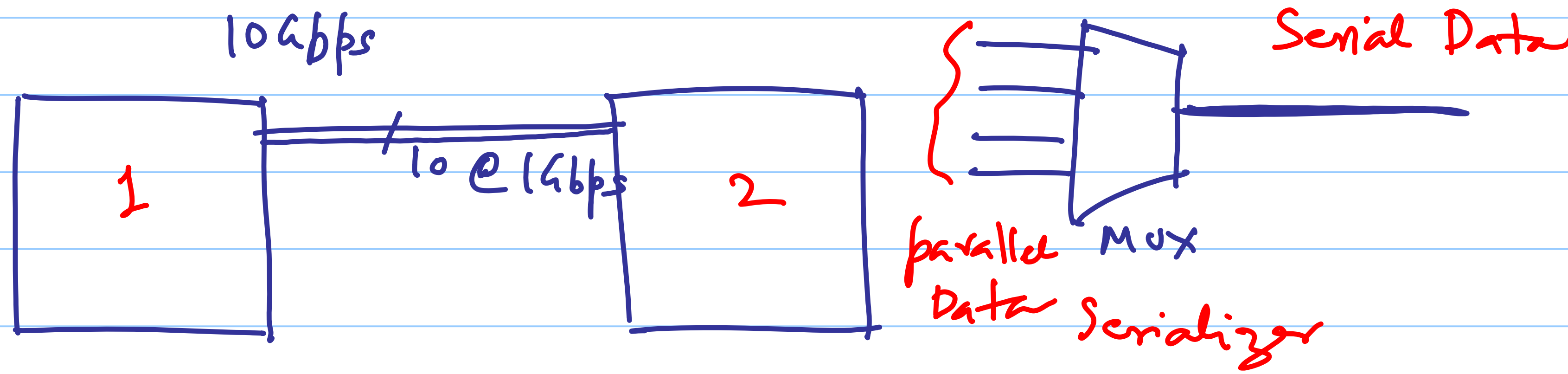
ECE 518 – Lecture 23

Note Title 4/9/2015

Clock and Data Recovery

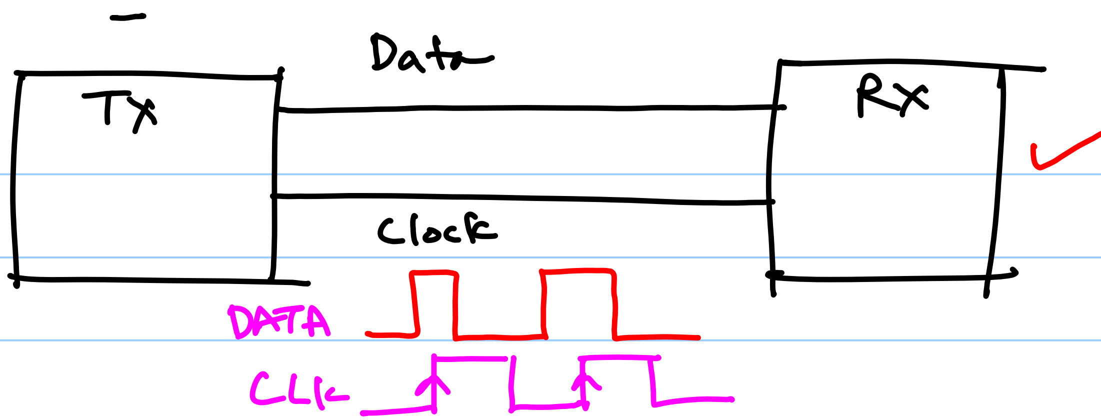
* Serial links
* SERDES

1Gbps ⟶ >28Gbps

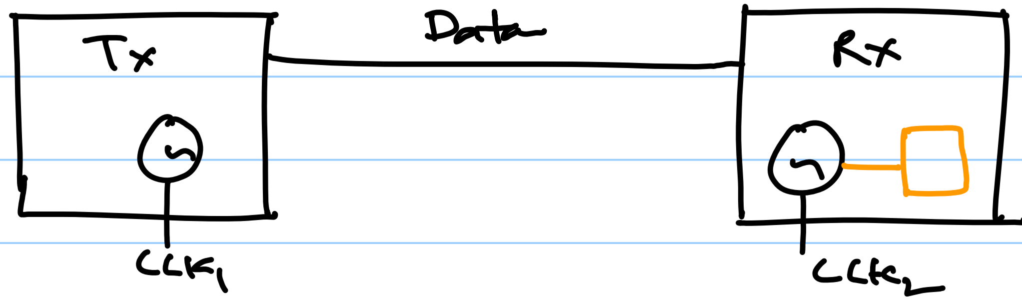


Serial interface: Backplane Transceivers
MicroProcessors, FPGAs
optical links
Data Center interconnects
HDMI etc.

Source synchronous



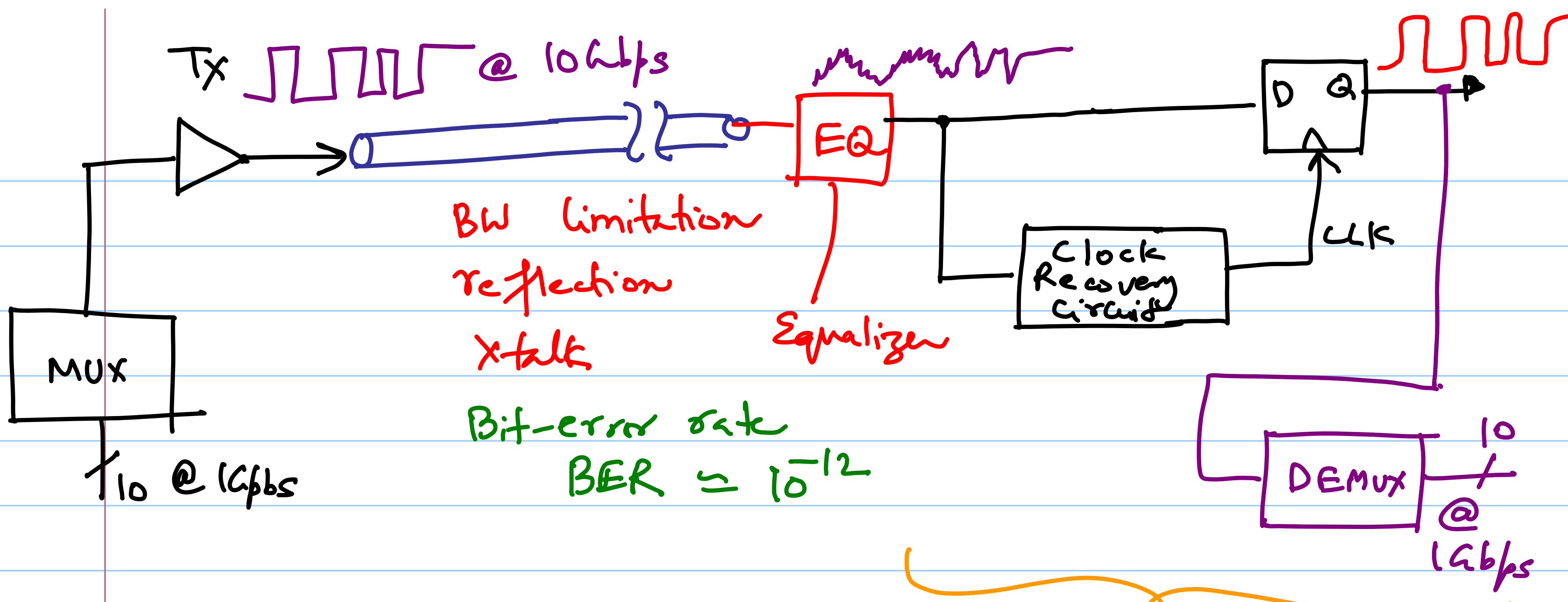
plesiochronous



clock-data recovery

* Data recieved from a serial interface is both asynchronous and noisy

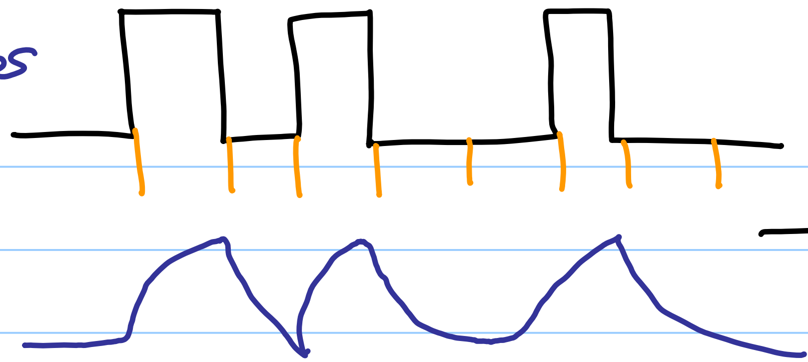
* A clock must be extracted to allow synchronous operation
  ↳ The data must be "retimed" such that the jitter accumulated during transmission is removed.

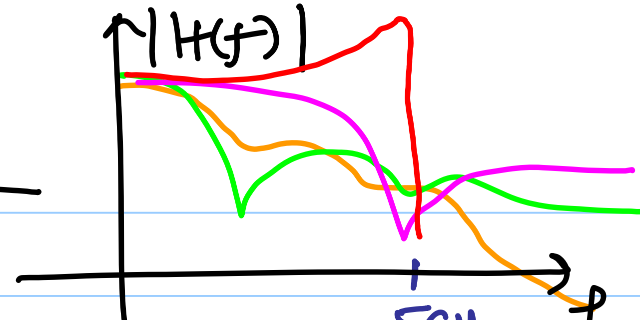


Clock and Data Recovery Circuit

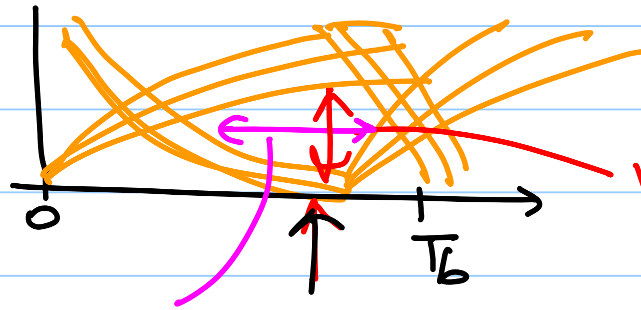
State-of-the-art
28 Gbps in 32nm CMOS

10 Gbps





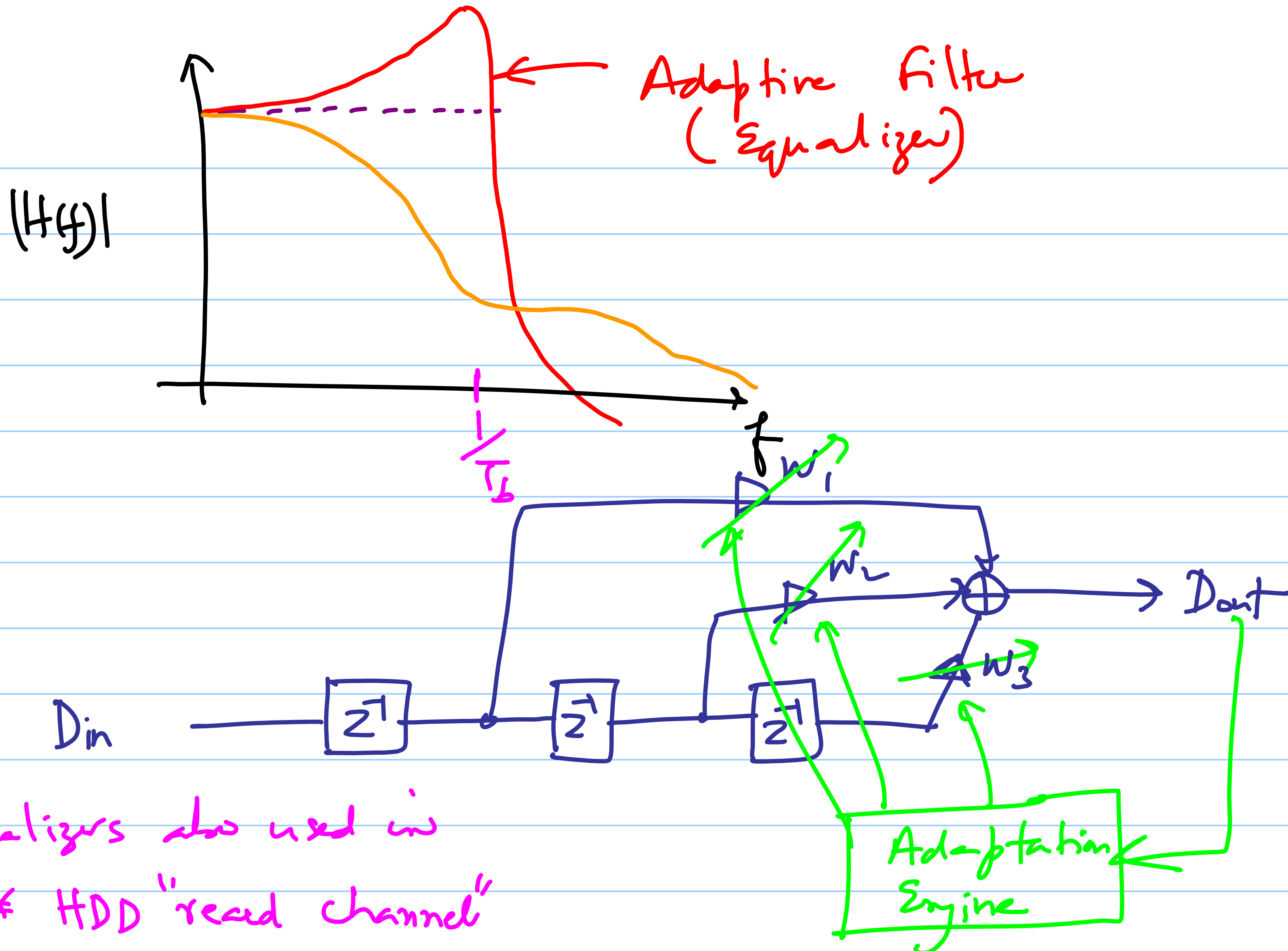
Eye Diagram



Vertical eye-opening

Horizontal eye-opening

"BW- dependent jitter"



Equalizers also used in
* HDD "read channel"
* future 60 GHz mmWave Radios

FIR type (FFE) feedforward
IIR type (DFE) Decision feedback equalizer

noisy data → zero crossings are corrupted by noise & jitter

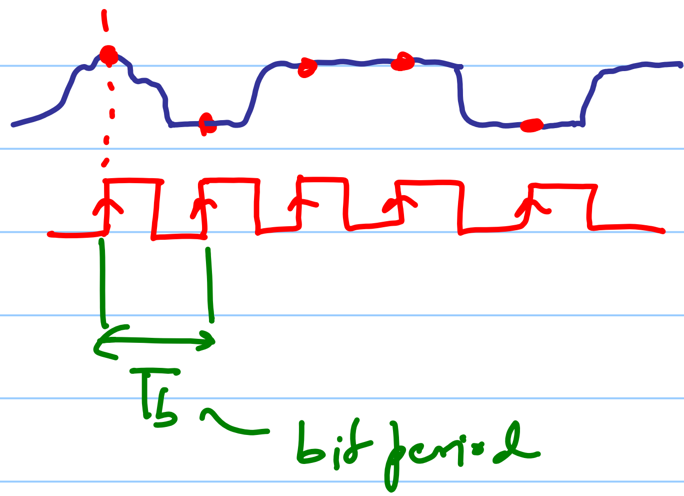
↳ CDR removes the timing errors and cleans up data transitions

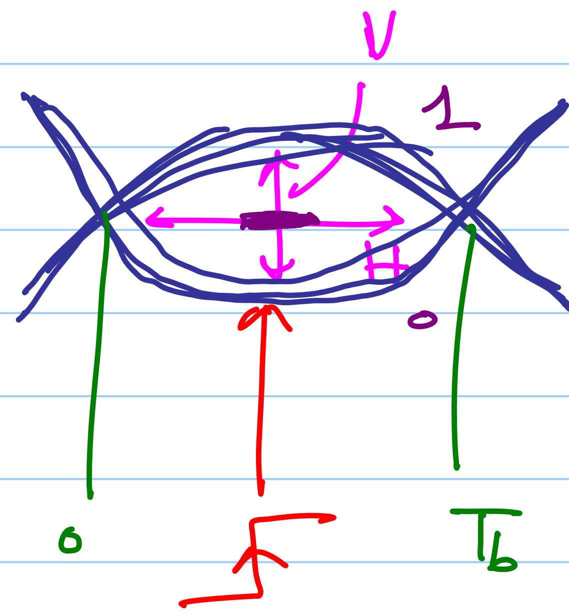
The recovered clock from data must satisfy

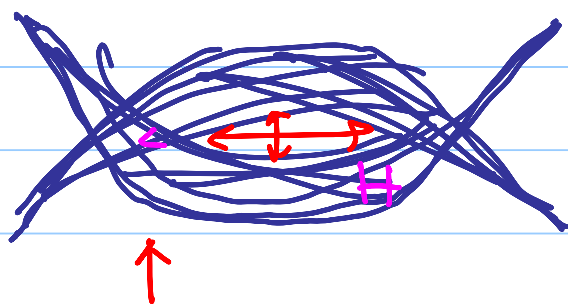
① It must have a frequency equal to the data rate

eg. 10 Gbps data rate must translate into 10 GHz clock frequency

② It must bear a certain phase relationship w.r.t data, allowing optimum sampling of data bits by the clock







closed-eye

↳ higher probability of error in data recovery.

③ It must exhibit small jitter as it is the principal contributor to the retimed data jitter

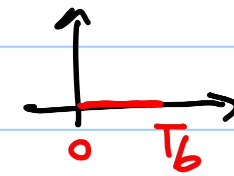
CDR { Jitter generation
Jitter tolerance

Edge Detection from Random Data

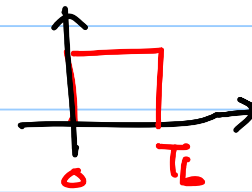
⇒ Random NRZ data

non return to zero

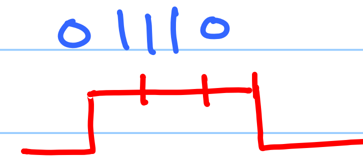
0



(NRZ) 1

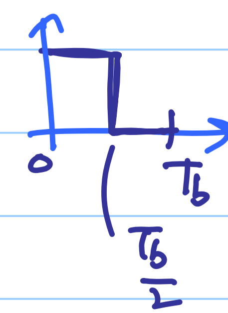


8b/10b encoding
64b/66b encoding } built into the standards

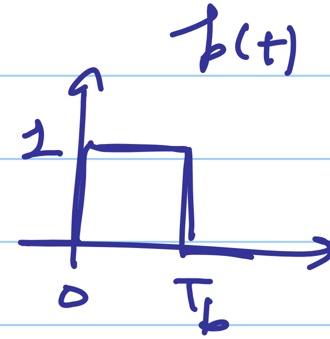


NRZ

1

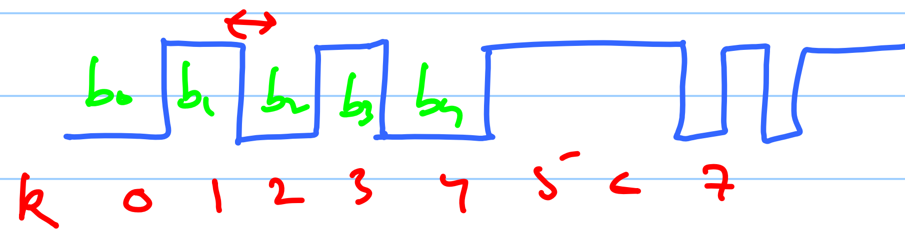


data rate $R_b = \frac{1}{T_b}$

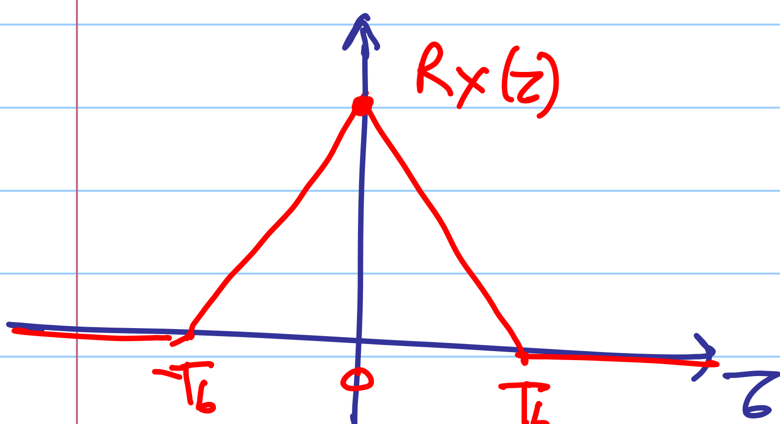


random $\{0,1\}$

$$x(t) = \sum_k b_k \cdot p(t - kT_b)$$



Autocorrelation $R_x(\tau) = E\left(x(t)\,x(t-\tau)\right)$

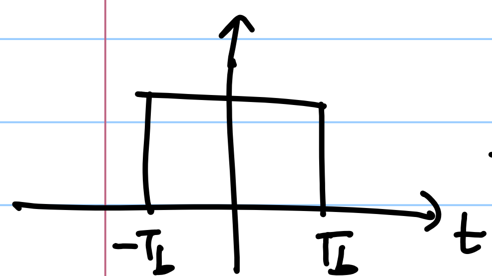


$$= \begin{cases} 1 - \frac{|\tau|}{T_b}, & |\tau| < T_b \\ 0, & |\tau| > T_b \end{cases}$$

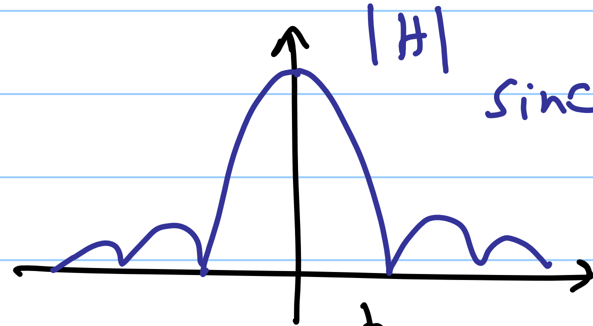
$$S_x(f) = T_b \operatorname{sinc}^2(f T_b)$$

$$x(t) \xrightarrow{\mathcal{F}} X$$

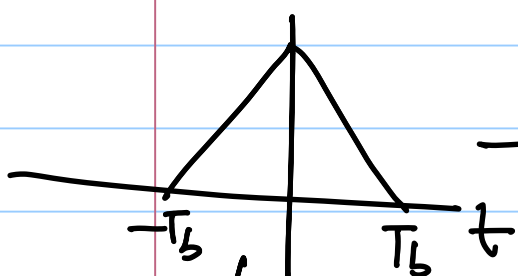
$$R_x(t) \xrightarrow{\mathcal{F}} \text{PSD of } x(t)$$



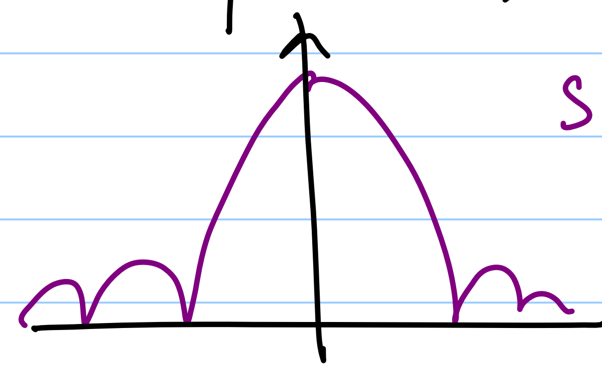
$\xrightarrow{\mathcal{F}}$



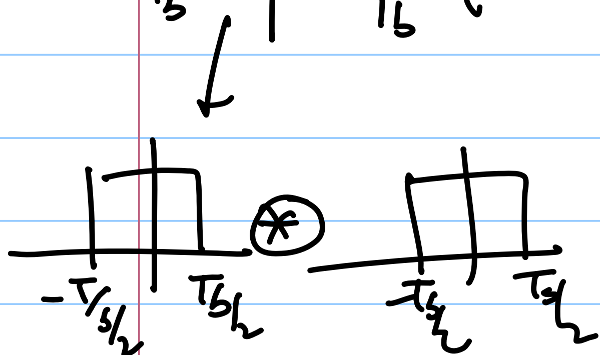
$$\text{sinc} = \frac{\sin(\pi x)}{\pi x}$$



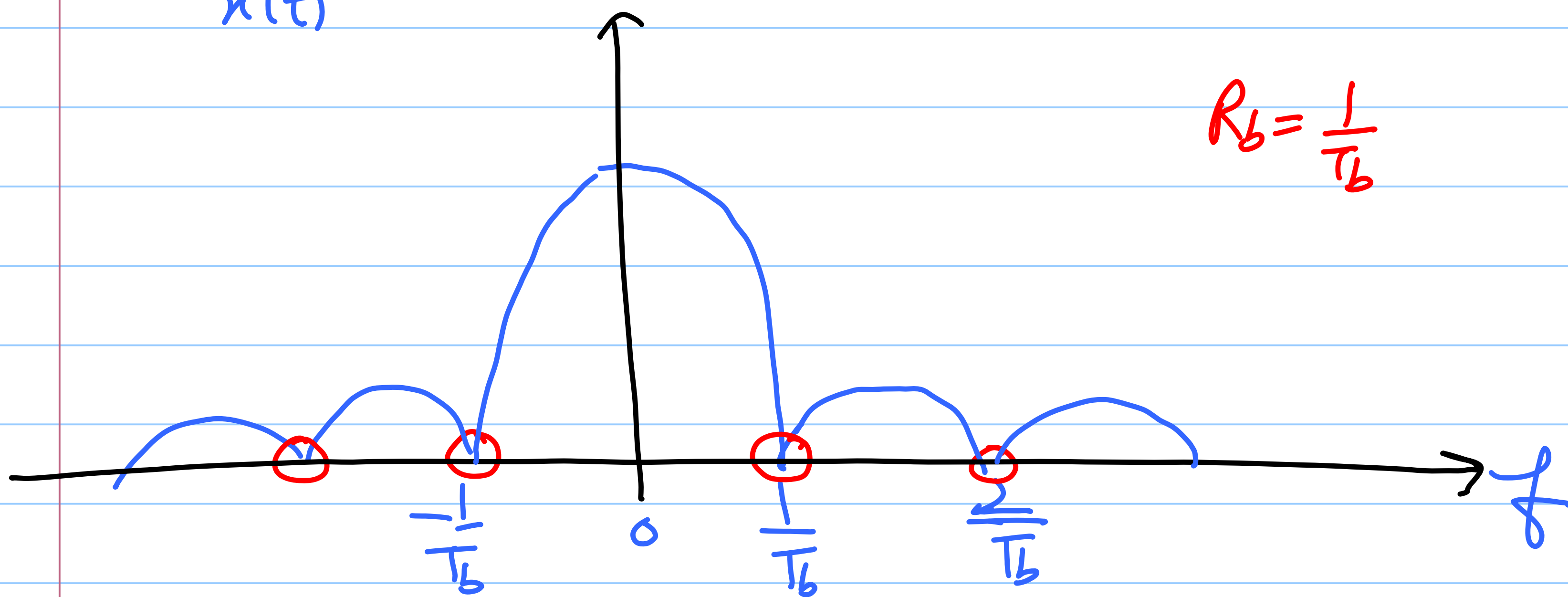
$\xrightarrow{\mathcal{F}}$



sinc^2



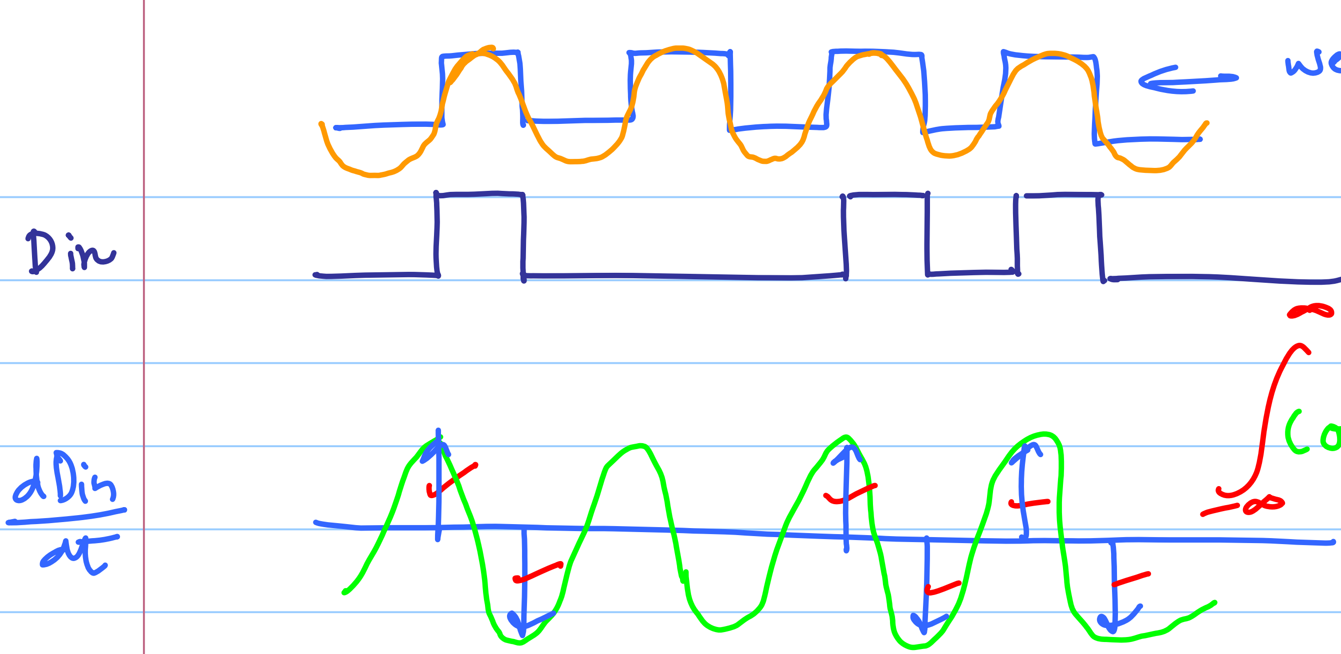
PSD of $x(t)$ $\Rightarrow S_x(f)$



* Spectral null at the data rate $\frac{1}{T_b}$

↳ no direct information for clock extraction!

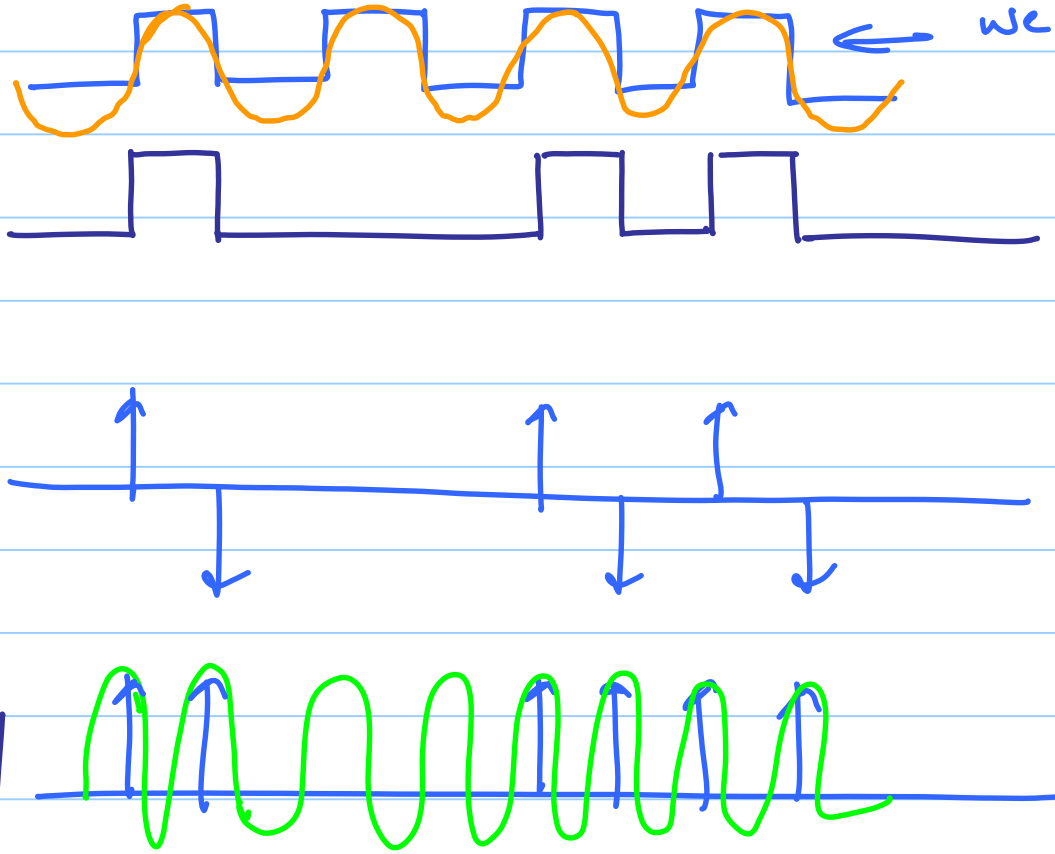
↳ need to use non-linear methods to generate a spectral line at $1/T_b$.



$\leftarrow$ we want this

$$\int_{-\infty}^{\infty} \cos\left(\frac{2\pi}{T_b} t + \theta\right) \cdot \frac{dD_{in}}{dt}\, dt$$

$$= 0$$



$\frac{dD_{in}}{dt}$

$\left|\frac{dD_{in}}{dt}\right|$