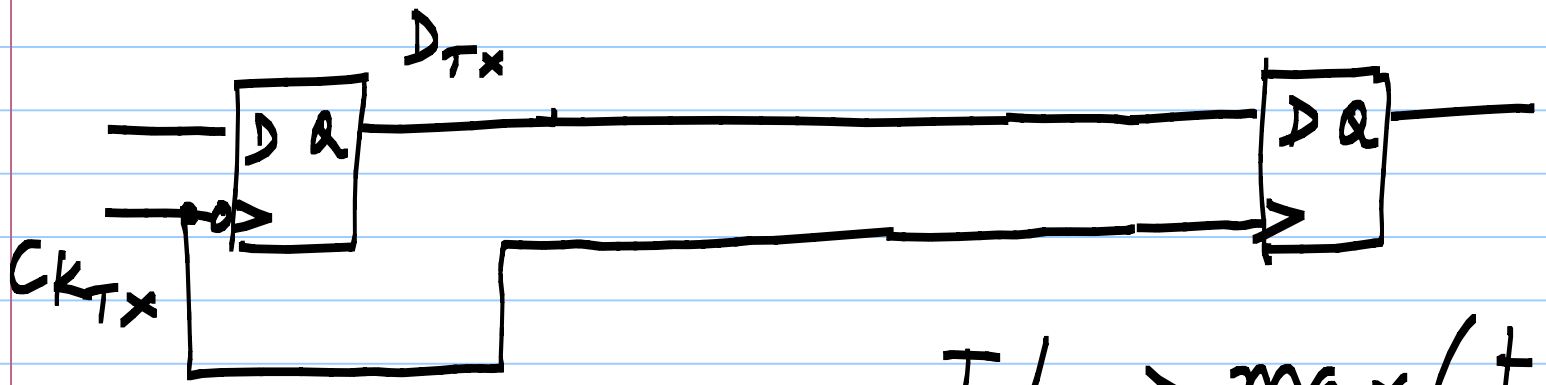
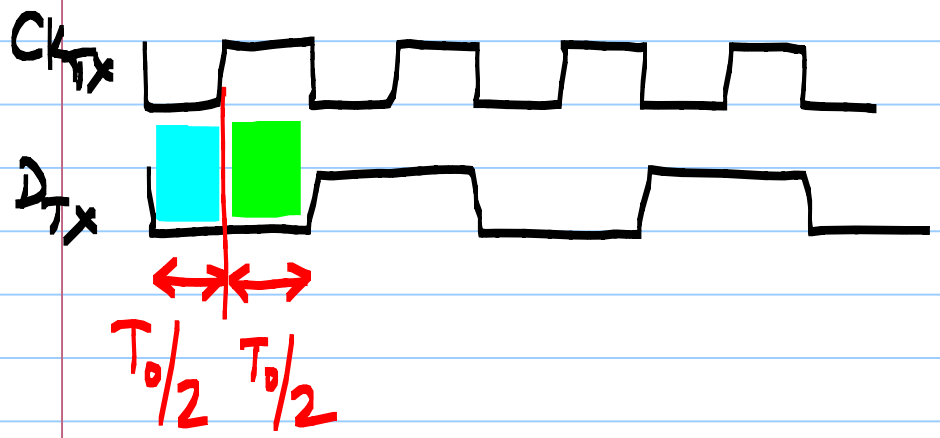
Transmitting and receiving digital data

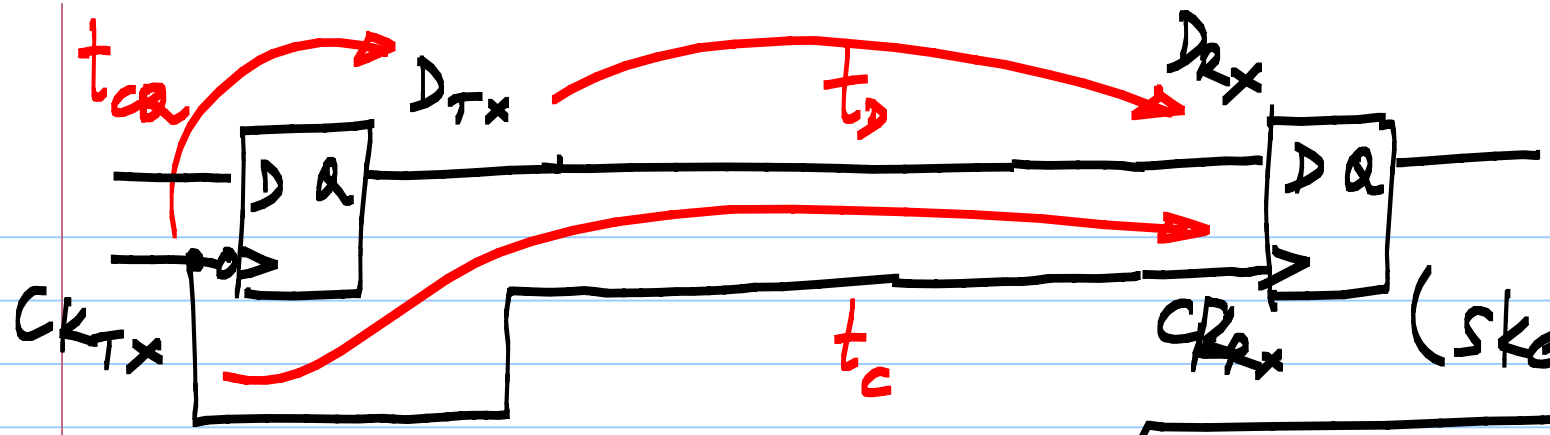


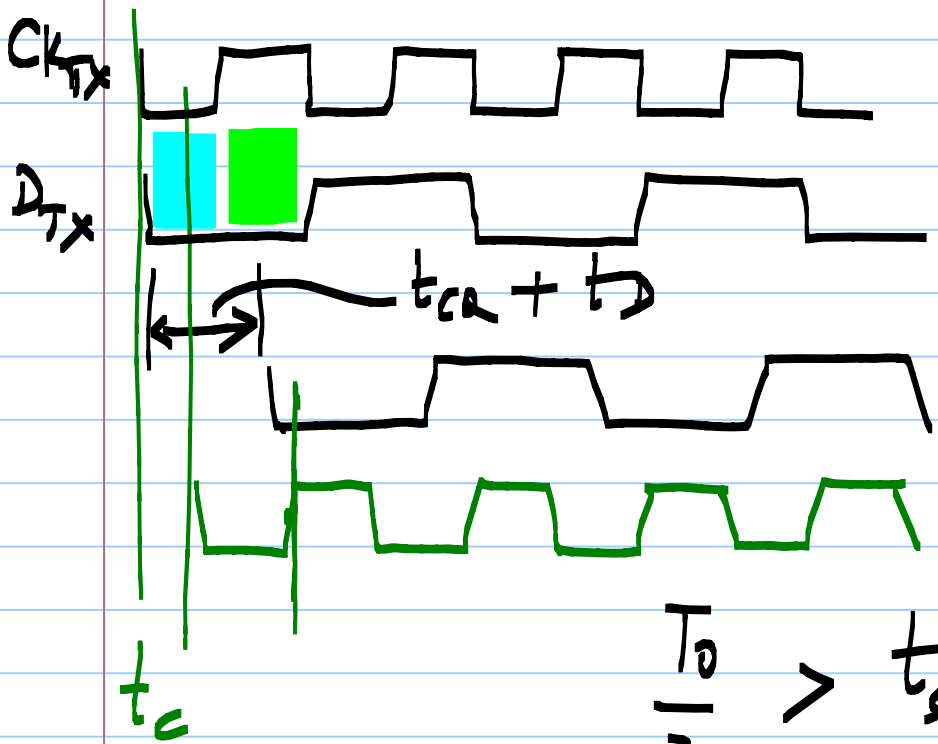
$$T_0/2 > \max(t_{su}, t_H)$$

$$T_0/2 > t_{su}$$

$$T_0/2 > t_H$$







$$t_C - (t_{CQ} + t_D) + \frac{T_0}{2} > t_{SU}$$

$$\frac{T_0}{2} + (t_{CQ} + t_D) - t_C > t_H$$

t_{skew}

$$\frac{T_0}{2} > t_{SU} + t_{skew}$$

$$T_0/2 > t_H - t_{skew}$$

$$\frac{T_0}{2} > \max(t_{SU} + t_{skew},\ t_H - t_{skew})$$

300m/ns

300 mm/ns 30cm

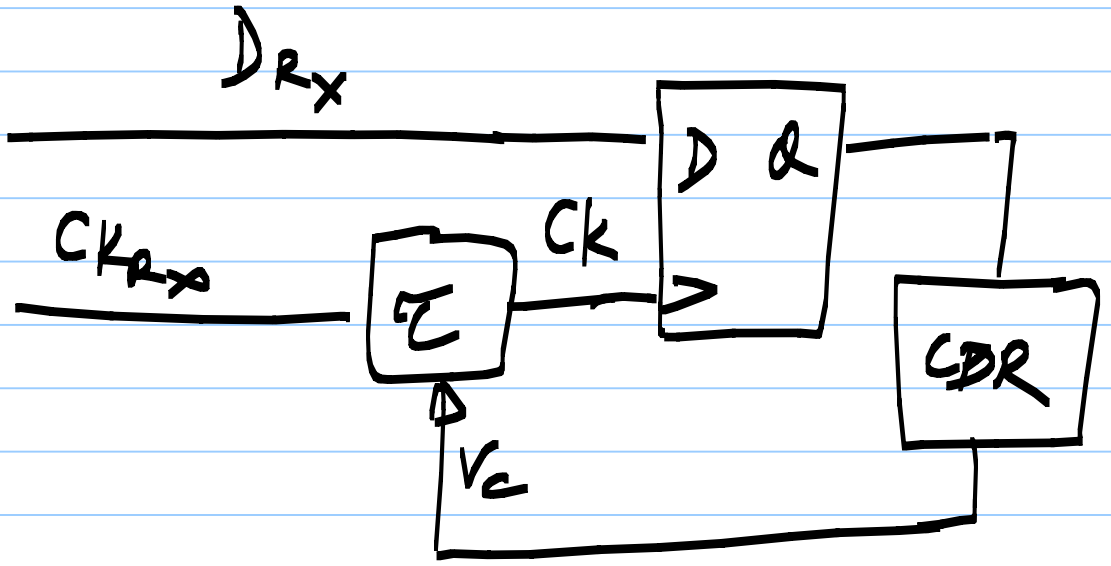
30 mm/loops in air

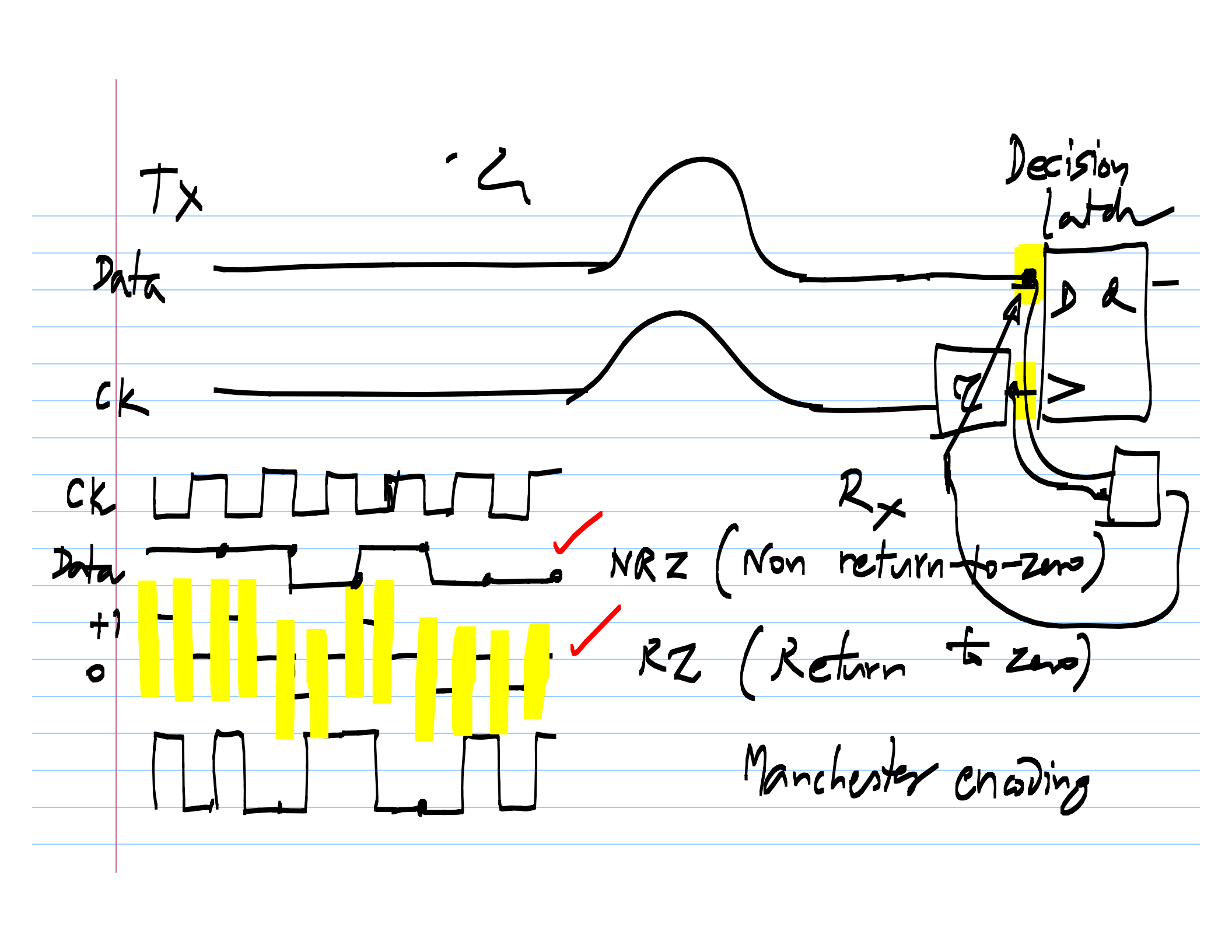
15mm/loops

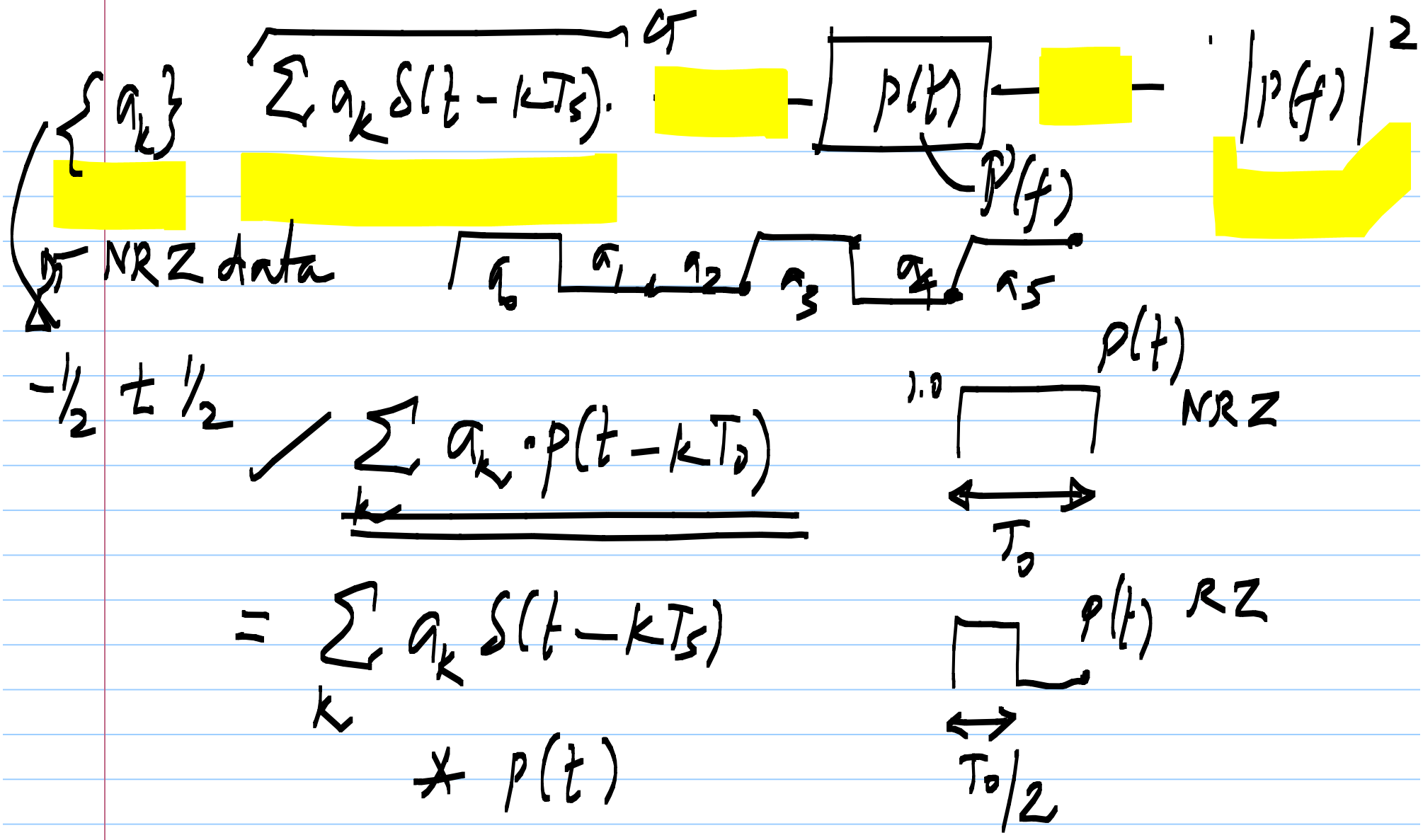
10Gb/s : loops

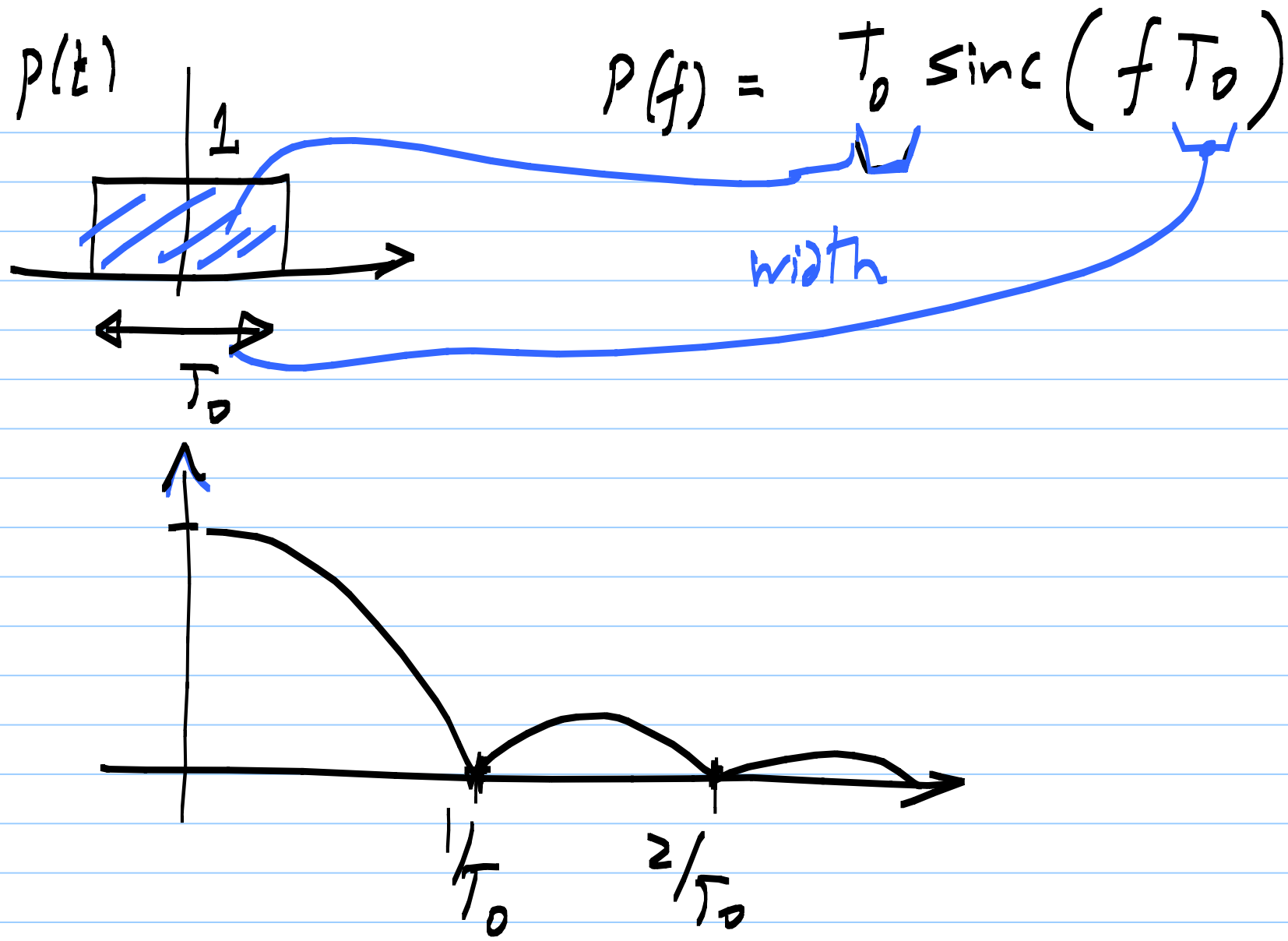
$$\frac{1}{\sqrt{\mu_r \epsilon_r}} \sim \frac{1}{2}$$

Clock & data recovery circuit




Tx
Data
ck
Decision latch
D
Q
Rx
CK
Data
+1
0
NRZ (Non return-to-zero)
RZ (Return to zero)
Manchester coading


$\{a_k\}$
$\sum a_k \delta(t - kT_s)$
$p(t)$
$P(f)$
$|P(f)|^2$
NRZ data
a_0 a_1 a_2 a_3 a_4
T_s
$-\frac{1}{2}$ $+\frac{1}{2}$
$\sum_k a_k \cdot p(t - kT_s)$
$= \sum_k a_k \delta(t - kT_s) * p(t)$
1.0
$p(t)$ NRZ
T_s
$p(t)$ RZ
$T_s/2$


p(t)
1
T_0
$P(f) = T_0 \, \mathrm{sinc}(fT_0)$
width
$1/T_0$
$2/T_0$

Data links with large delays on data & clock lines: Need an adaptive delay on the clock so that it is centered on the data

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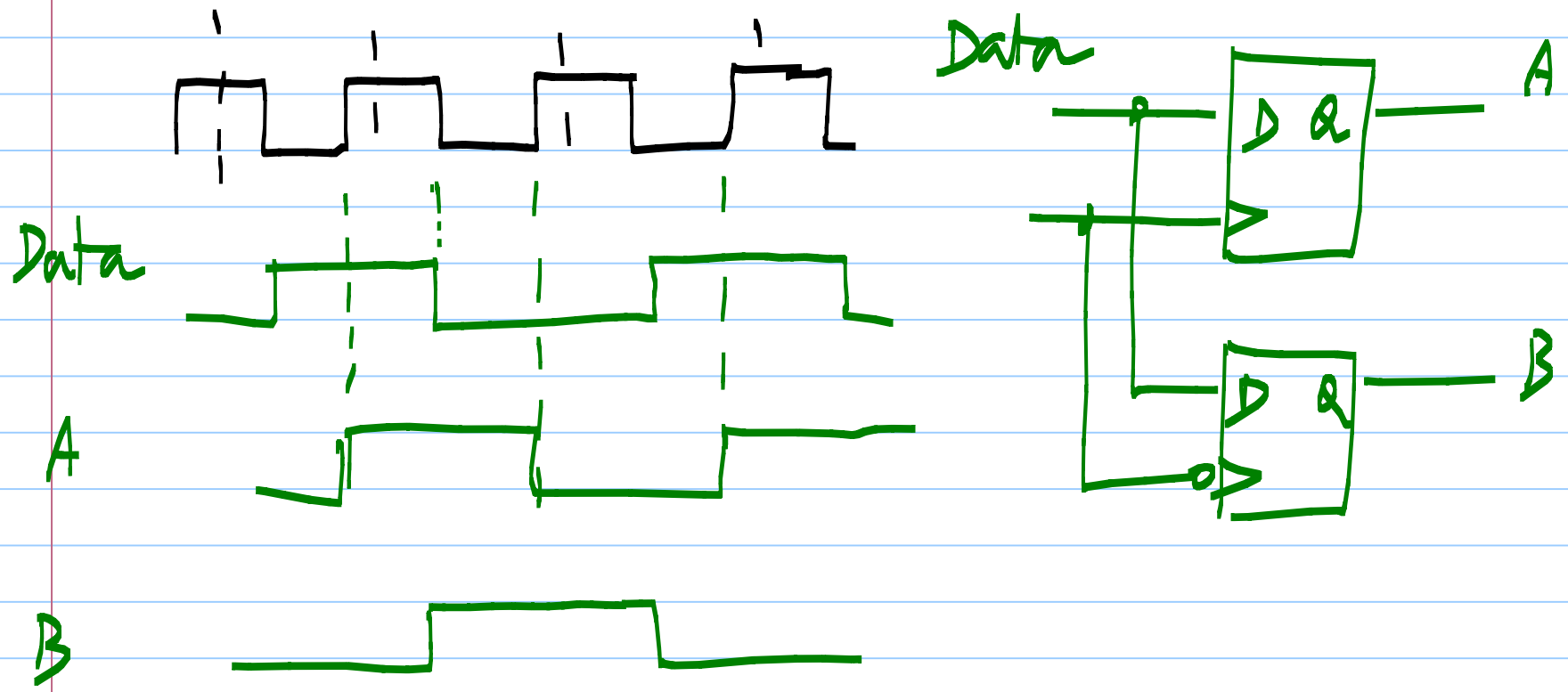
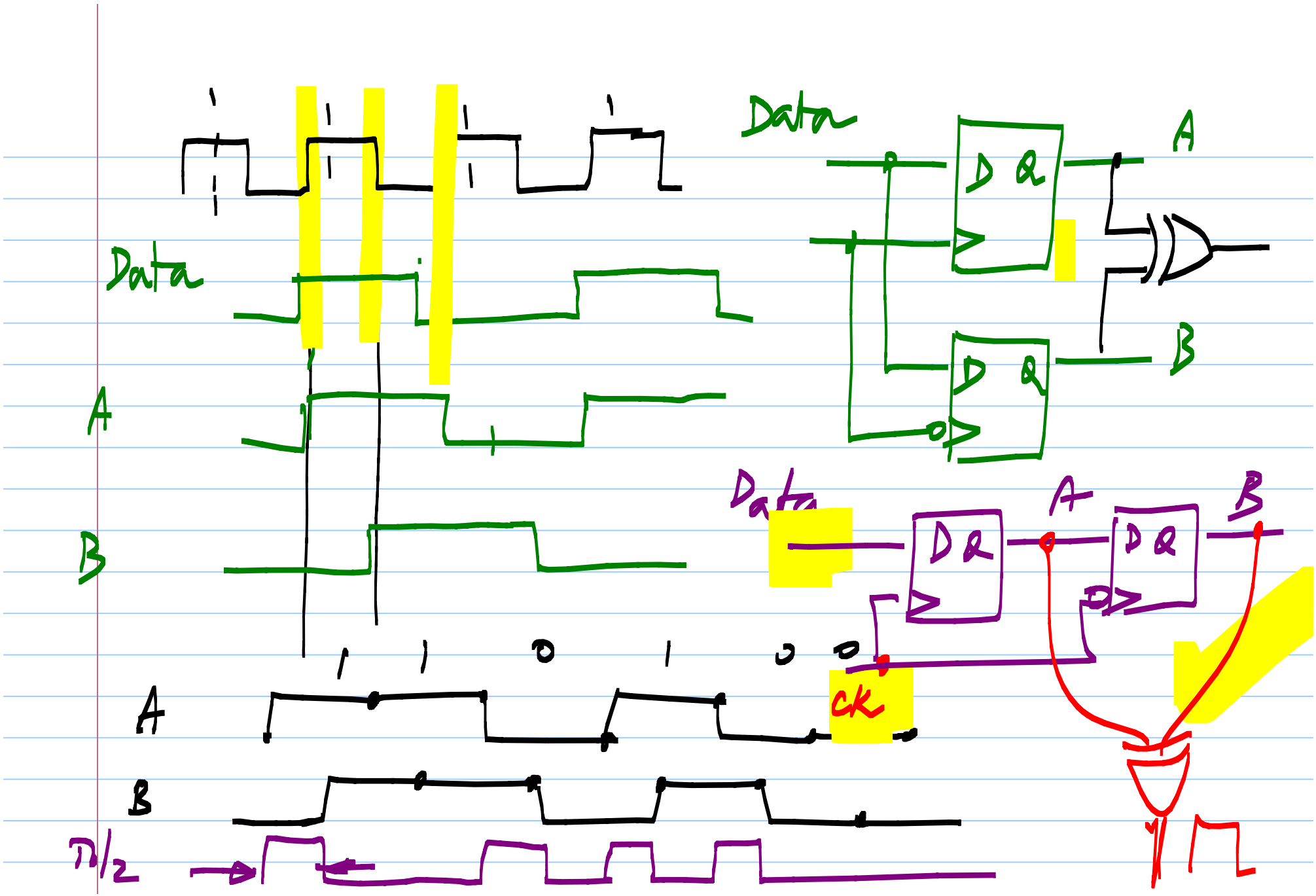
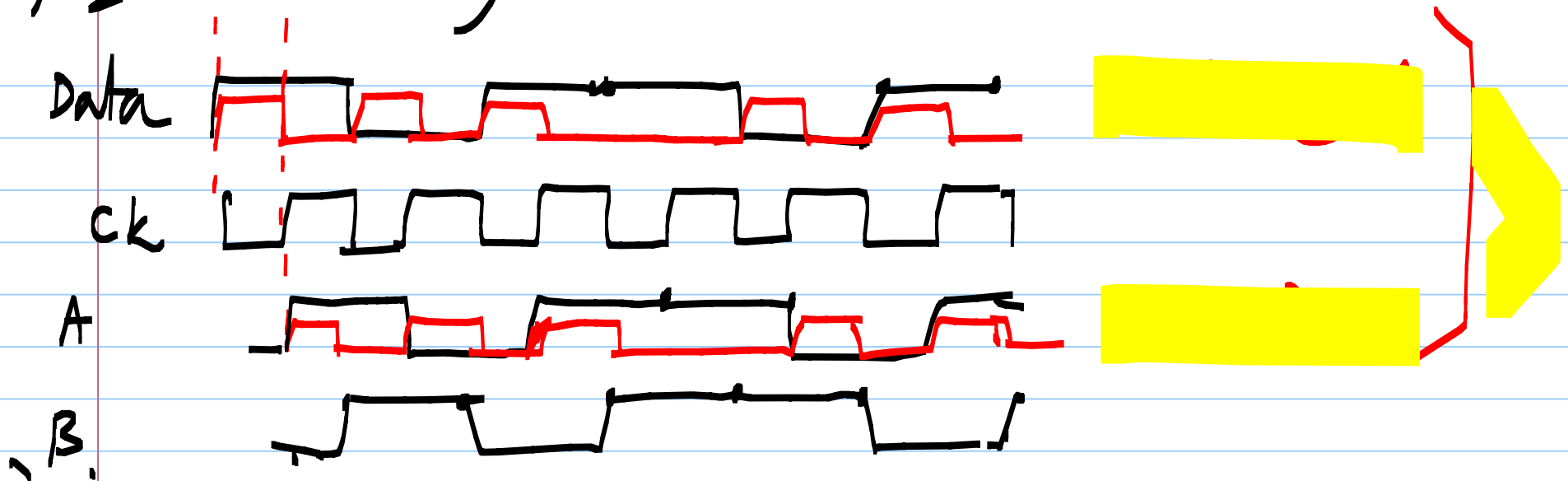
Measure the phase difference between data and clock. **phase detector**

Adjust the delay to get the desired phase difference. **variable delay**


Data
A
B
Data
D
Q
A
D
Q
B


Data
A
B
Data
D Q
A
B
D Q
Data
A
B
D Q
D Q
ck
A
B
π/2

Desired alignment



Data skewed to the right