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"If you can think, you can Achieve"
So start thinking..

Renu Raj Garg
M.Tech (VLSI Design)
13 Year of Teaching Experience
Worked 10 Year in NTRO

GATE 2024

प्रचण्ड Batch

COMMUNICATION

SAMPLING THEOREM

TIME- 9:00PM

RENU SIR

Chapter-2

Digital Communications

In today's lecture we will cover the following Topis :

1. *Sampling Theorem*

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AIR 571 ME VIJENDER MEENA

YouTube Classes Schedule

ENGINEERS

EE & EC ENGINEERING

EXAM TARGET	SUBJECT	TIME	FACULTY
ALL PSUs	ENGINEERING MATHS	11:00 AM	ANANT SIR
GATE 2024-25	NETWORK THEORY	6:00 PM	RAVI SIR
GATE 2024-25	ELECTRICAL MACHINE	7:30 PM	SANTAN SIR
GATE 2024-25	COMMUNICATION	9:00 PM	RENU SIR

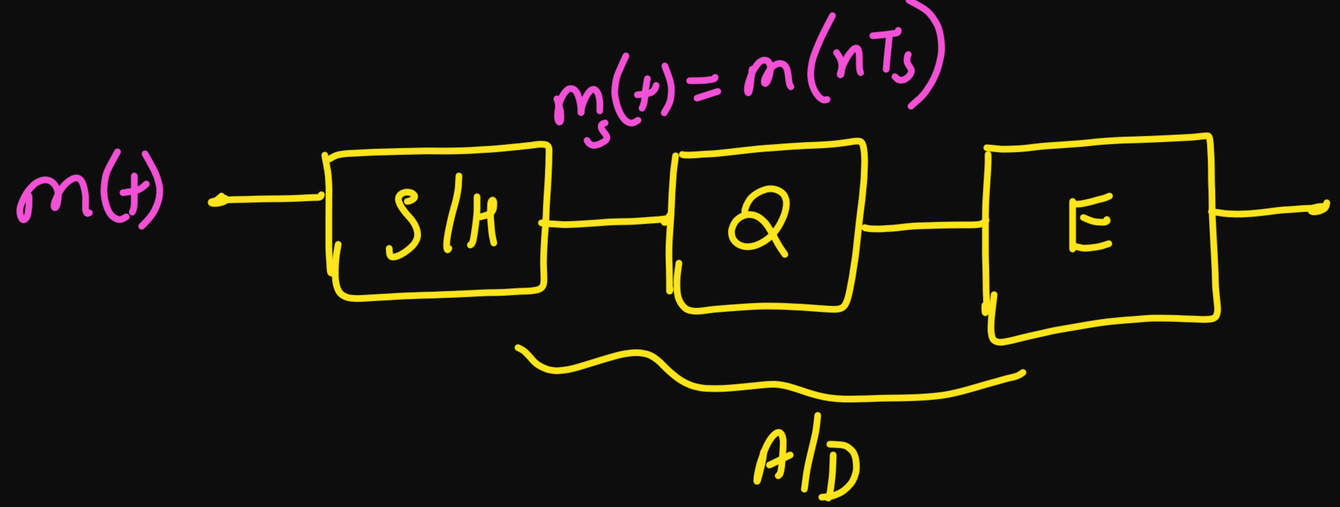
FREE APP
CLASS SCHEDULE

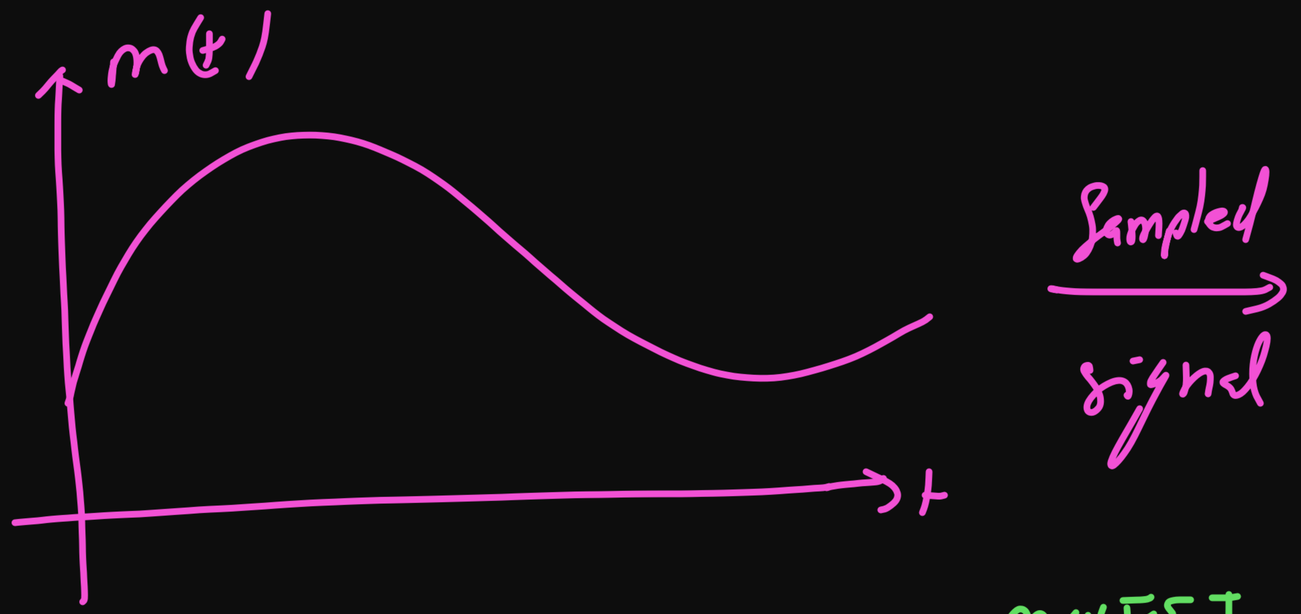
EE & ECEENGINEERING

GATE

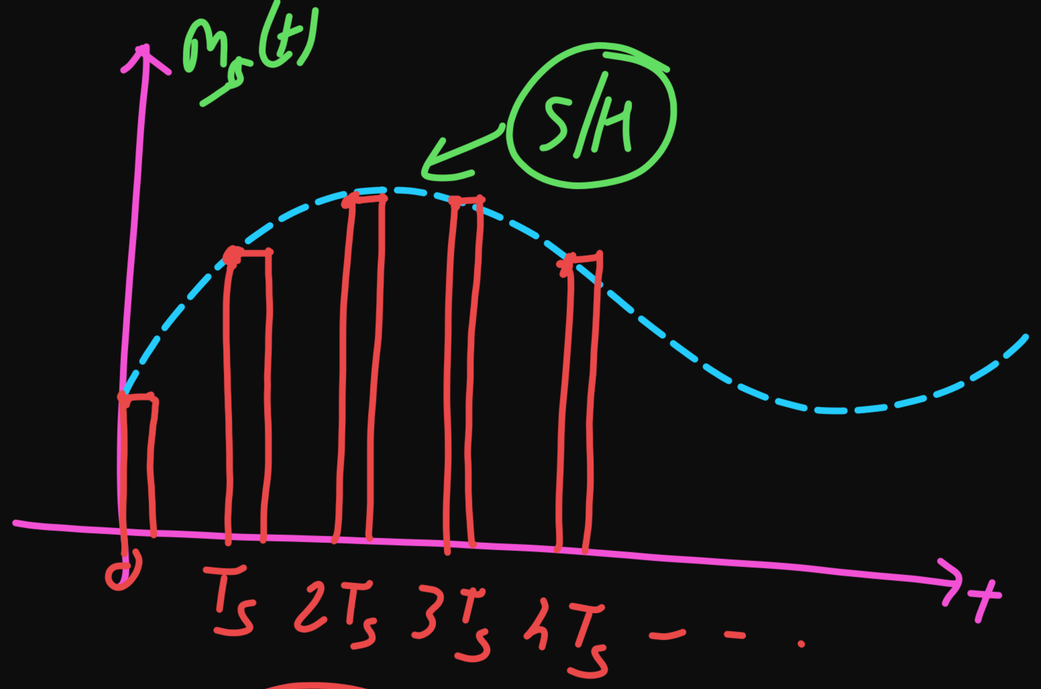
NETWORK THEORY	SATURDAY Live @11AM	RAVI SIR
COMMUNICATION	WEDNESDAY Live @8PM	RENU SIR
ANALOG ELECTRONICS	THURSDAY Live @8PM	LAWRENCE SIR
ENGINEERING MATHEMATICS	FRIDAY Live @11AM	ANANT SIR
ELECTRICAL MACHINE	MONDAY Live @8PM	SANTAN SIR

Sampling Theorem

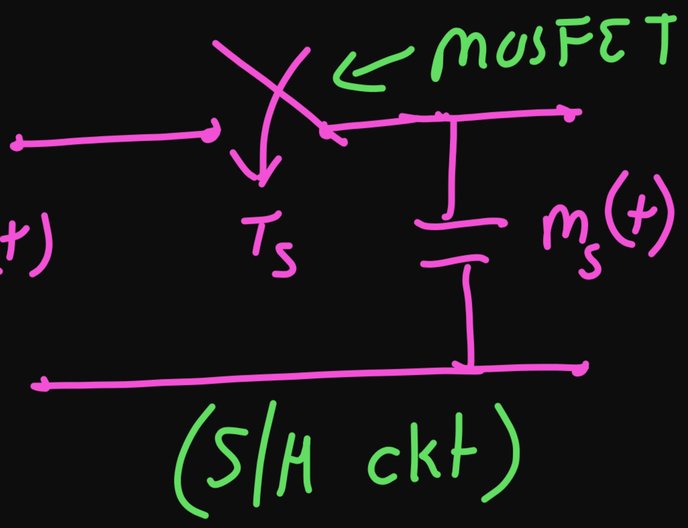




Sampled signal



Nyquist rate = minimum sampling freq.



$T_s|_{max}$

$f_s|_{min}$ = Sampling freq.

T_s = Sampling Interval = Sampling Time

Nyquist rate = N.R.

$$f_s \geq N.R.$$

$$N.R \leq f_s \leq 2NR$$

$$T_s \leq \frac{1}{N.R.}$$

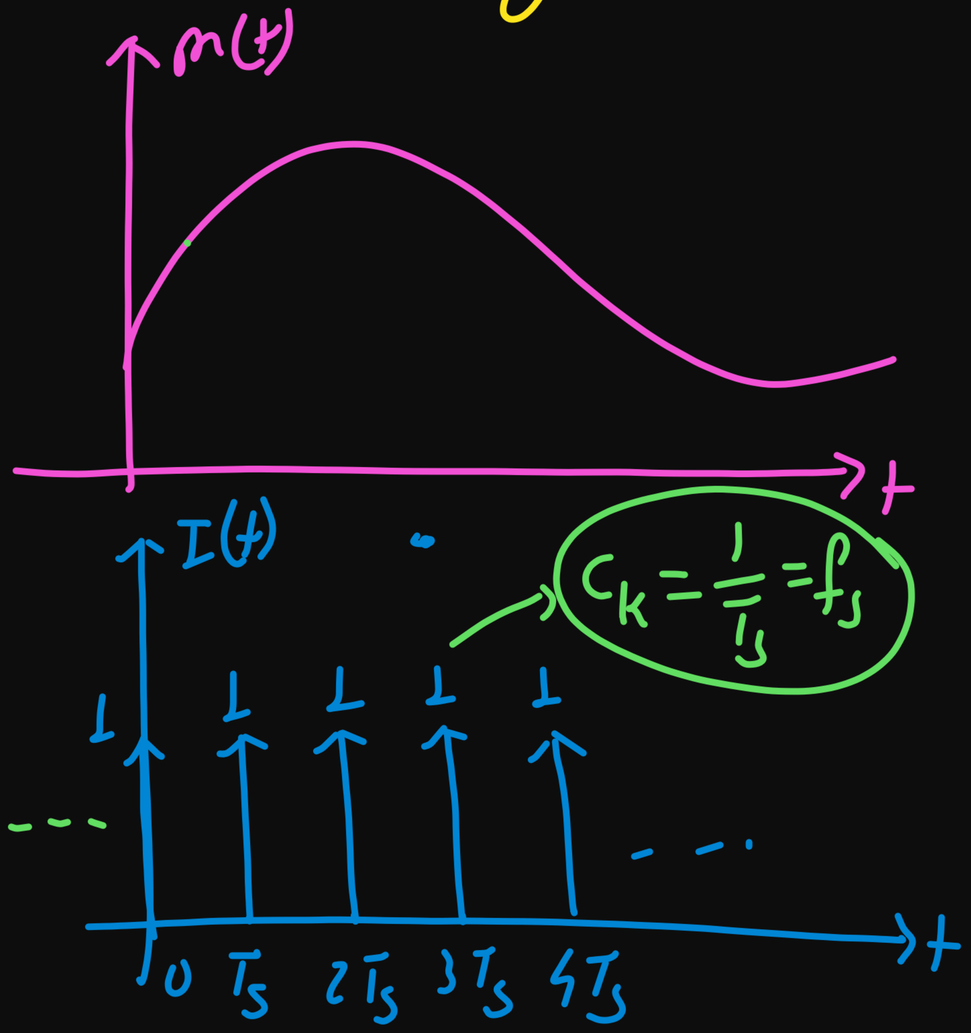
Types of Sampling:

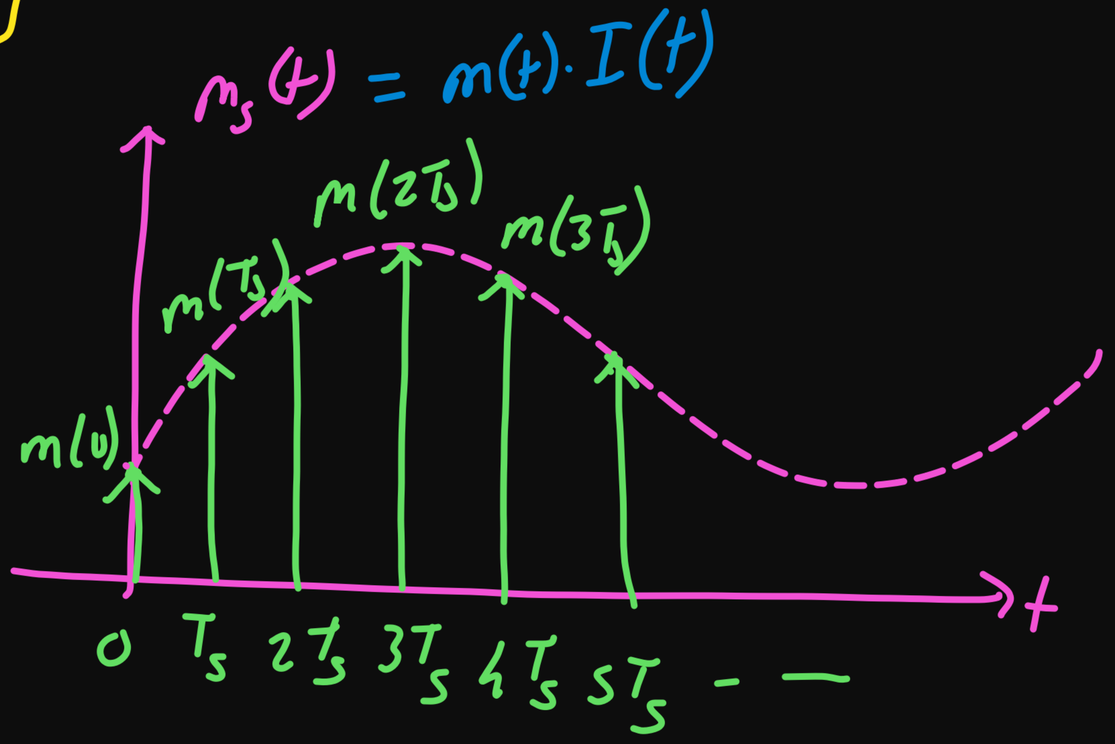
(i) Impulse Sampling (Ideal Sampling) ← S

(ii) Pulse sampling (Natural sampling)

(iii) Flat-top sampling → S/H

(i) Impulse sampling [Ideal sampling]





$$m(t) \cdot \delta(t) = m(0)\,\delta(t)$$

$$m(t) \cdot \delta(t - T_s) = m(T_s)\,\delta(t - T_s)$$

$$I(t) = \sum_{n=-\infty}^{\infty} \delta(t - nT_s)$$

$$x(t) \cdot \delta(t) = x(0)\,\delta(t)$$

$I(t)$ by F.S. $\Rightarrow$ $$I(t) = \sum_{K=-\infty}^{\infty} C_K e^{j2\pi K f_0 t}$$

$$C_K = \frac{1}{T_0}\int_{\langle T_0 \rangle} I(t)\, e^{-j2\pi K f_0 t}\, dt = \frac{1}{T_s}\int_{-T_s/2}^{+T_s/2} \delta(t) \cdot e^{-j2\pi K f_s t}\, dt$$

$$\boxed{C_K = \frac{1}{T_s} = f_s}$$

$$I(t)\Big|_{\text{By FS}} = \sum_{K=-\infty}^{\infty} C_K \, e^{j2\pi K f_s t}$$

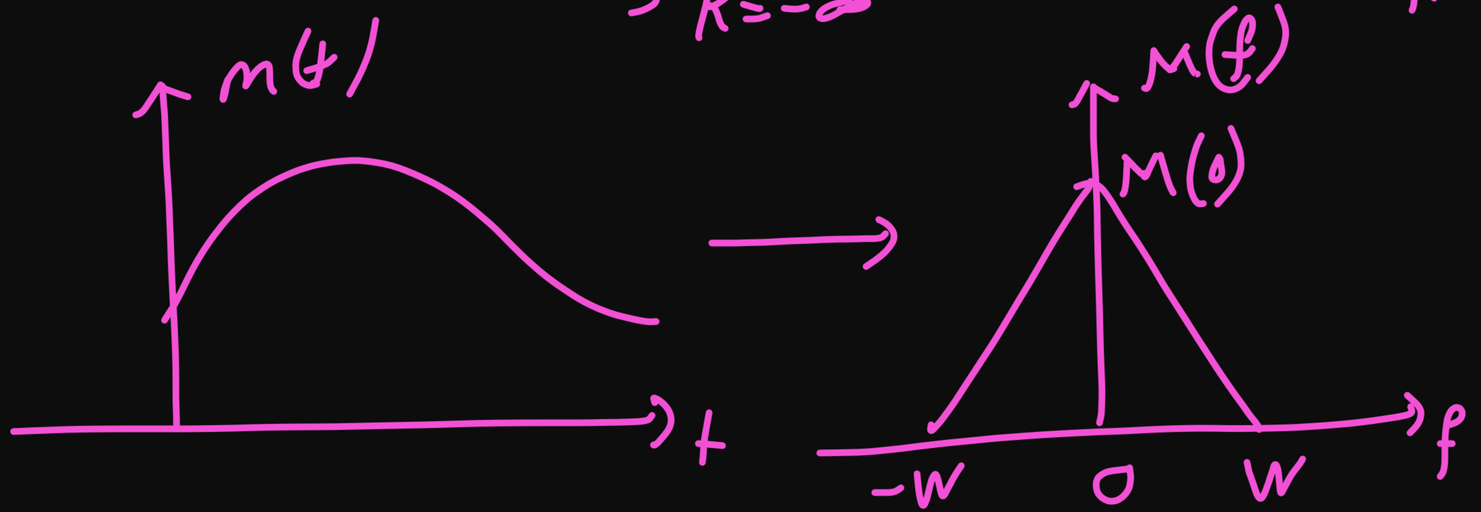
$$= \frac{1}{T_s} \sum_{K=-\infty}^{\infty} e^{j2\pi K f_s t} = \frac{1}{T_s} \sum_{K=-\infty}^{\infty} e^{jK\omega_s t}$$

$$I(t)\Big|_{\text{By FS}} = \frac{1}{T_s} \sum_{K=-\infty}^{\infty} e^{j2\pi K f_s t}$$

$$I(t)\Big|_{\text{By series}} = \sum_{n=-\infty}^{\infty} \delta(t - nT_s)$$

$$m_s(t) = m(t)\, I(t)$$

$$m_s(t) = m(t) \cdot \frac{1}{T_s} \sum_{K=-\infty}^{\infty} e^{j2\pi K f_s t} = \frac{1}{T_s} \sum_{K=-\infty}^{\infty} m(t)\, e^{j2\pi K f_s t}$$



$x(t)\, e^{j2\pi f_0 t} \xrightarrow{FT} X(f - f_0)$

$m(t)\, e^{j2\pi K f_s t} \xrightarrow{FT} M(f - K f_s)$

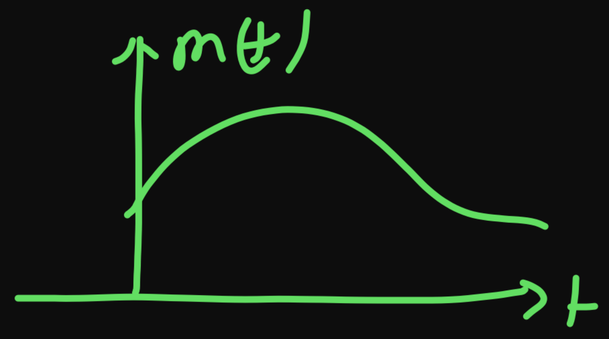
$$m_s(t) \xrightarrow{FT} M_s(f) = \frac{1}{T_s} \sum_{K=-\infty}^{\infty} M(f - K f_s)$$

$m(t) \xrightarrow{\text{Sampling}} m_s(t)$

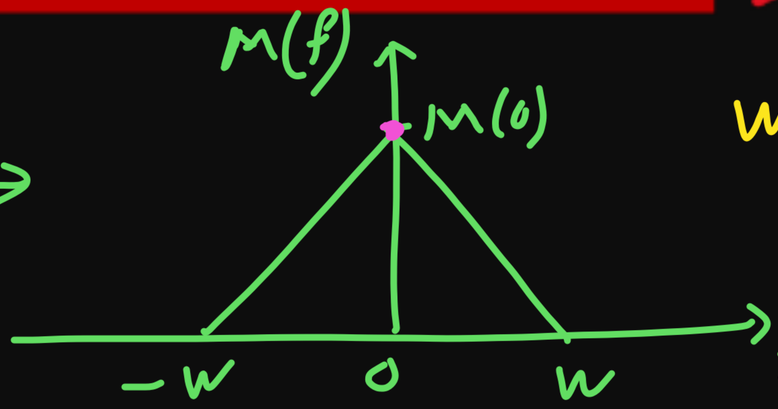
$m(t) \downarrow \qquad m_s(t) \downarrow$

$M(f) \qquad M_s(f) = \frac{1}{T_s} \sum_{n=-\infty}^{\infty} M(f - nf_s)$

$$M_s(f) = f_s \sum_{n=-\infty}^{\infty} M(f - nf_s)$$

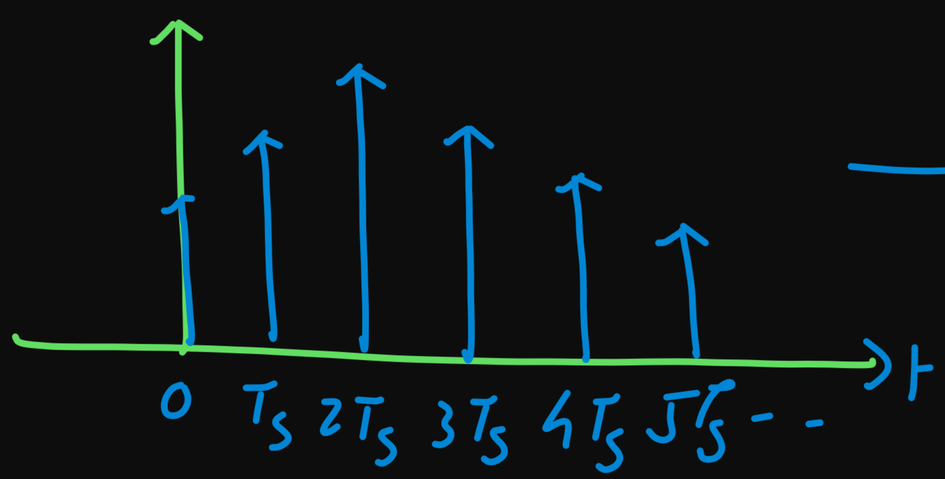


F.T.



W = Highest freq. component of msg signal

sampled signal



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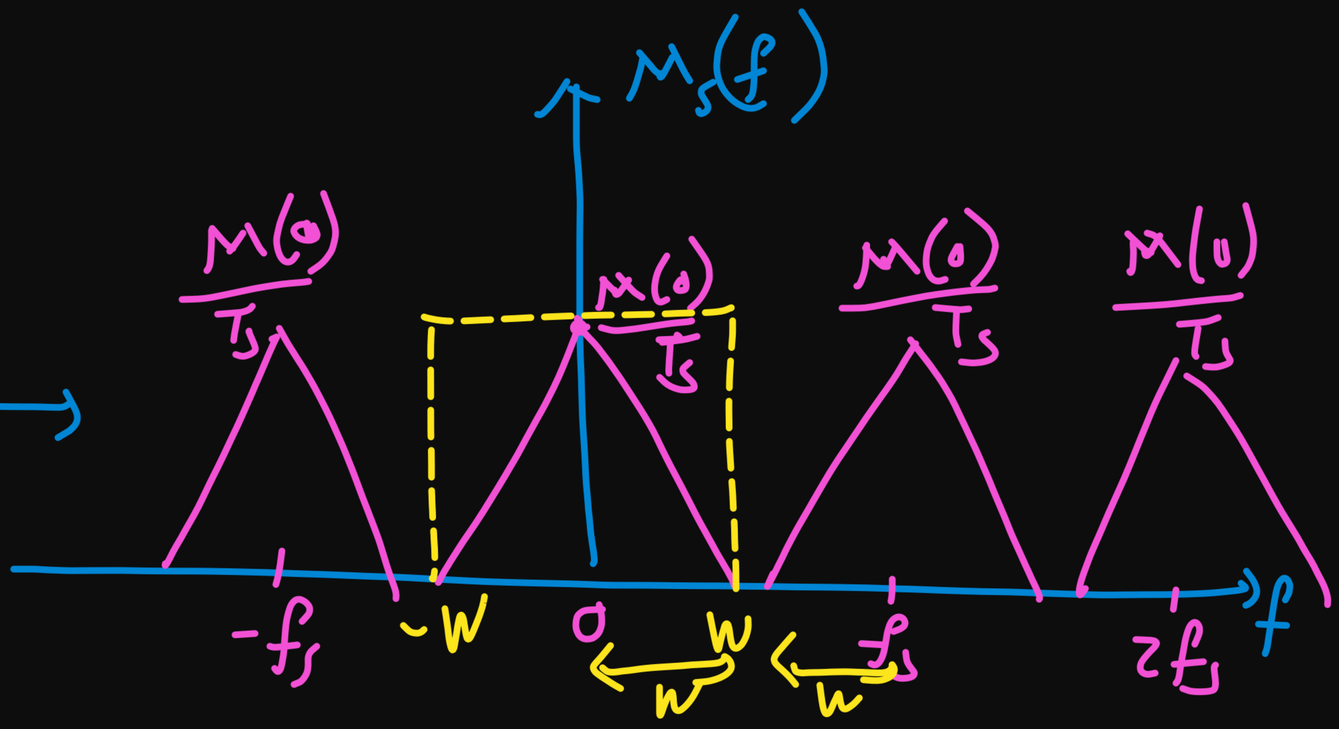


$$(f_s)_{min} = M.R. = 2W$$

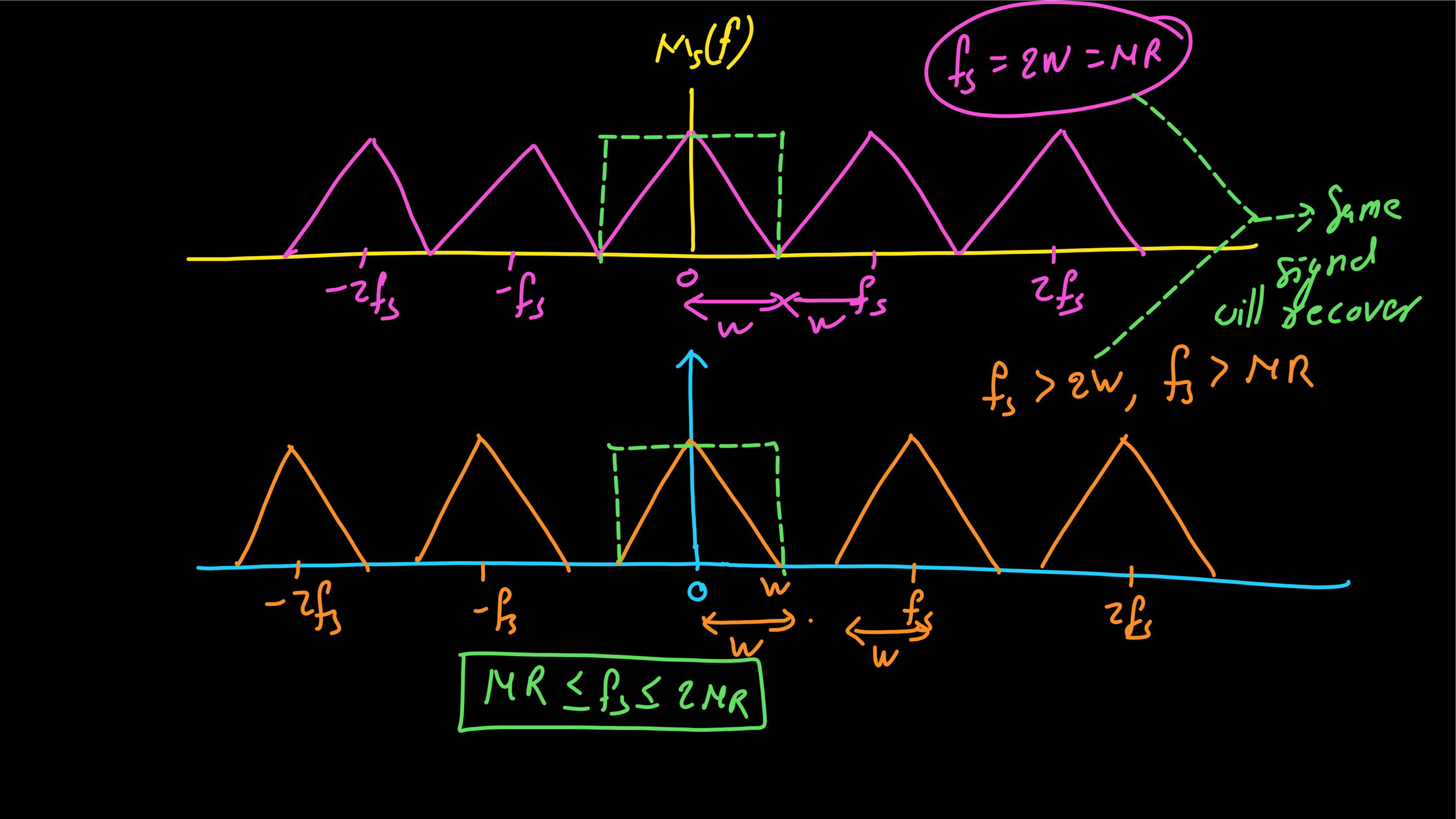
$$(T_s)_{max} = \frac{1}{M.R.} = \frac{1}{2W}$$

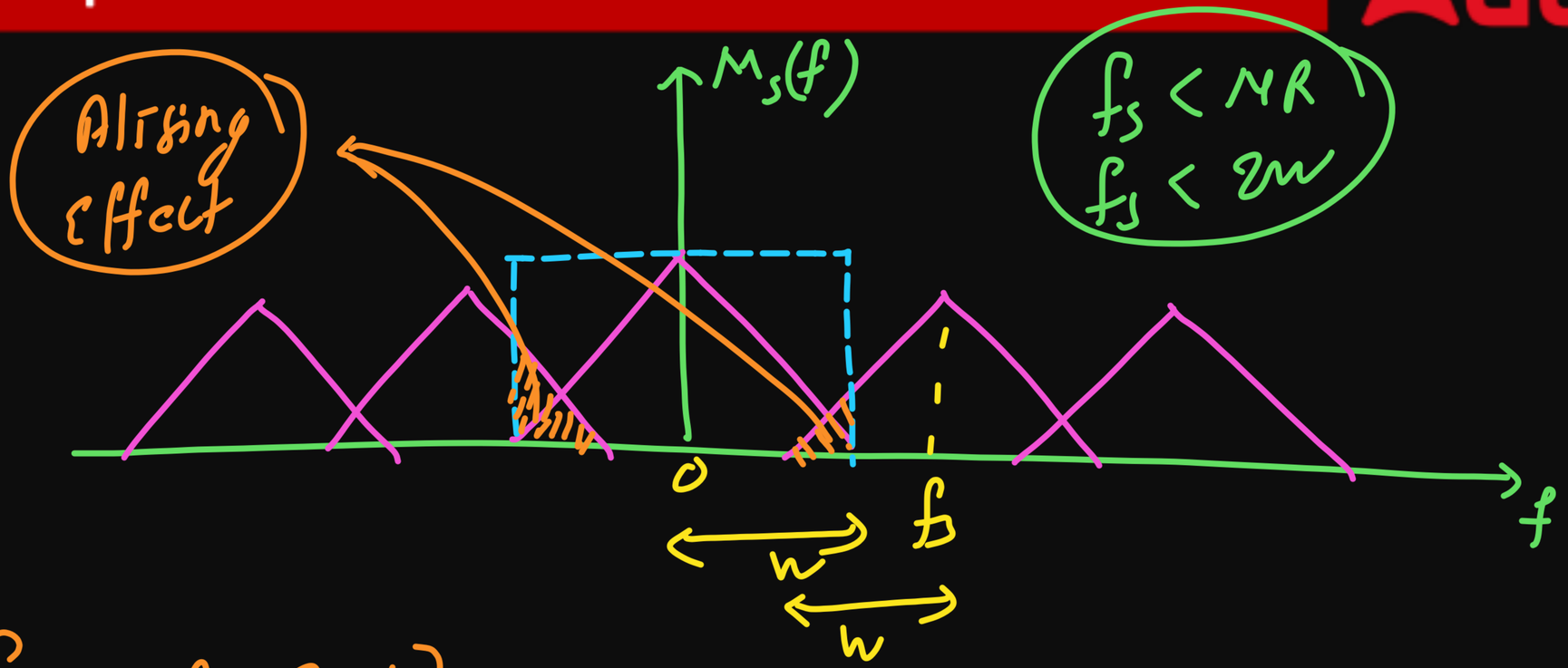
$$f_s \geq M.R$$

$$f_s \geq 2W$$

$$T_s \leq \frac{1}{2W}$$

$$T_s \leq \frac{1}{MR}$$


$M_s(f)$
$f_s = 2W = MR$
$\Rightarrow$ Same signal will recover
$-2f_s$
$-f_s$
0
W
W
f_s
$2f_s$
$f_s > 2W, \; f_s > MR$
$-2f_s$
$-f_s$
0
W
W
f_s
W
$2f_s$
$MR \leq f_s \leq 2MR$

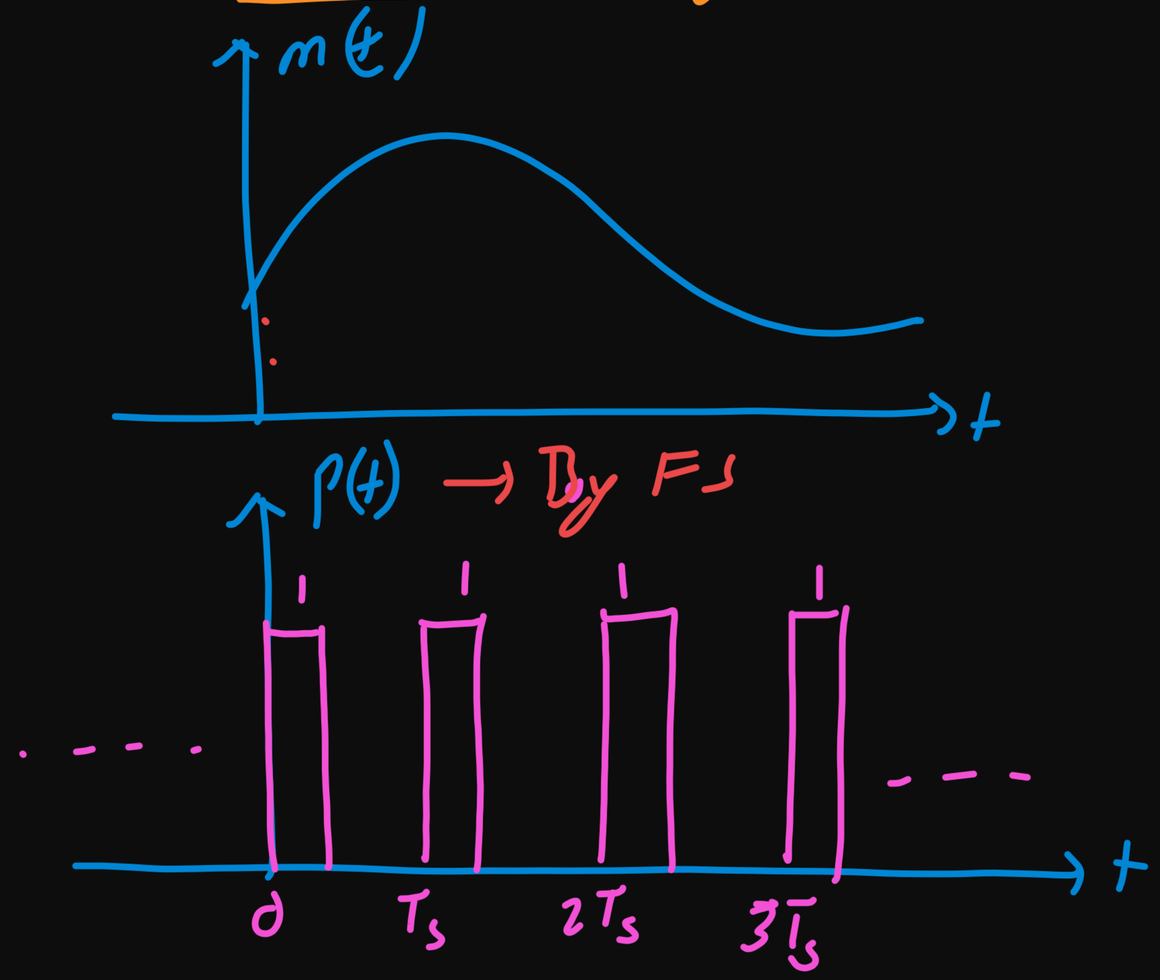


$f_s = NR = 2W$ → Reconstruction of signal is possible

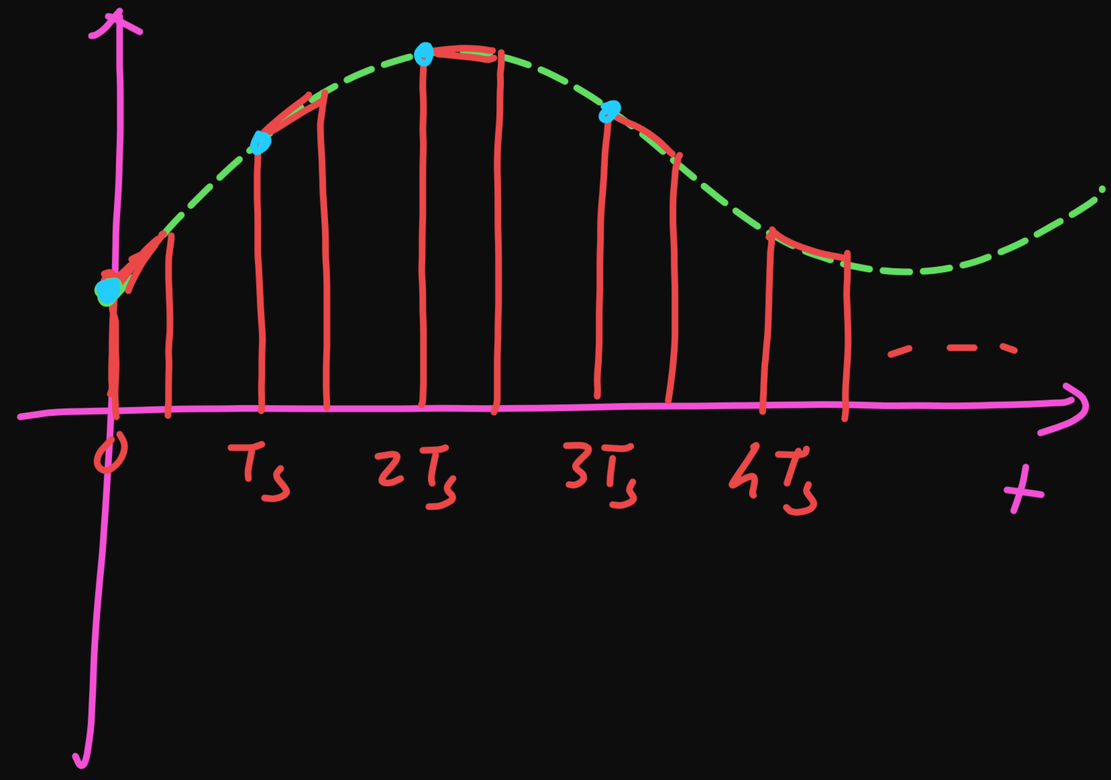
$f_s > NR = 2W$ → Reconstruction of signal is possible

$f_s < NR = 2W$ → Reconstruction of signal is not possible

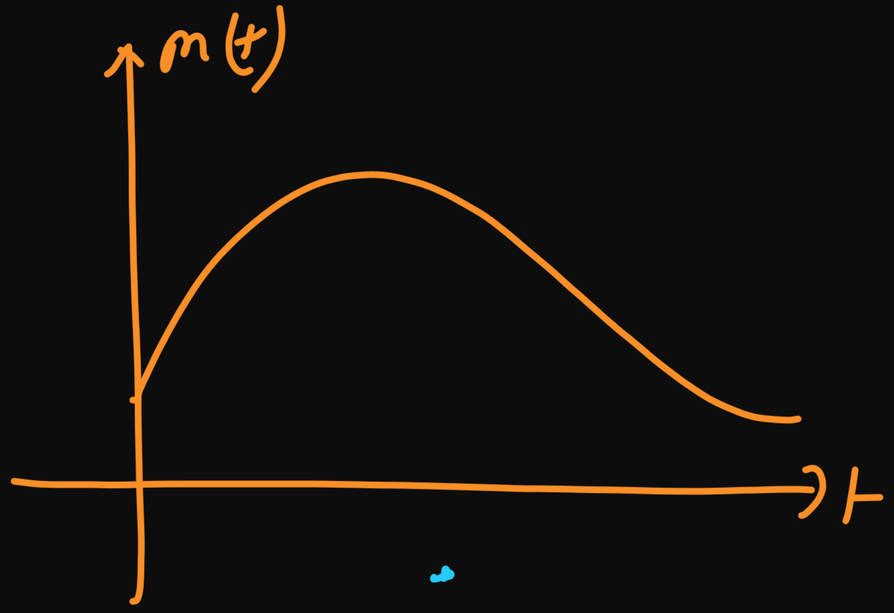
* (ii) Natural Sampling (Pulse Sampling):



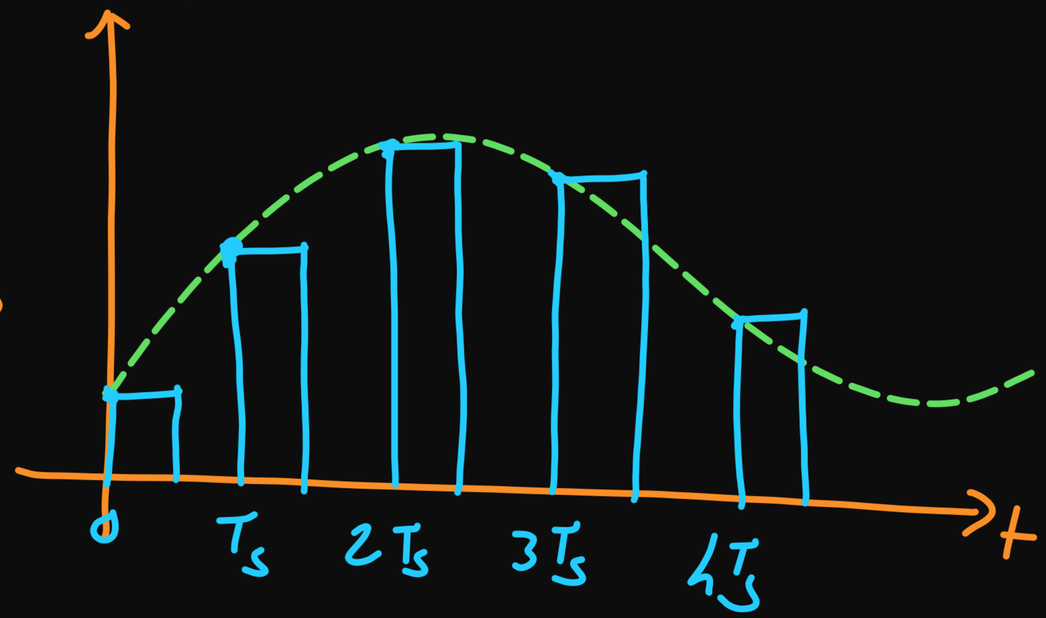
$$m_{sh}(t) = m(t) \cdot P(t)$$



* (iii) Flat-top Sampling:



S/H



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