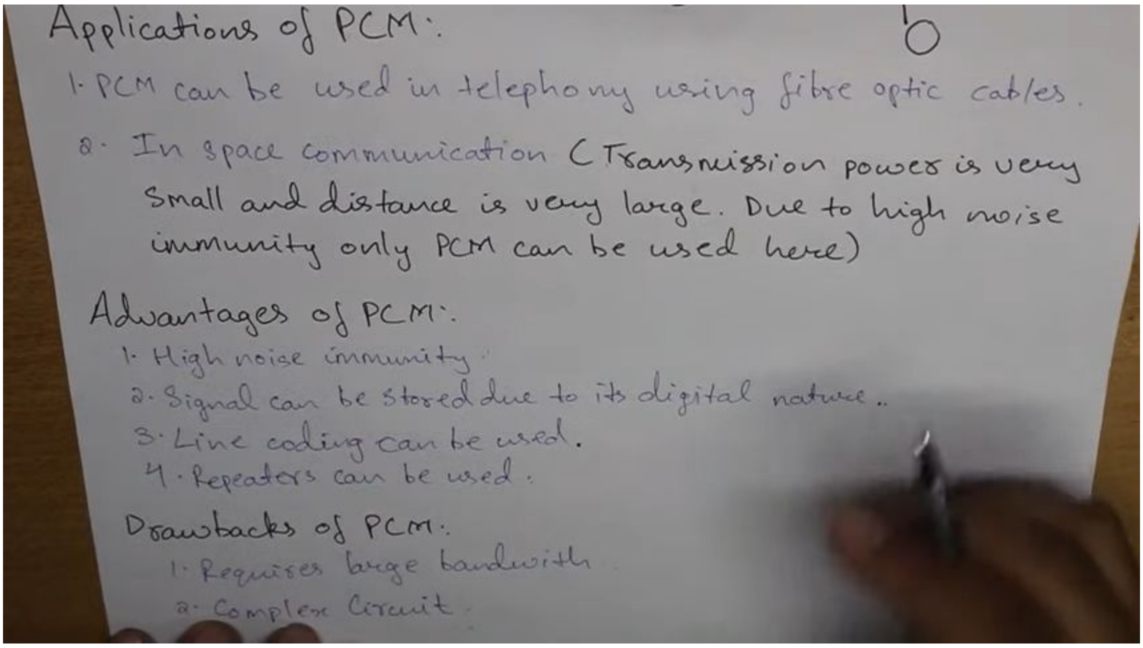
00:57

00:57



Applications of PCM:

1. PCM can be used in telephony using fibre optic cables.
2. In space communication (Transmission power is very small and distance is very large. Due to high noise immunity only PCM can be used here)

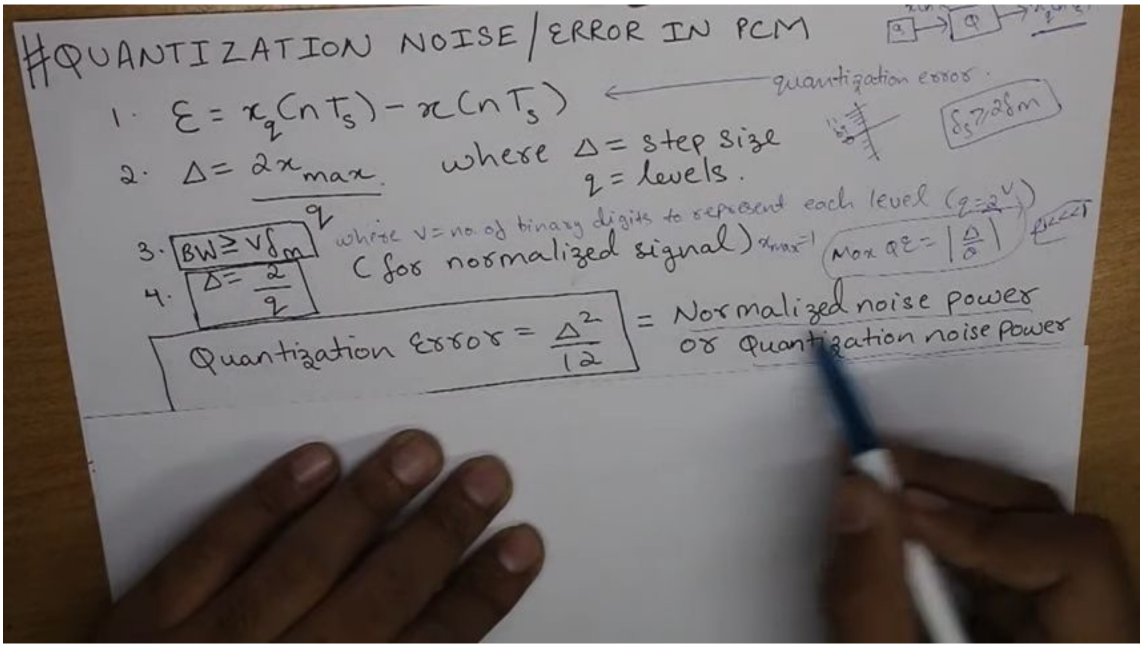
Advantages of PCM:

1. High noise immunity.
2. Signal can be stored due to its digital nature.
3. Line coding can be used.
4. Repeaters can be used.

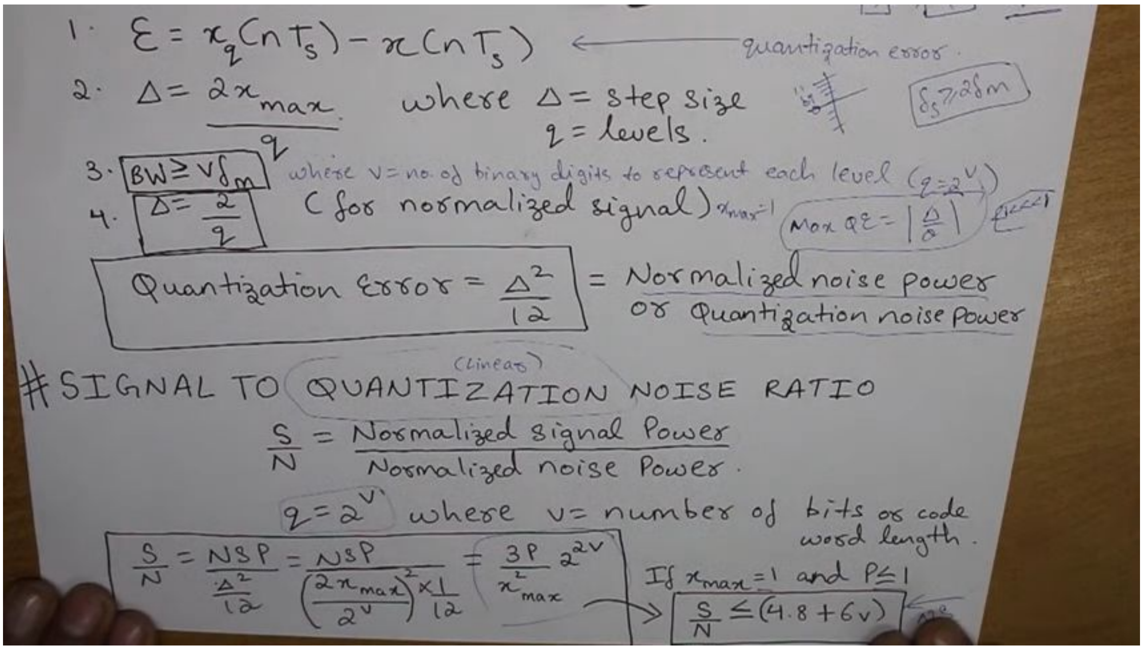
Drawbacks of PCM:

1. Requires large bandwith
2. Complex Circuit.

05:45

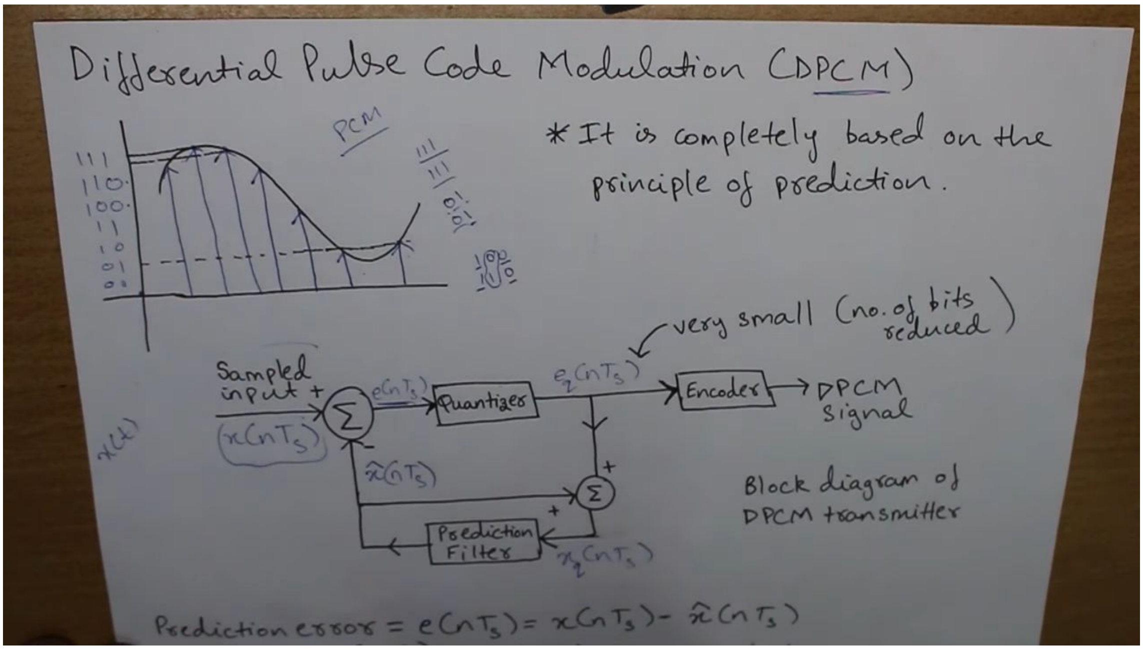


06:53

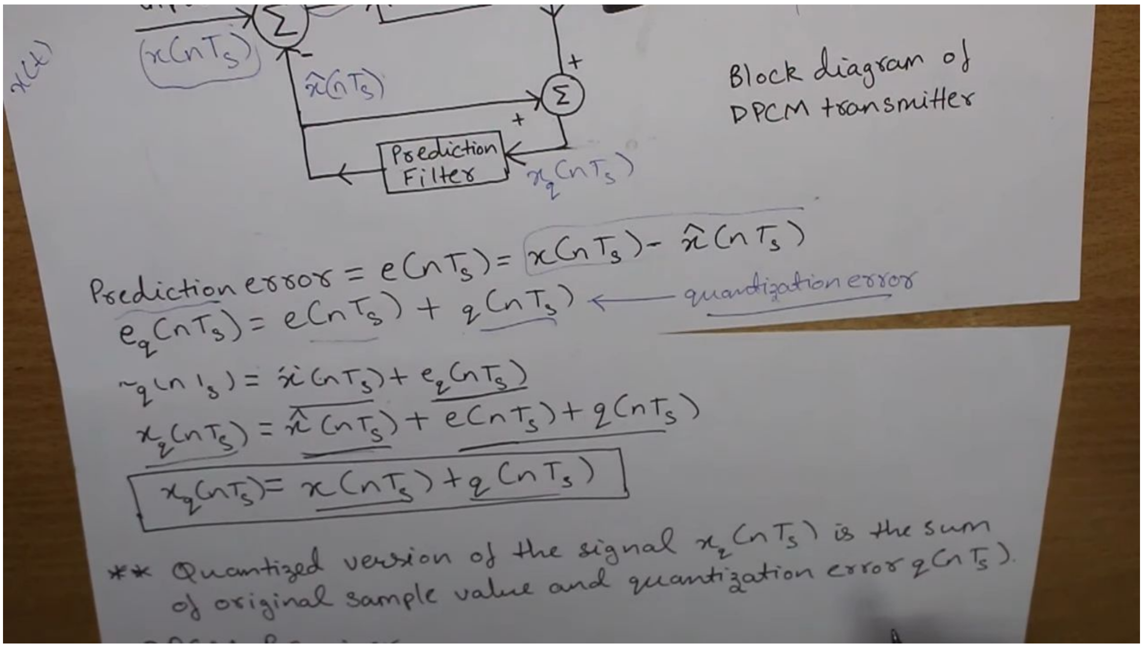


Differential Pulse Code Modulation (DPCM)

03:28


Differential Pulse Code Modulation (DPCM)
PCM
111
110
100
11
10
01
00
* It is completely based on the principle of prediction.
very small (no. of bits reduced)
Sampled input
x(t)
x(nTs)
e(nTs)
Quantizer
eq(nTs)
Encoder
DPCM signal
x̂(nTs)
Prediction Filter
xq(nTs)
Block diagram of DPCM transmitter
Prediction error = e(nTs) = x(nTs) - x̂(nTs)

07:16


x(t)
x(nTs)
x̂(nTs)
Prediction Filter
xq(nTs)
Block diagram of DPCM transmitter
Prediction error = e(nTs) = x(nTs) - x̂(nTs)
eq(nTs) = e(nTs) + q(nTs) ← quantization error
xq(nTs) = x̂(nTs) + eq(nTs)
xq(nTs) = x̂(nTs) + e(nTs) + q(nTs)
xq(nTs) = x(nTs) + q(nTs)
** Quantized version of the signal xq(nTs) is the sum of original sample value and quantization error q(nTs).

08:45

$x_q(nT_s) = x(nT_s) + e_q(nT_s)$

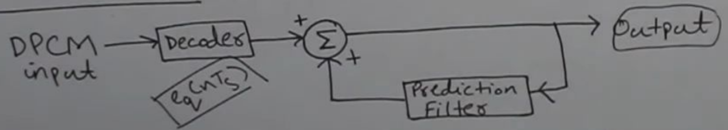
$x_q(nT_s) = \hat{x}(nT_s) + e(nT_s) + q(nT_s)$

$$\boxed{x_q(nT_s) = x(nT_s) + q(nT_s)}$$

** Quantized version of the signal $x_q(nT_s)$ is the sum of original sample value and quantization error $q(nT_s)$.

T ⟶ R

DPCM Receiver



Decoder: reconstructs the quantized error signal from incoming binary signal.

* Signal at the receiver differs from actual signal by quantization error $q(nT_s)$.

10:25

Advantages of DPCM:

1. Bandwith is lesser than PCM
2. Less no. of quantization levels.
3. Less no. of bits required to represent quantization levels

Evaluation of Output Signal to Noise (S/N) ratio

$$SNR = \frac{\text{Mean square value of a signal}}{\text{Mean square value of quantization noise}}$$

$$\boxed{SNR = \frac{\sigma_x^2}{\sigma_Q^2}}$$

$$SNR = \underbrace{\left(\frac{\sigma_x^2}{\sigma_E^2}\right)}_{\text{Prediction gain}} \times \underbrace{\left(\frac{\sigma_E^2}{\sigma_Q^2}\right)}_{\text{Prediction error to quantization ... ratio}}$$

where σ_E^2 = Variance of prediction error $e(nT_s)$.

===

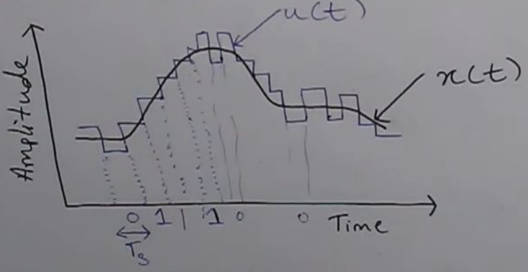
03:37

Delta Modulation

(PCM → DPCM → DM → ADM   CT → DT

PCM: all samples; DPCM: Difference of samples; DM: only one bit. Bandwidth is further reduced

It transmits only one bit per sample, depending upon whether the present value has increased or decreased as compared to the previous value.



1 0

+	1
−	0

$T_s \equiv$ sampling interval

$$e(nT_s) = x(nT_s) - \hat{x}(nT_s)$$

$e(nT_s) \equiv$ error in present sample

$x(nT_s) \equiv$ sampled signal of $x(t)$

$u[(n-1)T_s] = \hat{x}(nT_s) \equiv$ last sample approximation of the staircase

05:16

$u(nT_s) =$ present sample approximation of staircase output

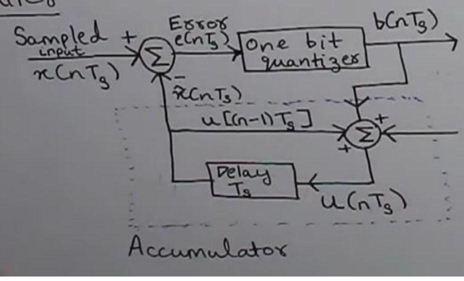
$u[(n-1)T_s] = \hat{x}(nT_s) =$ last sample approximation of staircase waveform.

$$b(nT_s) = \Delta\,\mathrm{sgn}[e(nT_s)]$$

$$= \begin{cases} +\Delta & \text{if } x(nT_s) \geq \hat{x}(nT_s) \\ -\Delta & \text{if } x(nT_s) < \hat{x}(nT_s) \end{cases}$$

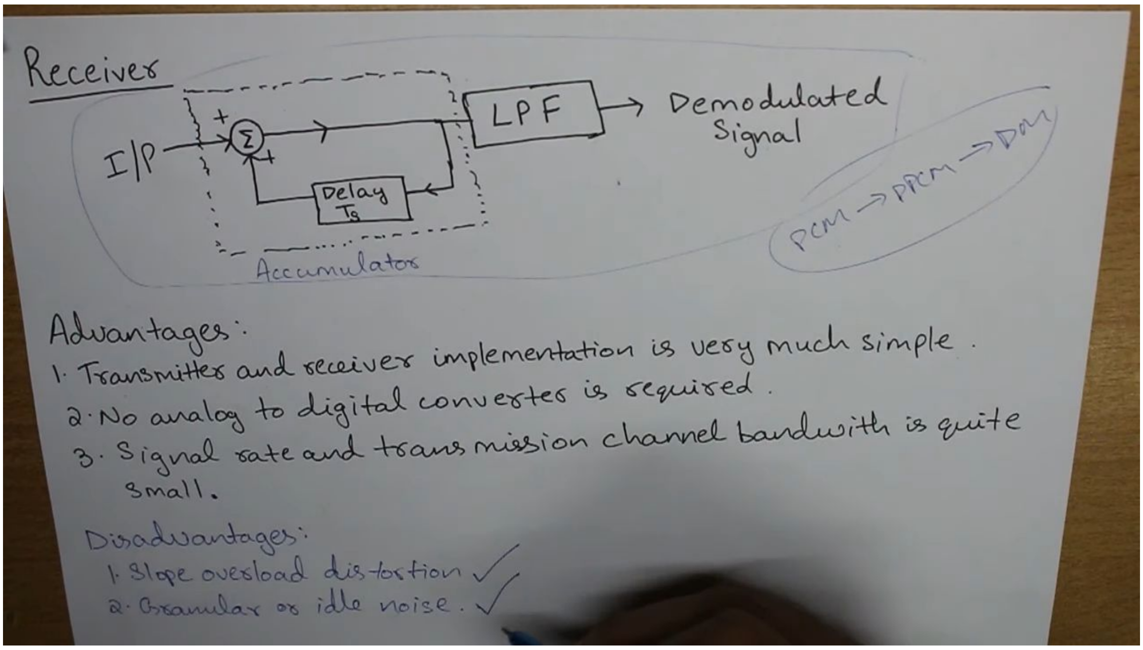
1 is transmitted
0 is transmitted

Transmitter

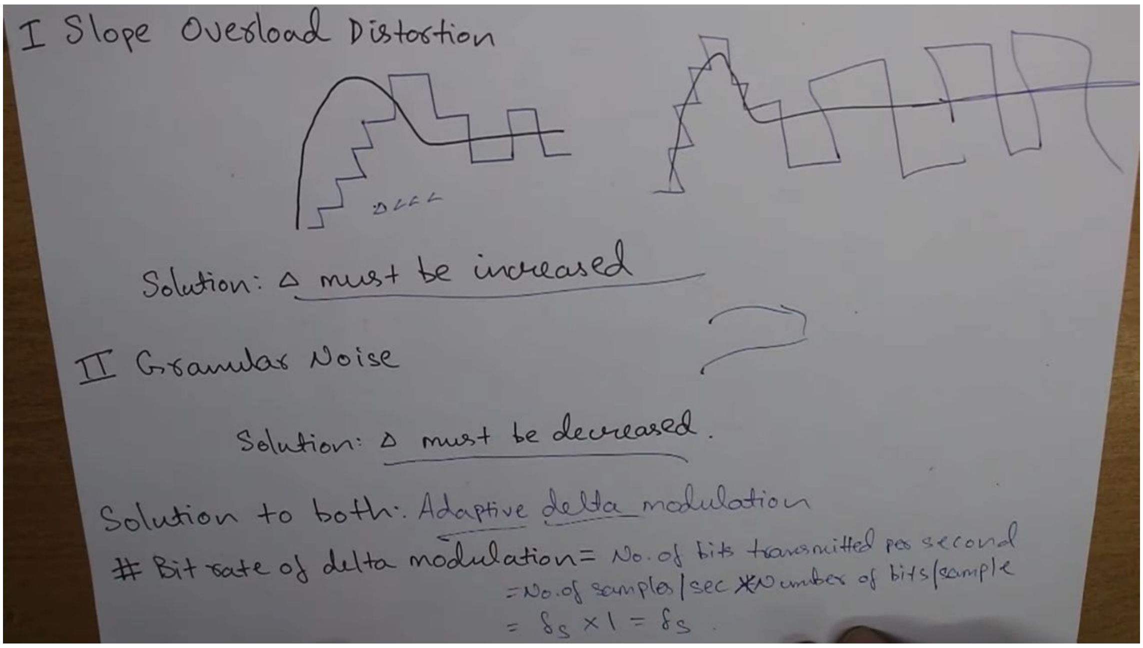


$$** \; u(nT_s) = u[(n-1)T_s] + [\pm\Delta]$$
$$= u[(n-1)T_s] + b(nT_s)$$

09:56

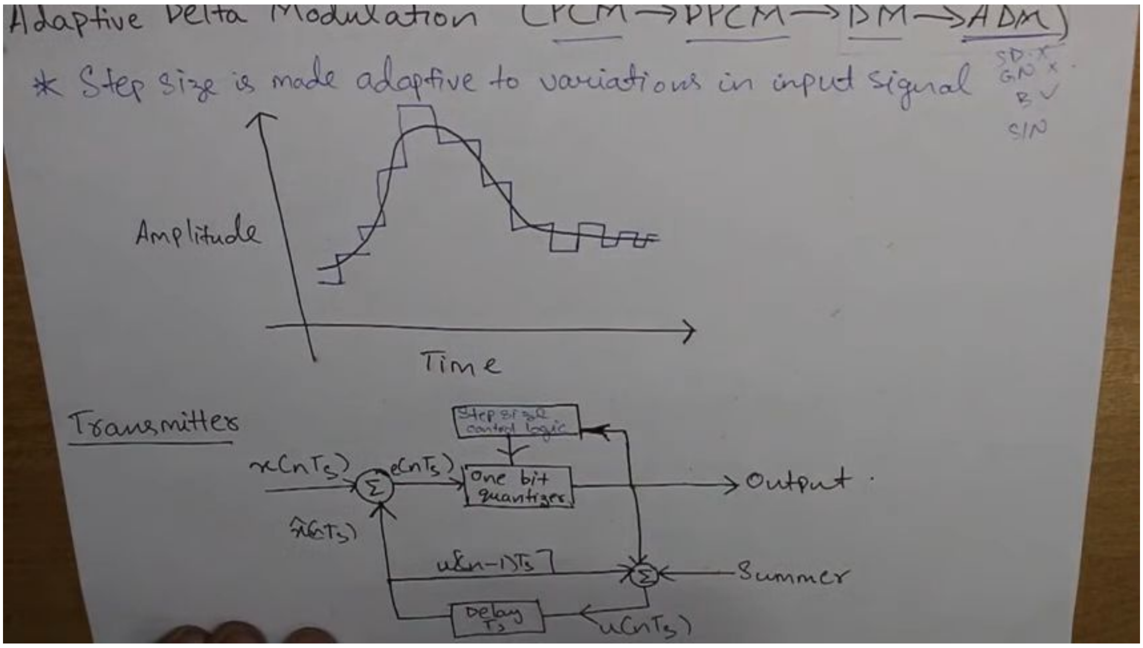


11:47

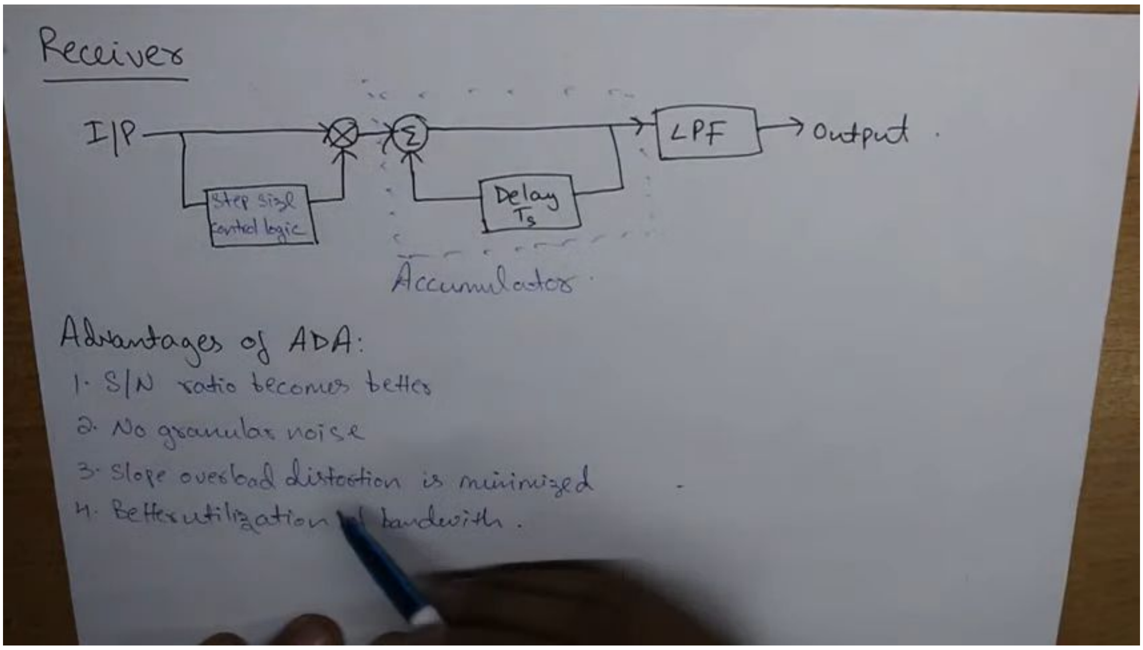


Adaptive Delta Modulation (ADM): Analysis

02:52

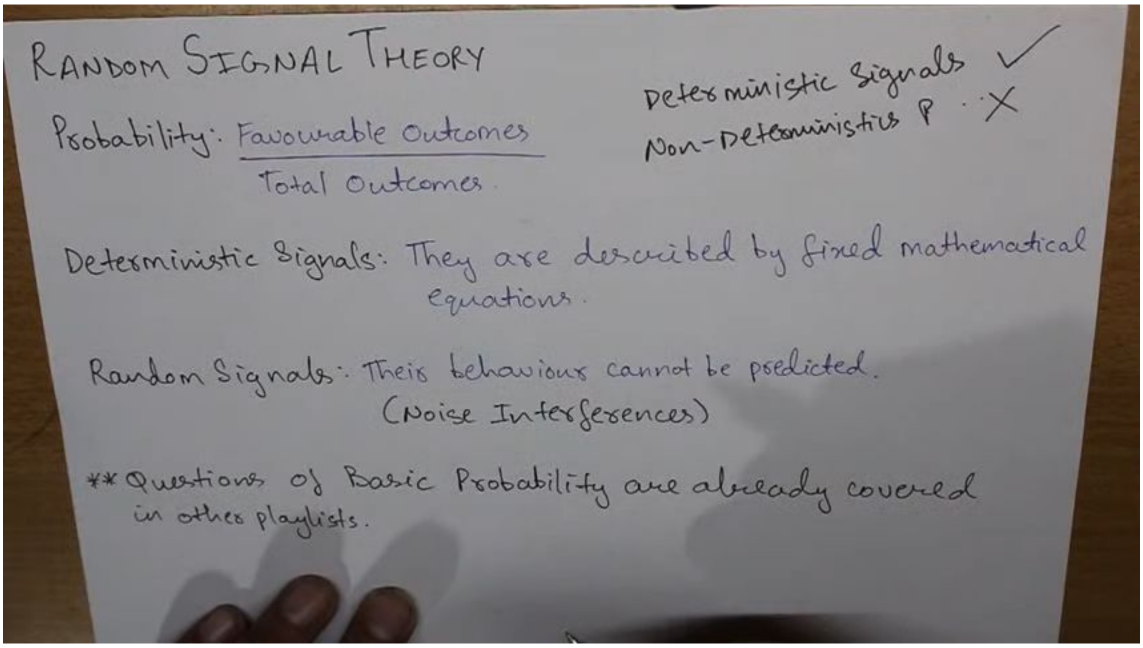


03:08

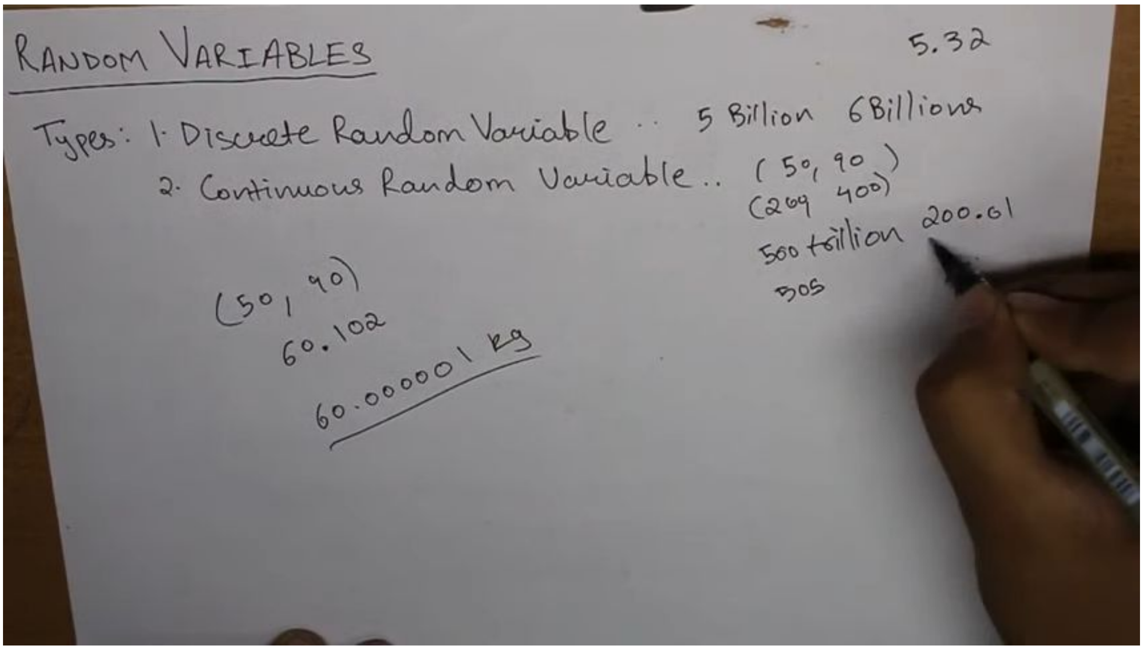


Random Variable | Random Signal Theory

01:53

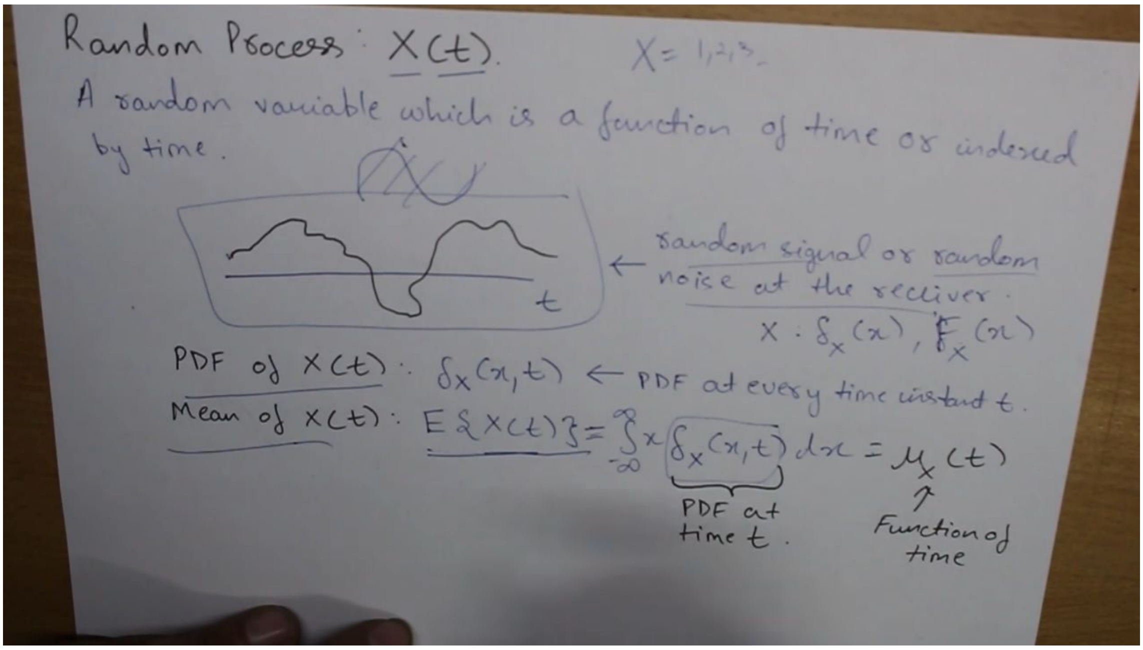


05:37

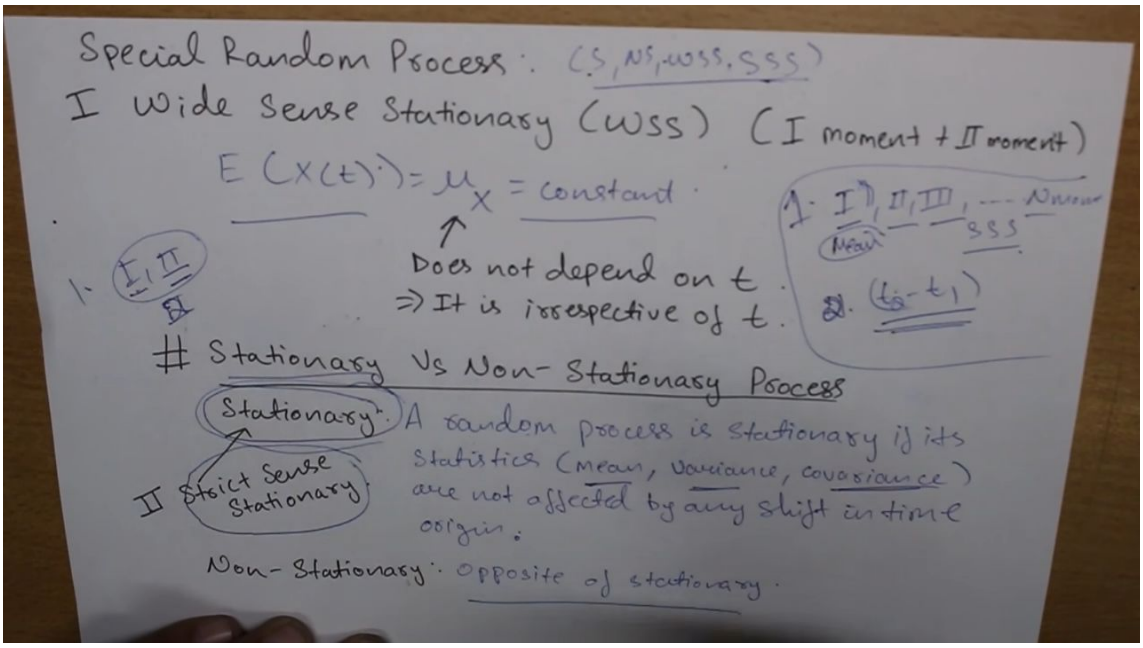


WSS & SSS Random Process | Random Signal Theory

02:09

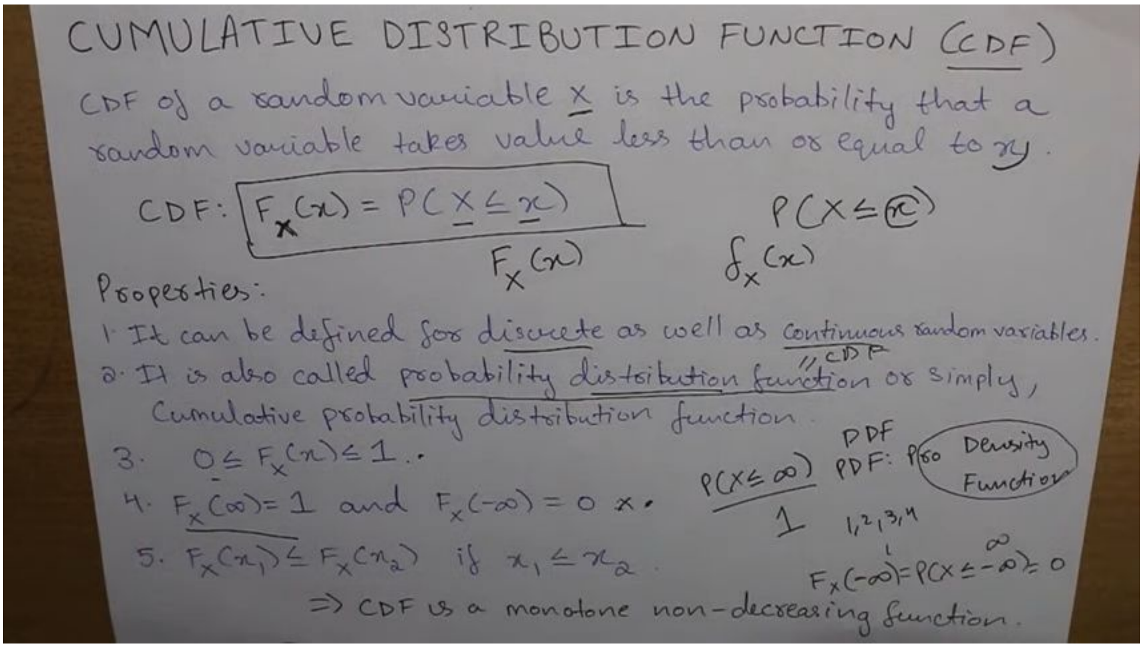


06:20

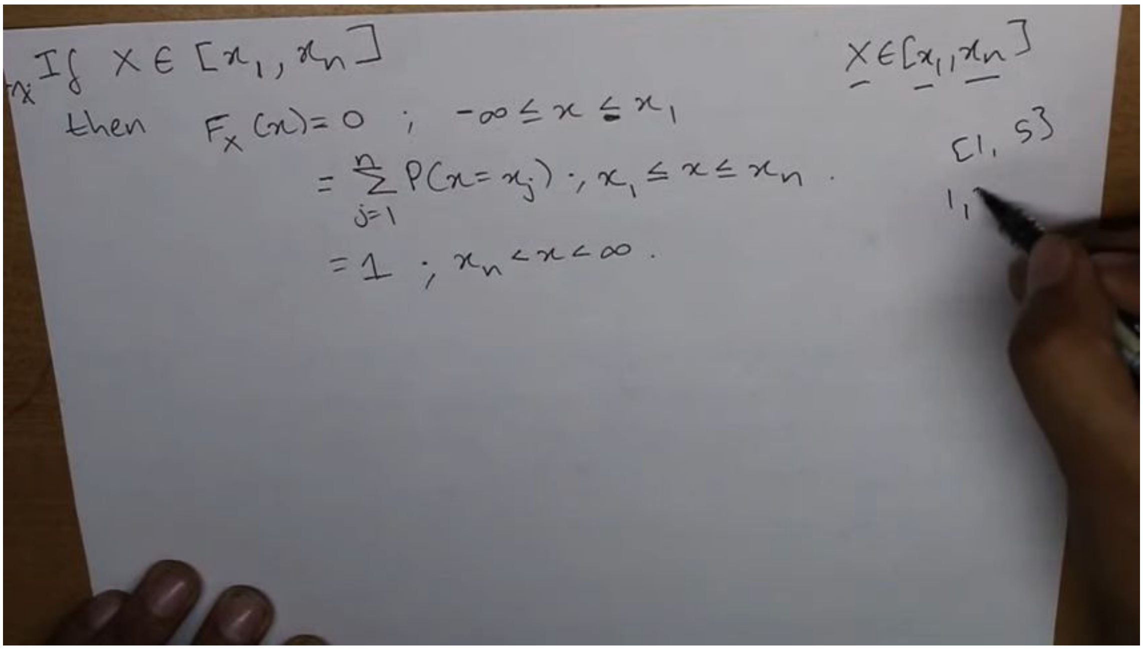


Cumulative Distribution Function (CDF)

03:16



04:12



Probability Density Function (PDF)

01:19

Probability Density Function (PDF)

CDF

PDF: $f_X(x) = \frac{d}{dx}\underbrace{F_X(x)}_{CDF}$

$f_X(x) =$

CDF
PPF

* It is more convenient for continuous random variable.

Properties:

1. $f_X(x) \geq 0$ for every x [because CDF is non-decreasing]
2. $\int_{-\infty}^{\infty} f_X(x)\,dx = 1$.
3. $F_X(x) = \int_{-\infty}^{x} f_X(x)\,dx$.
4. $P(x_1 < X \le x_2) = \int_{x_1}^{x_2} f_X(x)\,dx$.

04:53

Q PDF is given by $f_X(x) = ae^{-b|x|}$ where X is a random variable whose value lie in the range $x = -\infty$ to $x = +\infty$.

$X \in (-\infty, \infty)$

Determine:

(i) The relationship b/w a & b.

(ii) CDF.

(iii) The probability that outcome lies b/w 1 and 2.

$\rightarrow \int_{-\infty}^{\infty} f_X(x)\,dx = 1$

$-\infty, 0$

$0, \infty$

$\frac{-x}{x}$

$P(1 \le X \le 2)$

$\int_{1}^{2} f_X(x)\,dx$.

$f_X(x) = ae^{-b|x|}$

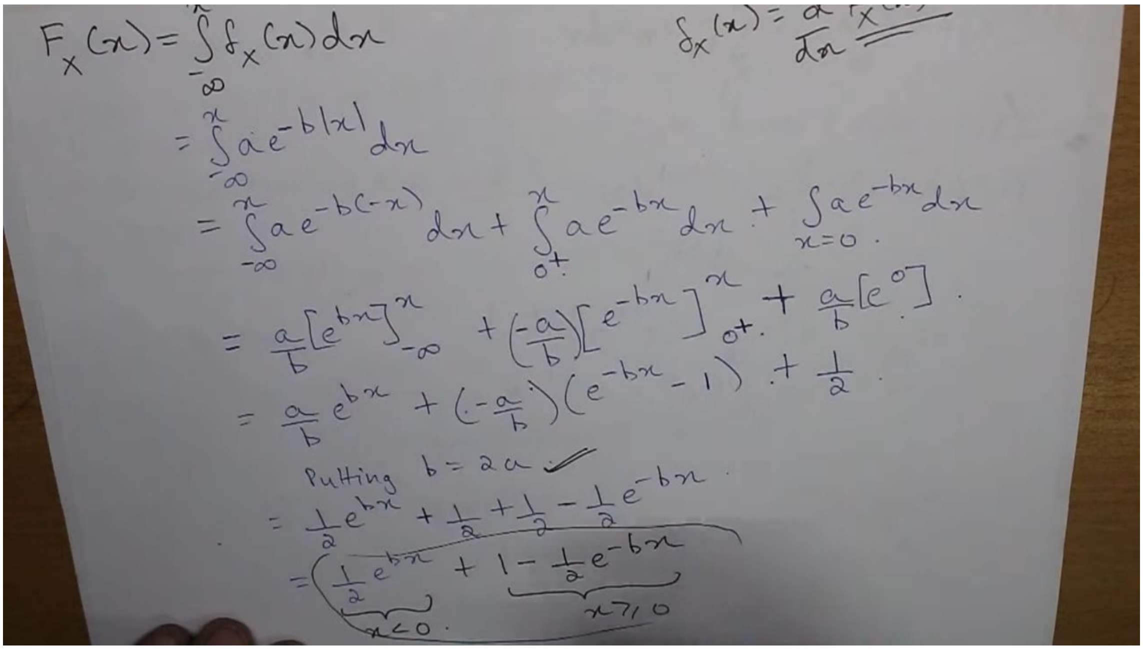
$\Rightarrow \int_{-\infty}^{0} ae^{-b(-x)}\,dx + \int_{0}^{\infty} ae^{-bx}\,dx = 1$

$\frac{a}{b}[e^{x}]_{-\infty}^{0} + -\frac{a}{b}[e^{-bx}]_{0}^{\infty} = 1$.

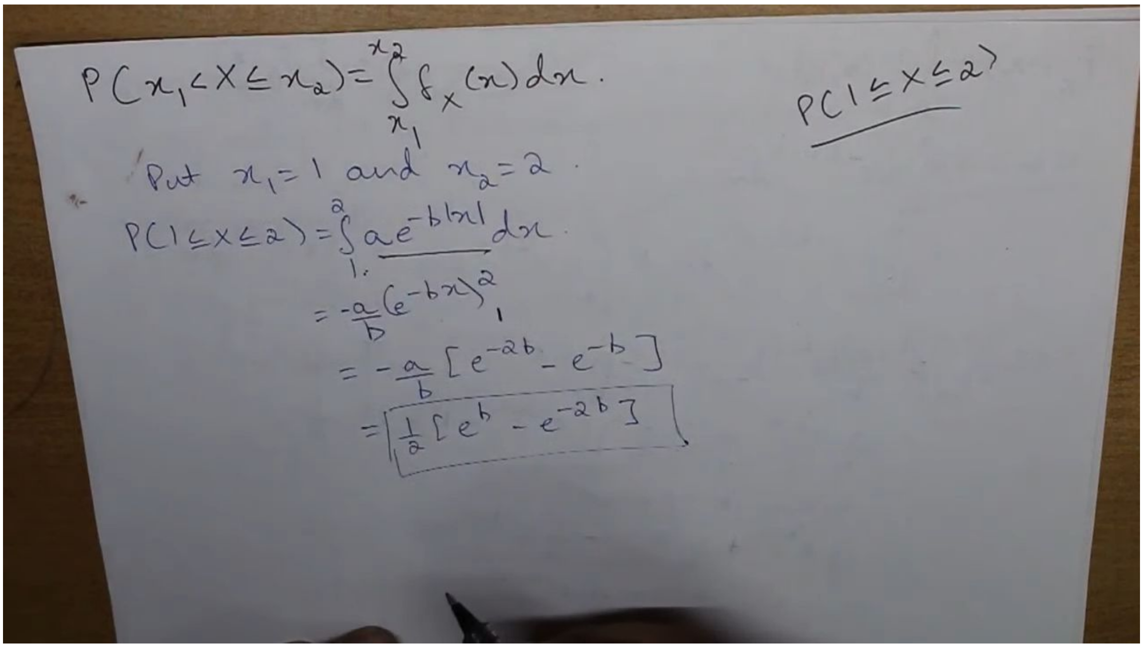
$\frac{a}{b}[1] - \frac{a}{b}[-1] = 1$.

$\Rightarrow \boxed{b = 2a}$

06:13



06:35



Joint PDF & Joint CDF

00:59

JOINT CDF

It is defined for two random variables X and Y and gives the probability that a random variable X is less than or equal to a specified value x and that the random variable Y is less than or equal to specified value of y.

$$F_{XY}(x,y) = P(X \le x, Y \le y)$$

$F_X(x) = P(X \le x)$

$F_{XY}(x,y)$

Properties:

1. $F_{XY}(x,y) \geqslant 0$
2. Non-decreasing
3. Always continuous in the xy plane.

01:56

JOINT PDF

Joint PDF of two random variables X and Y may be defined as the partial derivative of the joint CDF with respect to the variables x and y.

$$f_{XY}(x,y) = \frac{\partial^2 F_{XY}(x,y)}{\partial x \, \partial y}.$$

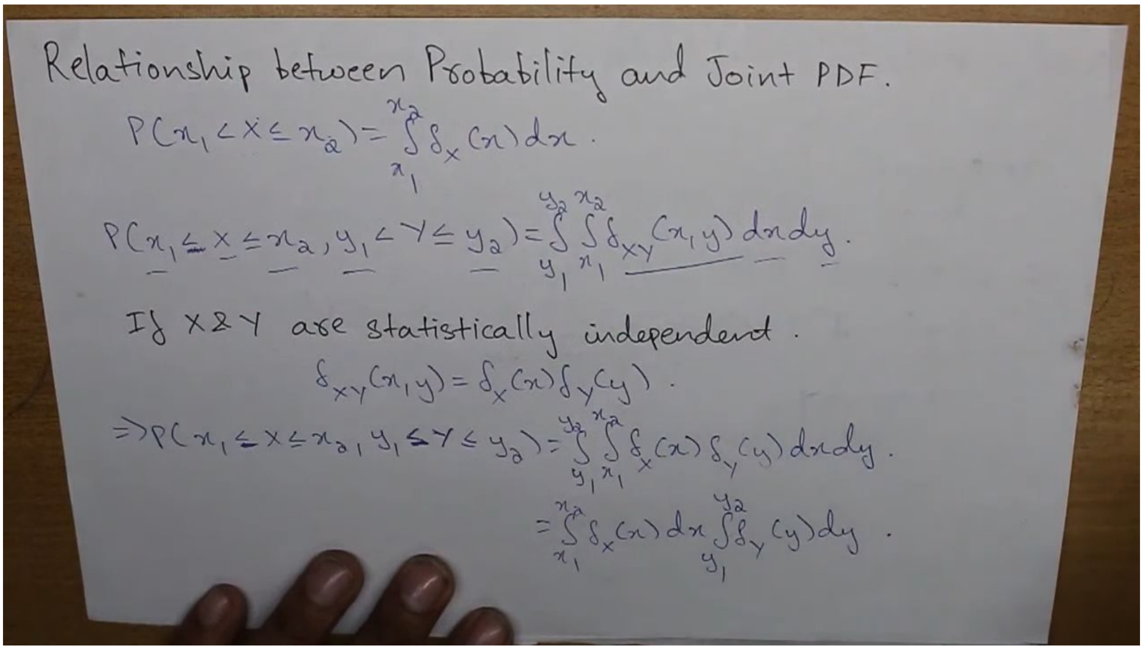
$f_X(x) = \frac{d}{dx} F_X(x)$

$\frac{\partial^2 F_{XY}(x,y)}{\partial x \partial y} = \frac{\partial}{\partial x}\left(\frac{\partial F_{XY}(x,y)}{\partial y}\right)$

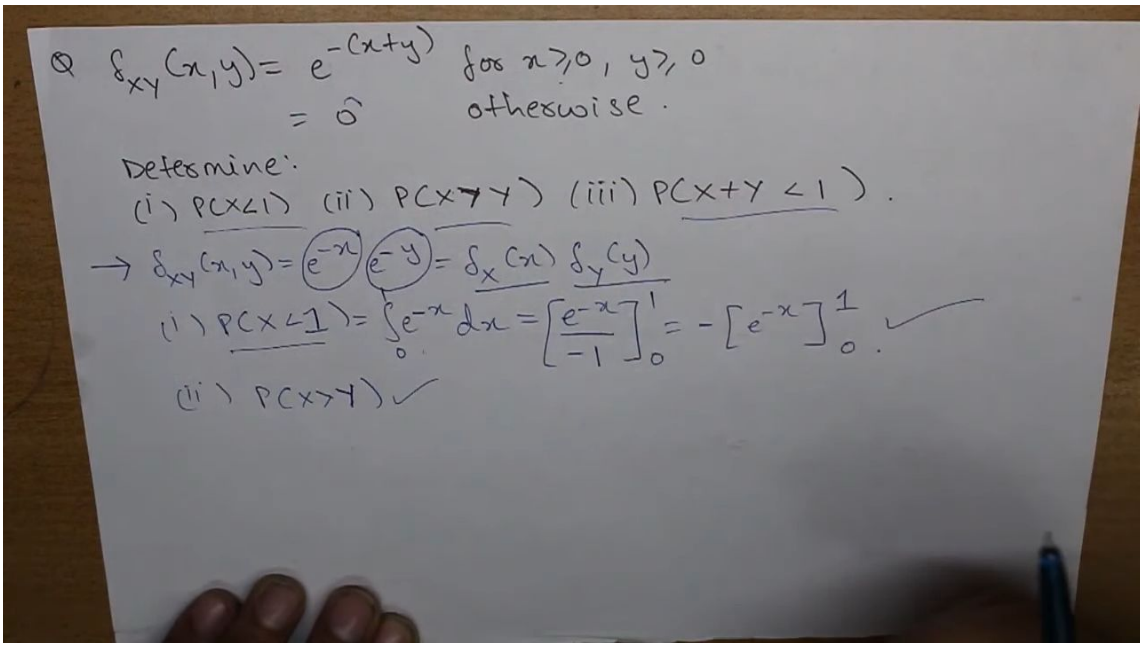
Properties:

1. $f_{XY}(x,y) \geqslant 0$.
2. $\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f_{XY}(x,y)\,dx\,dy = 1$.
3. Everywhere continuous.

03:35

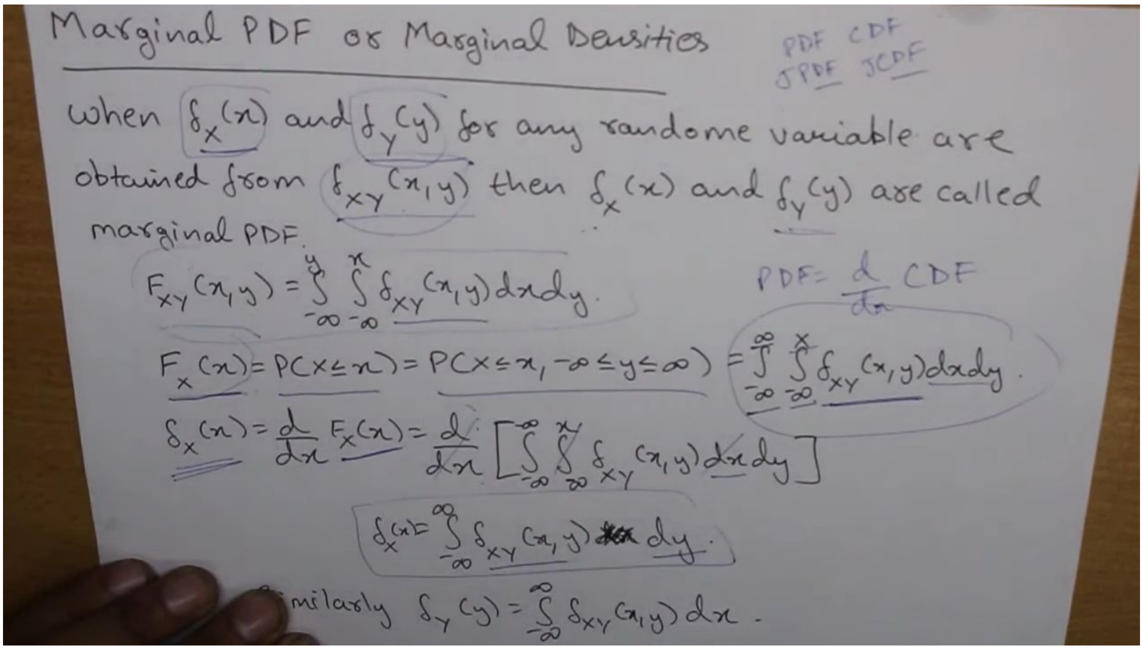


05:18



Marginal PDF or Marginal Densities

03:43



Marginal PDF or Marginal Densities

PDF CDF
JPDF JCDF

When $f_X(x)$ and $f_Y(y)$ for any randome variable are obtained from $f_{XY}(x,y)$ then $f_X(x)$ and $f_Y(y)$ are called marginal PDF.

$$F_{XY}(x,y)=\int_{-\infty}^{y}\int_{-\infty}^{x} f_{XY}(x,y)\,dx\,dy.$$

PDF $=\frac{d}{dx}$ CDF

$$F_X(x)=P(X\le x)=P(X\le x,-\infty\le y\le\infty)=\int_{-\infty}^{\infty}\int_{-\infty}^{x} f_{XY}(x,y)\,dx\,dy.$$

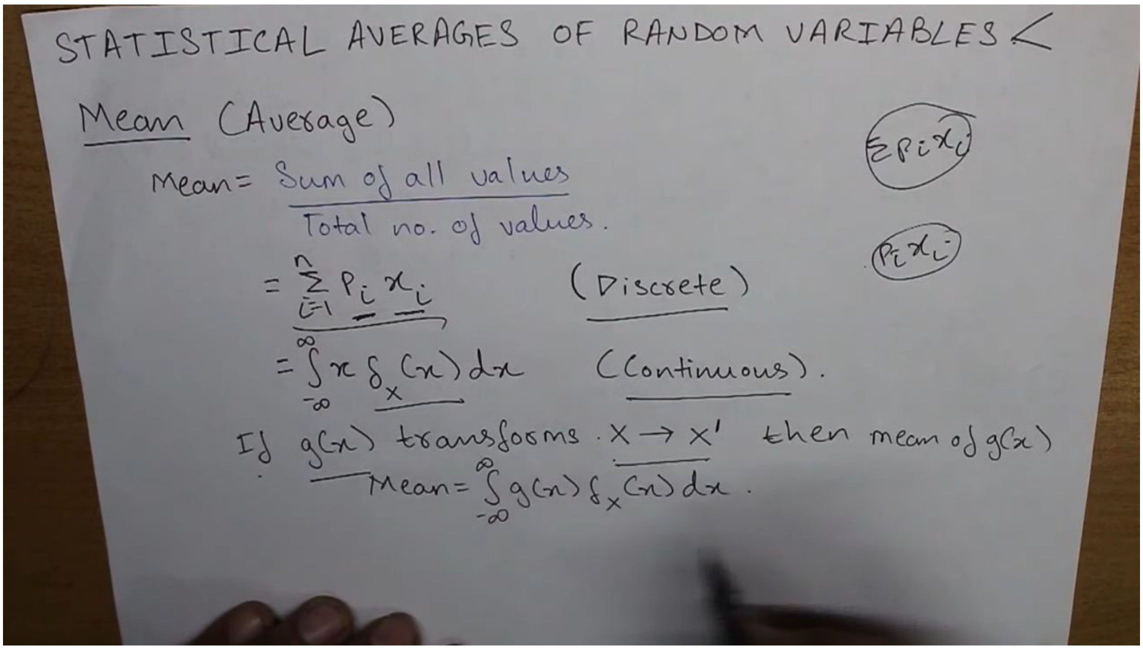
$$f_X(x)=\frac{d}{dx}F_X(x)=\frac{d}{dx}\left[\int_{-\infty}^{\infty}\int_{-\infty}^{x} f_{XY}(x,y)\,dx\,dy\right]$$

$$f_X(x)=\int_{-\infty}^{\infty} f_{XY}(x,y)\,dy.$$

Similarly $f_Y(y)=\int_{-\infty}^{\infty} f_{XY}(x,y)\,dx$.

Mean, Moments and Central Moment

00:47



STATISTICAL AVERAGES OF RANDOM VARIABLES

Mean (Average)

$\sum p_i x_i$

$p_i x_i$

Mean $=\dfrac{\text{Sum of all values}}{\text{Total no. of values}}$.

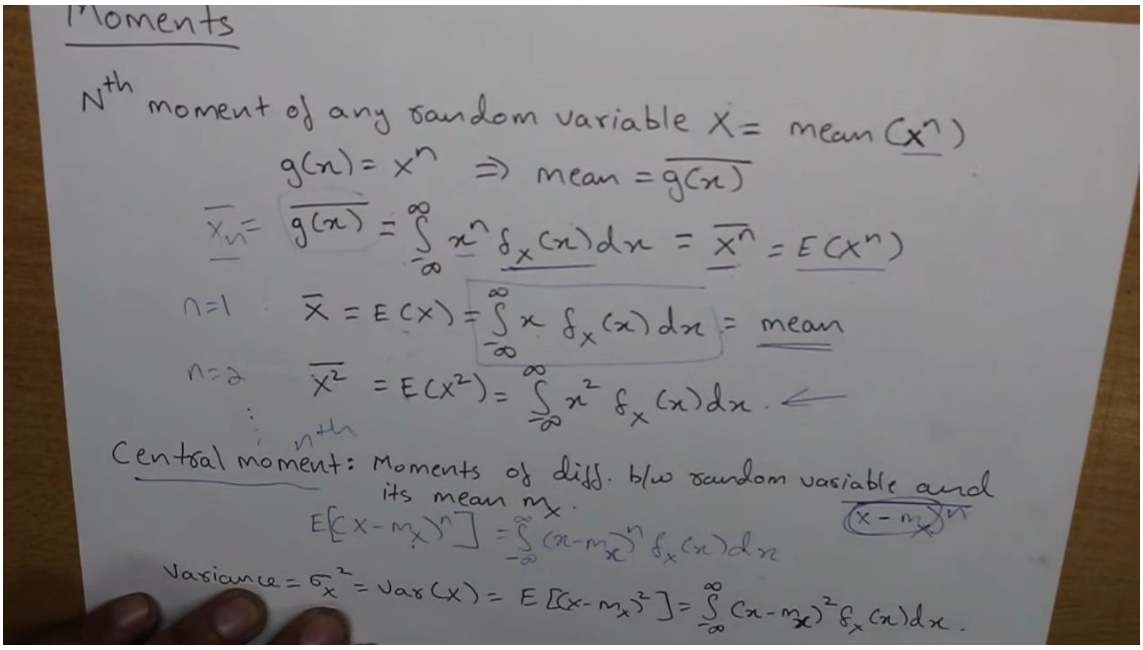
$=\sum_{i=1}^{n} p_i x_i$ (Discrete)

$=\int_{-\infty}^{\infty} x\, f_X(x)\,dx$ (Continuous).

If $g(x)$ transforms $X \to X'$ then mean of $g(x)$

Mean $=\int_{-\infty}^{\infty} g(x)\, f_X(x)\,dx$.

03:40



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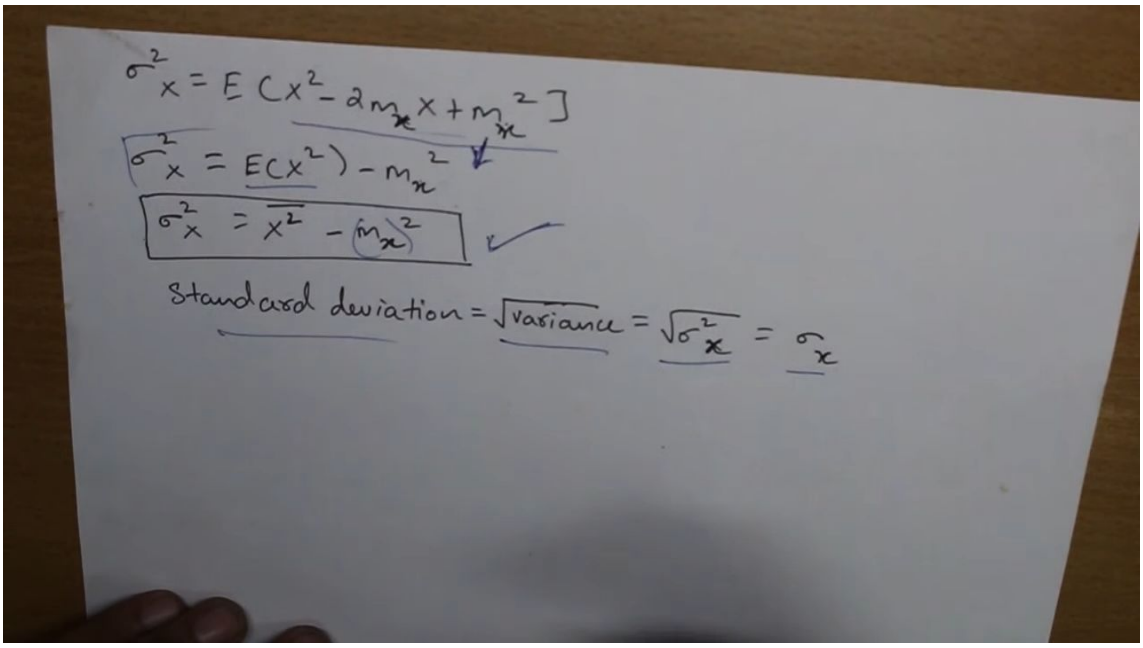

Correlation Function and its types

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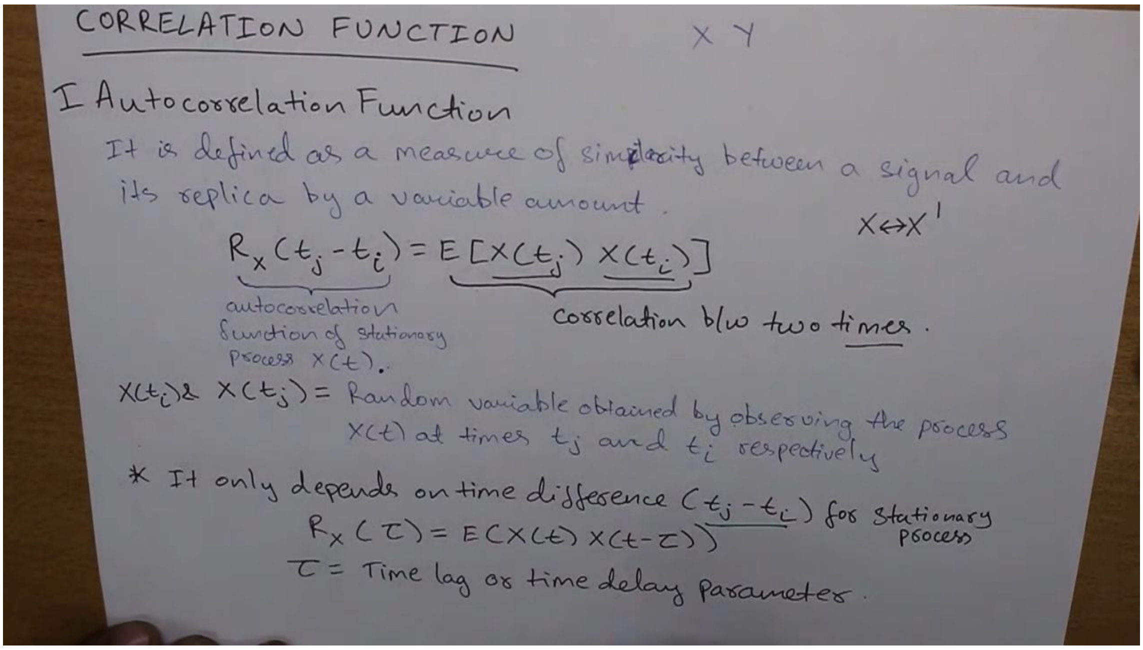

CORRELATION FUNCTION

X Y

I Autocorrelation Function

It is defined as a measure of similarity between a signal and its replica by a variable amount.

$X \leftrightarrow X'$

$$\underbrace{R_X(t_j - t_i)}_{\text{autocorrelation function of stationary process } X(t).} = E[\underbrace{X(t_j)\, X(t_i)}_{\text{correlation b/w two times.}}]$$

$X(t_i)$ & $X(t_j)$ = Random variable obtained by observing the process $X(t)$ at times t_j and t_i respectively

* It only depends on time difference $(t_j - t_i)$ for stationary process

$$R_X(\tau) = E(X(t)\,X(t-\tau))$$

τ = Time lag or time delay parameter.

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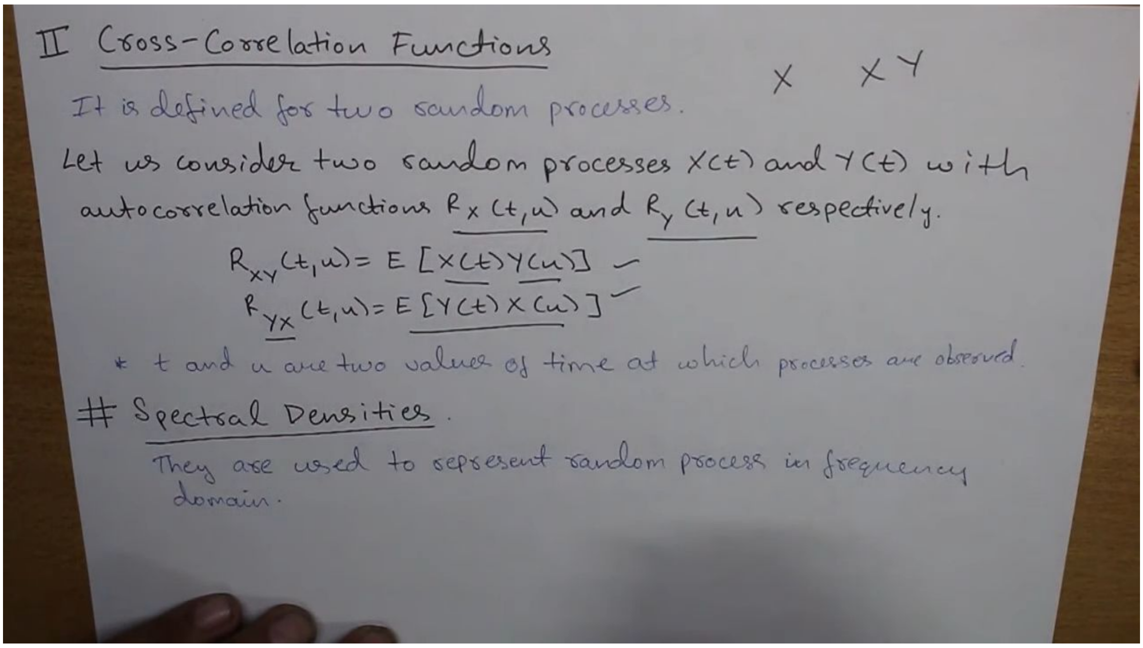

II Cross-Correlation Functions

X XY

It is defined for two random processes.

Let us consider two random processes $X(t)$ and $Y(t)$ with autocorrelation functions $R_X(t,u)$ and $R_Y(t,u)$ respectively.

$$R_{XY}(t,u) = E[X(t)Y(u)]$$

$$R_{YX}(t,u) = E[Y(t)X(u)]$$

* t and u are two values of time at which processes are observed.

Spectral Densities.

They are used to represent random process in frequency domain.

Power Spectral Density (PSD)

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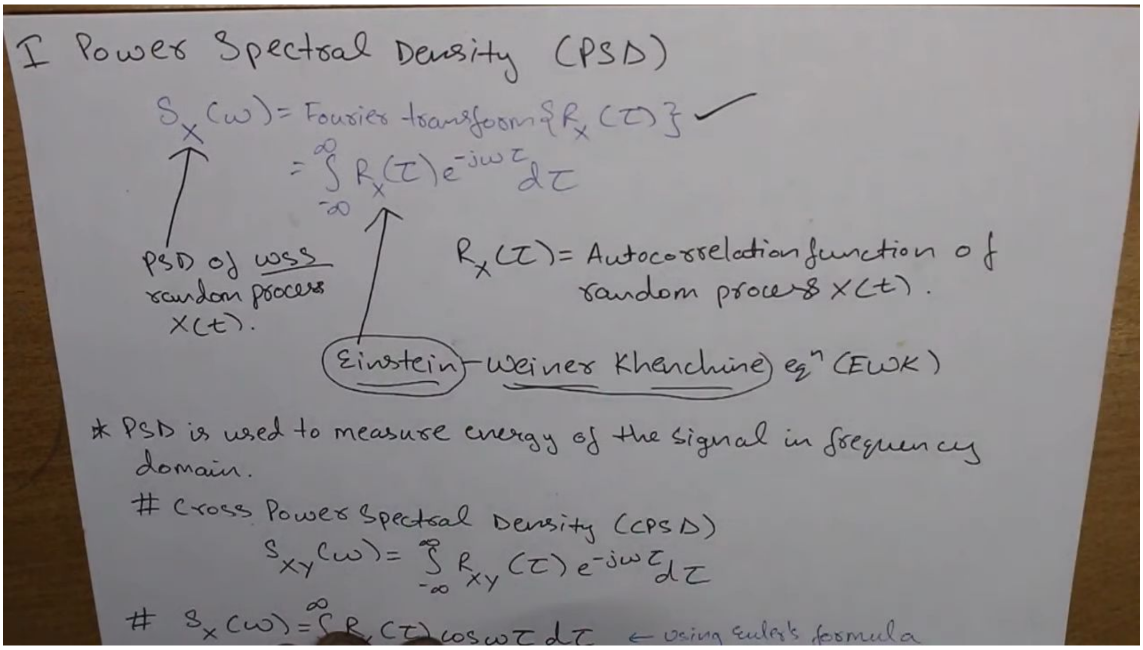

I Power Spectral Density (PSD)

$S_X(\omega)$ = Fourier transform$\{R_X(\tau)\}$

$= \int_{-\infty}^{\infty} R_X(\tau) e^{-j\omega\tau} d\tau$

PSD of WSS random process X(t).

$R_X(\tau)$ = Autocorrelation function of random process X(t).

Einstein Weiner Khenchine eq^n (EWK)

* PSD is used to measure energy of the signal in frequency domain.

Cross Power Spectral Density (CPSD)

$S_{XY}(\omega) = \int_{-\infty}^{\infty} R_{XY}(\tau) e^{-j\omega\tau} d\tau$

$S_X(\omega) = \int_{-\infty}^{\infty} R_X(\tau) \cos\omega\tau \, d\tau$ ← using Euler's formula

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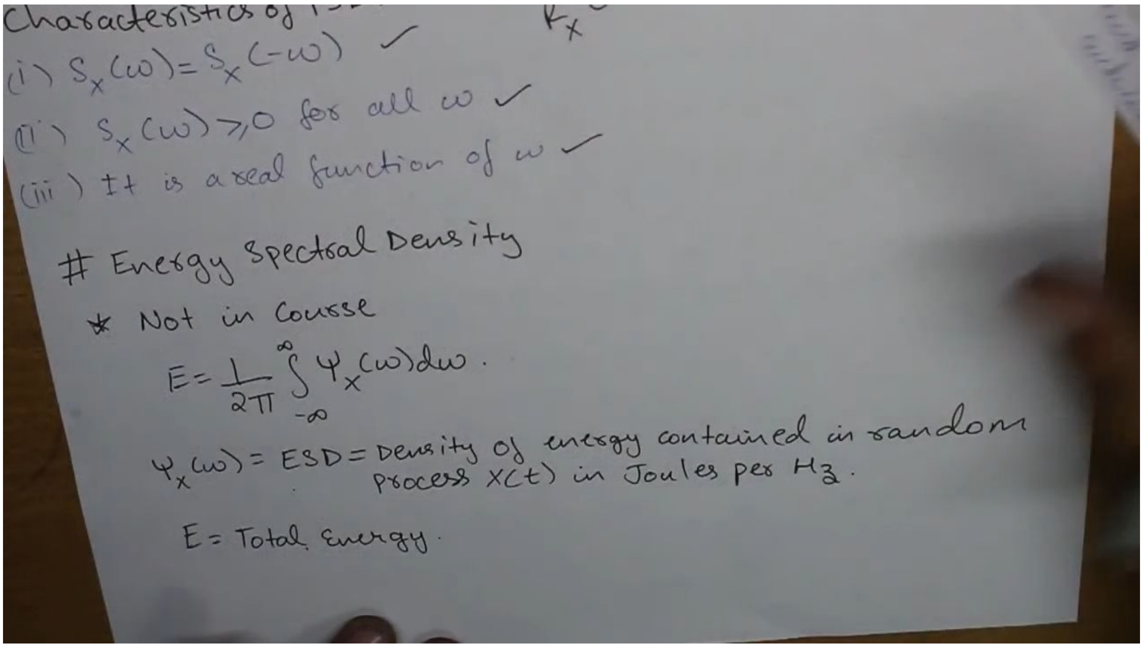


Characteristics of

(i) $S_X(\omega) = S_X(-\omega)$

(ii) $S_X(\omega) \geq 0$ for all ω

(iii) It is a real function of ω

Energy Spectral Density

* Not in Course

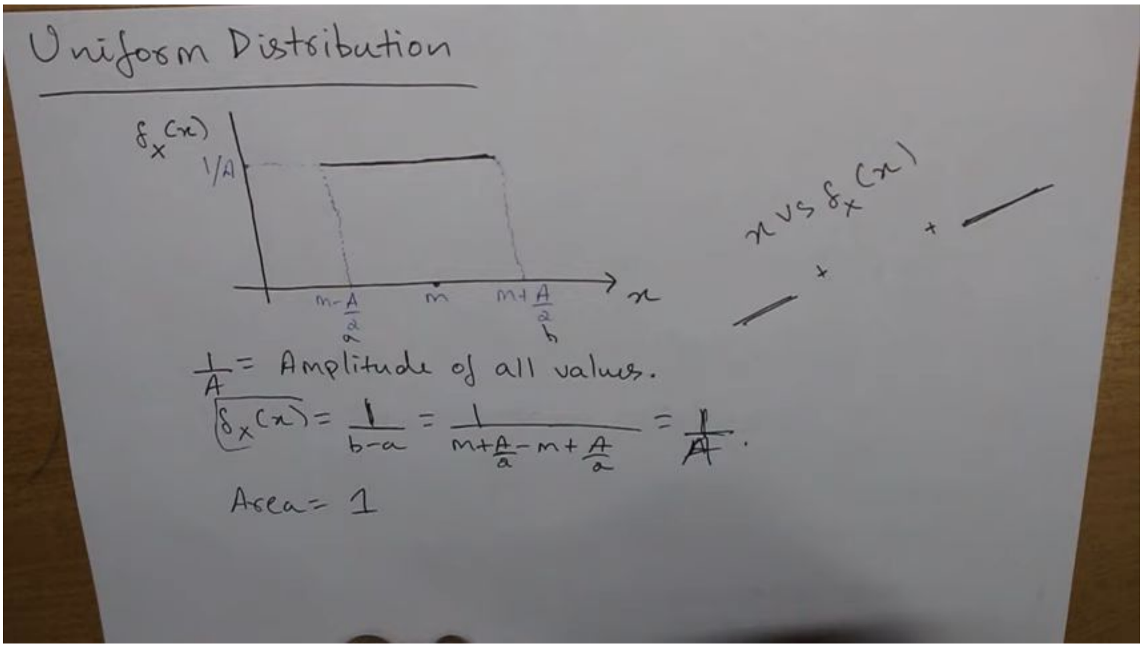
$E = \frac{1}{2\pi}\int_{-\infty}^{\infty} \Psi_X(\omega) d\omega$.

$\Psi_X(\omega)$ = ESD = Density of energy contained in random process X(t) in Joules per Hz.

E = Total Energy.

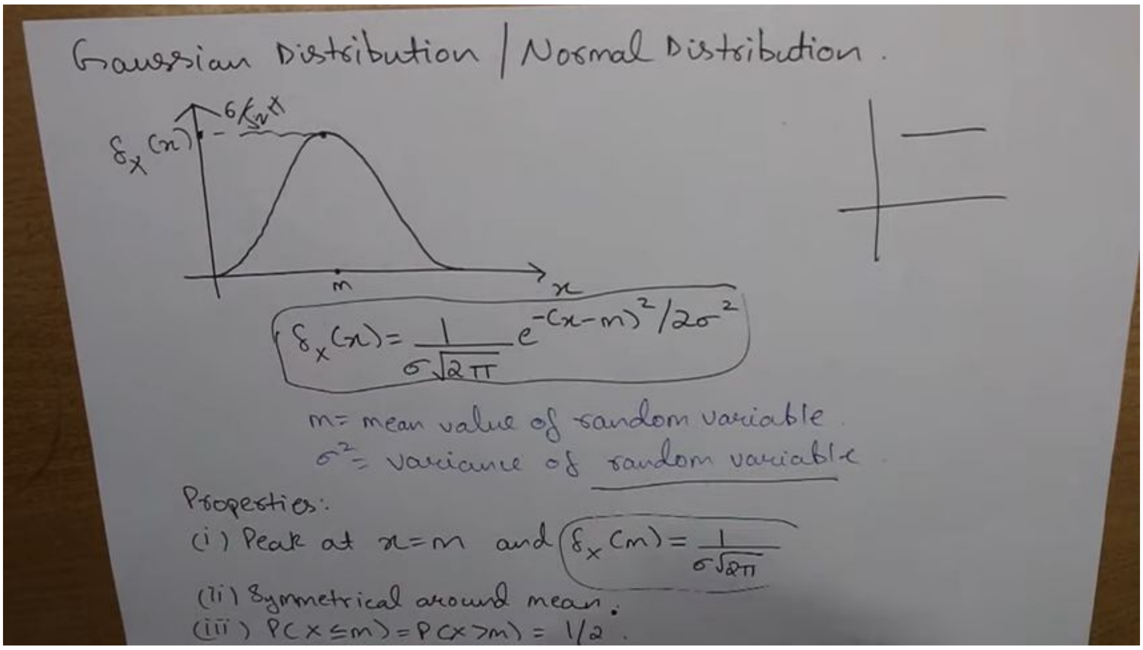
All Distributions in Brief

01:01



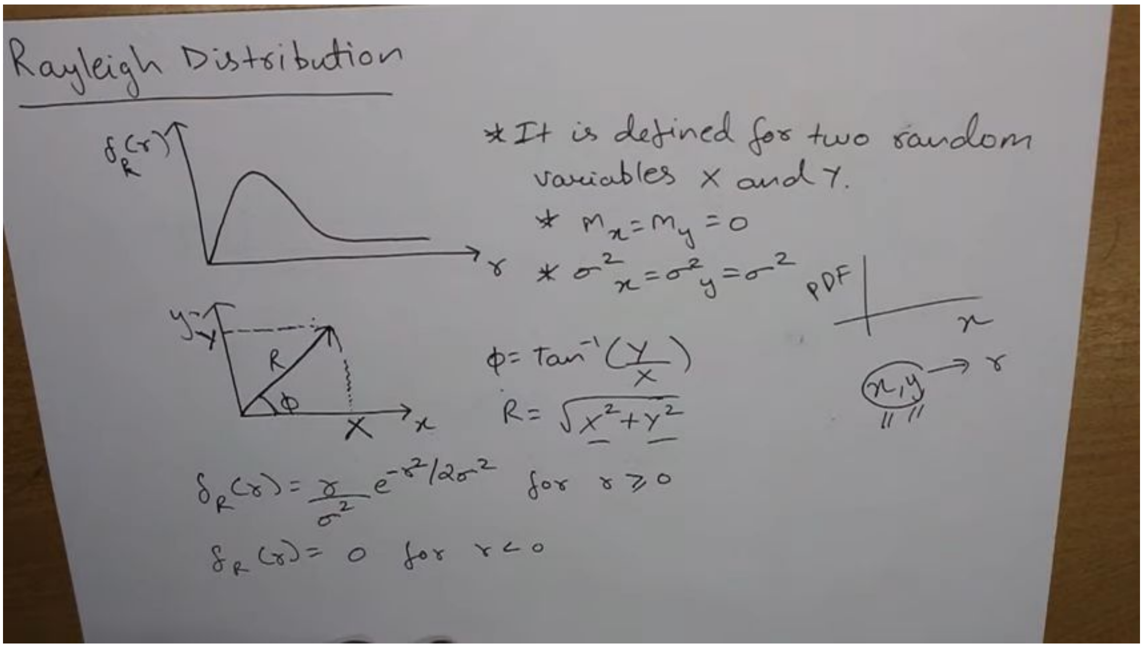
Uniform Distribution
$f_X(x)$
1/A
m-A/2
a
m
m+A/2
b
x
x vs $f_X(x)$
$\frac{1}{A}$ = Amplitude of all values.
$f_X(x) = \frac{1}{b-a} = \frac{1}{m+\frac{A}{2}-m+\frac{A}{2}} = \frac{1}{A}$.
Area = 1

03:22

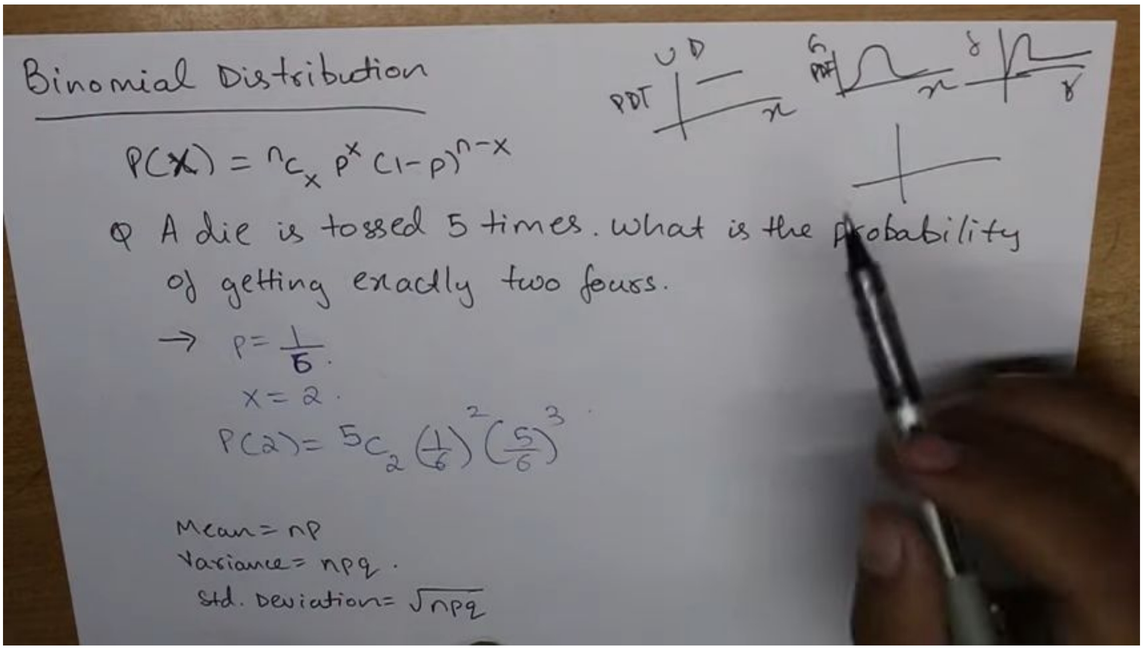


Gaussian Distribution / Normal Distribution.
$f_X(x)$
m
x
$f_X(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-m)^2/2\sigma^2}$
m = mean value of random variable
σ^2 = variance of random variable
Properties:
(i) Peak at x = m and $f_X(m) = \frac{1}{\sigma\sqrt{2\pi}}$
(ii) Symmetrical around mean.
(iii) $P(X \le m) = P(X > m) = 1/2$.

04:57


Rayleigh Distribution
fR(r)
r
* It is defined for two random variables X and Y.
* mx = my = 0
* σ²x = σ²y = σ²
PDF
x
(x, y) → r
y
Y
R
φ
X
x
φ = Tan⁻¹(Y/X)
R = √(X² + Y²)
fR(r) = r/σ² e^(-r²/2σ²) for r ≥ 0
fR(r) = 0 for r < 0

06:50


Binomial Distribution
UD
PDF
x
r
P(X) = ⁿCx pˣ (1-p)ⁿ⁻ˣ
Q A die is tossed 5 times. what is the probability of getting exactly two fours.
→ p = 1/6.
X = 2.
P(2) = ⁵C₂ (1/6)² (5/6)³
Mean = np
Variance = npq.
Std. Deviation = √npq

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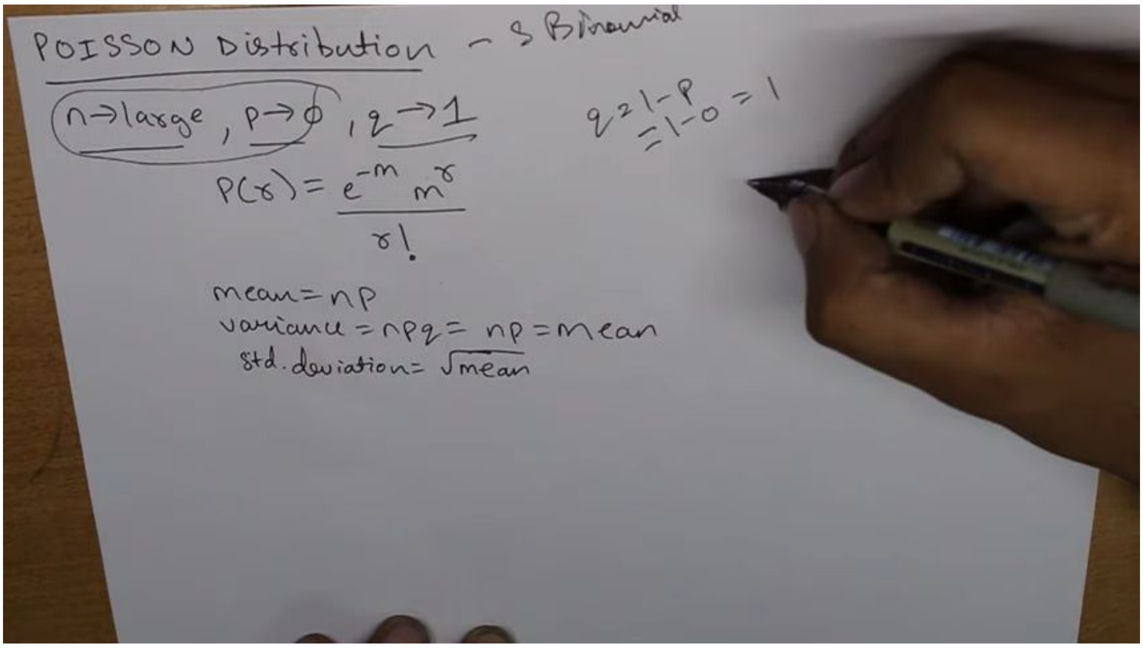

Central Limit Theorem

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