ECE 447 Fall 2025

Lesson 25
Digital Receivers: Timing, Detection, & Eye Diagrams

Schedule and Admin

- Schedule updated.
- Admin
  - **HW4**. Needs graded
  - **Lab 4**. Due TONIGHT.
  - **HW5**. Posted on website. Due M27 (23 Oct).

Review

- What is Nyquist's First Criterion?
- True or False. For error-free communication, we need zero ISI across the pulse width, T_b.
- f_x is the excess bandwidth. In excess of what value?

SCRAMBLING

- Section 6.4 - not part of your reading assignments
- Uses shift registers to mix up the 1's and 0's
- Makes the data appear random - helpful for timing extraction and security purposes
- Not the same as encryption

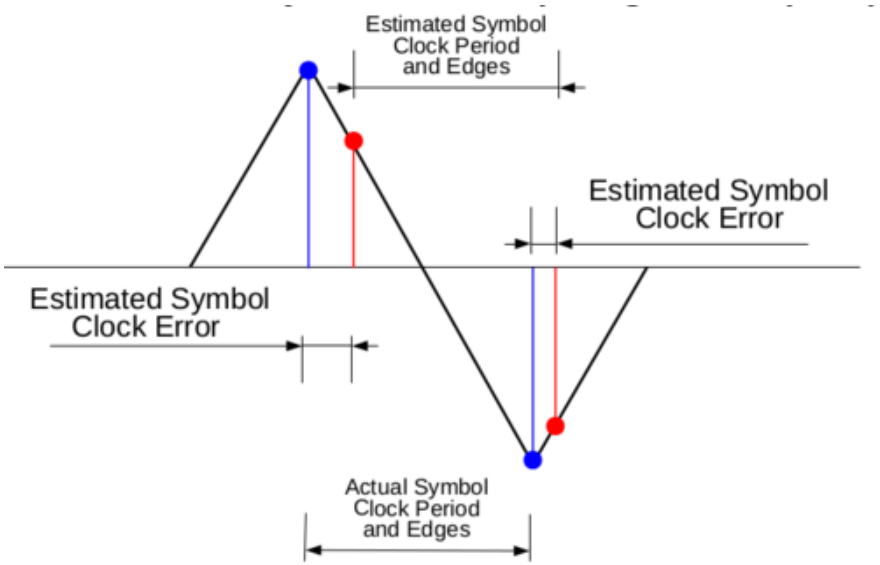
EQUALIZERS

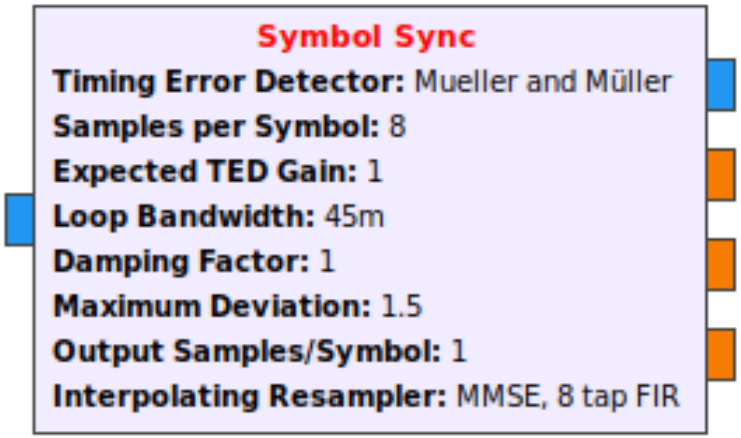
- Section 6.5.1 - also not part of your reading assignments
- Received signals usually attenuated and distorted by the channel - how do we compensate for the attenuation?

- Distortion is compensated by an equalizer
- Goal is to mitigate ISI while simultaneously suppressing the channel noise - but you can't do both at the same time
- Digital signals, however, don't need to worry about fully mitigating ISI
- Equalizer types: zero-forcing, MMSE, adaptive
- Lab 5 uses an adaptive, *blind* equalizer in the flowgraph (see Section 11.10 for more on blind equalization)

Timing Extraction

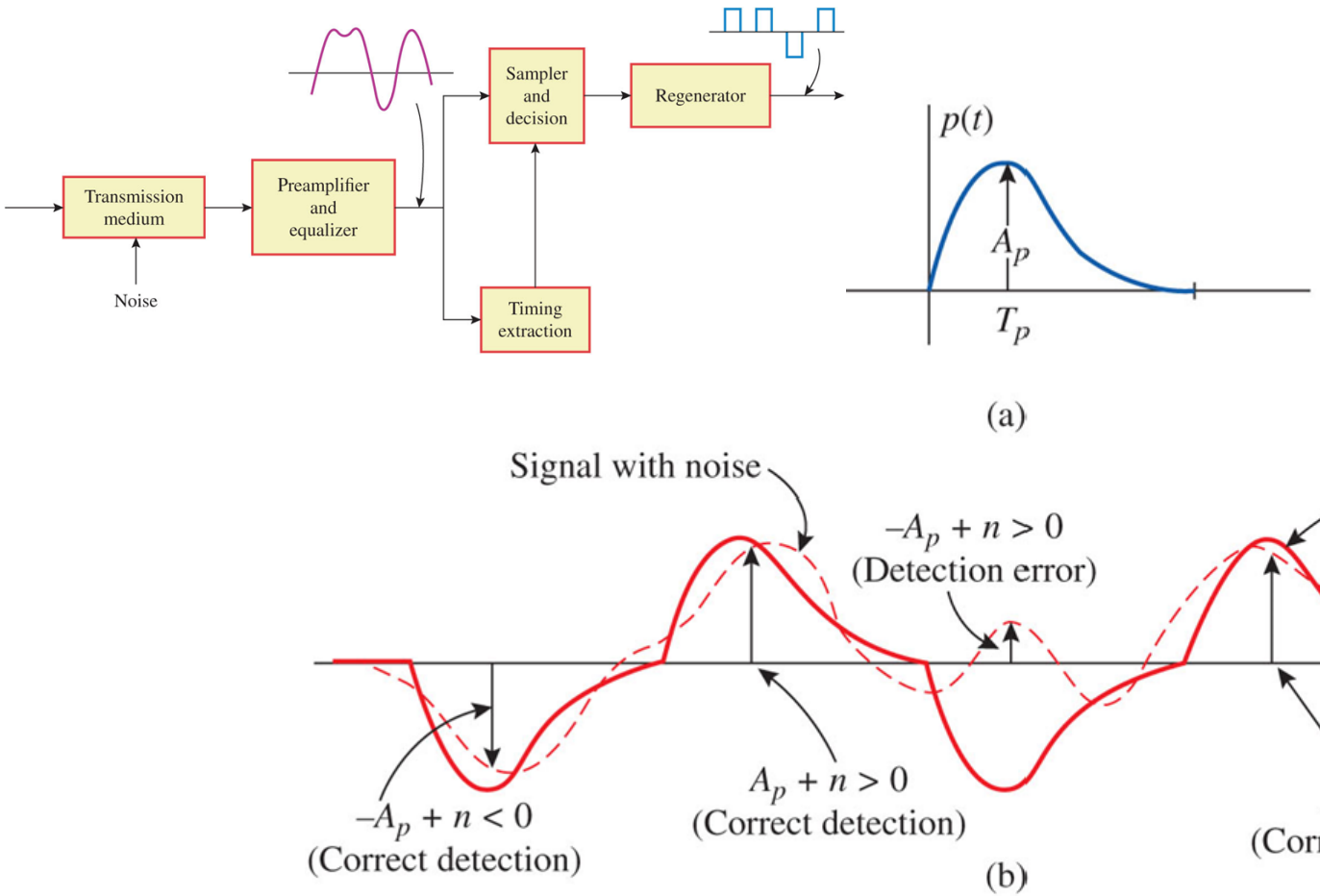
- Precise synchronization critical for symbol detection - 3 approaches are:
  1. Derive from a primary or secondary clock (e.g., GPS or a German atomic clock broadcasting as a master timing source)
  2. Send as separate signal (pilot)
  3. Self-clocking signal (ideal)
- Lab 5 - uses Symbol Sync block for timing synchronization, signal decimation, and filtering





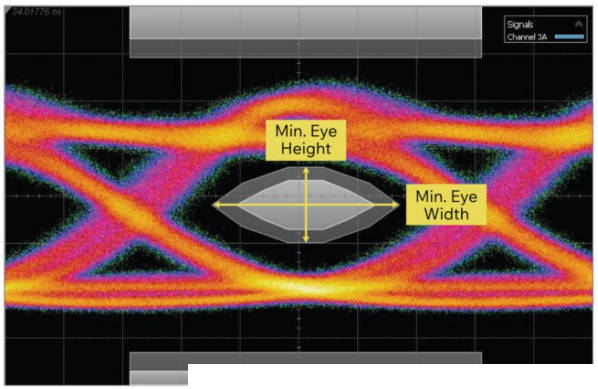
Detection

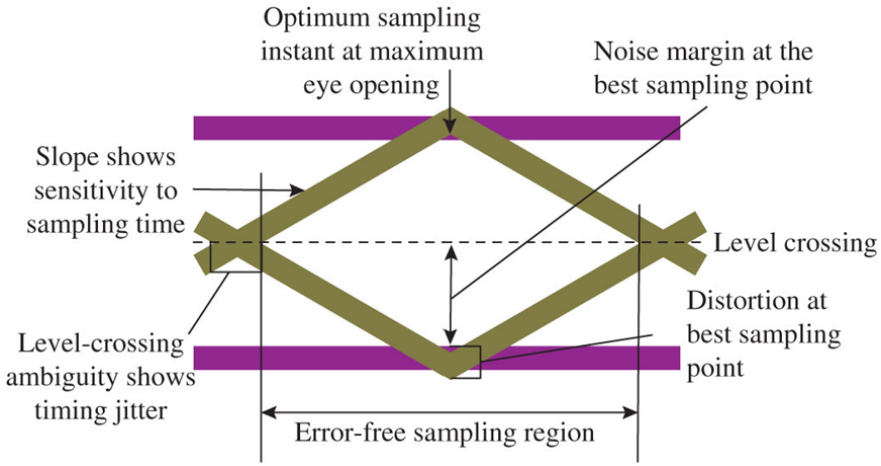
- Occurs after equalization and timing extraction
- Received signal = equalized pulse train + AWGN



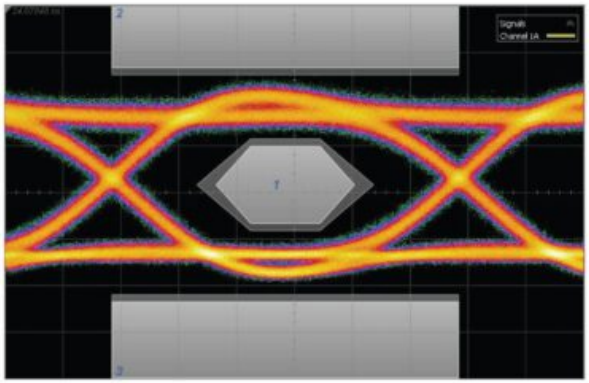
Eye Diagrams

- Practical engineering tool used to diagnose level of noise, tolerance to jitter/timing issues, level of jitter, noise margin, rise/fall times
- Eye diagrams in practice

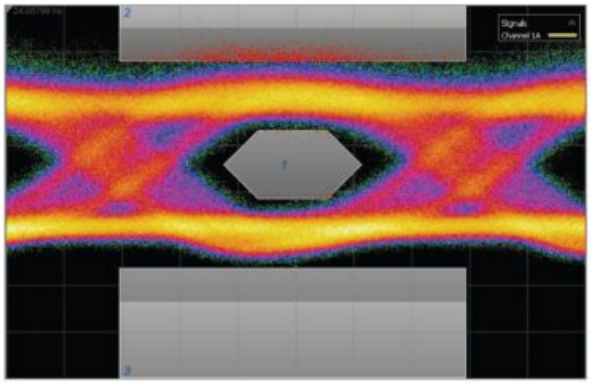




Stable Eye Diagram



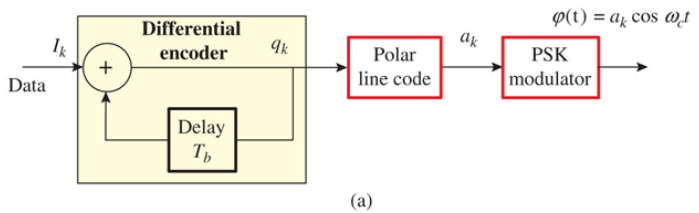
Unstable Eye Diagram



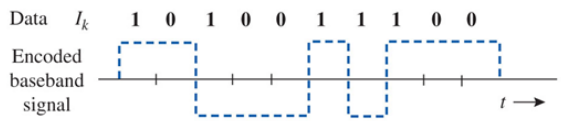
Images from connectorsupplier.com

Differential Encoding

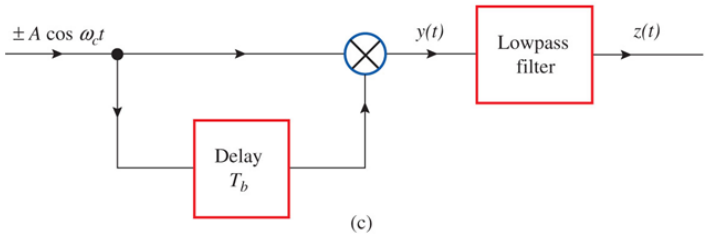
- Lab 5 uses DQPSK, or Differential Quadrature Phase Shift Keying
- Receiver only looks at relative difference between successive pulses vs. absolute phase
- Allows for noncoherent demodulation



(a)



(b)



(c)

Time k	0	1	2	3	4	5	6	7	8	9	10
I_k		1	0	1	0	0	1	1	1	0	0
q_k	0	1	1	0	0	0	1	0	1	1	1
Line code a_k	-1	1	1	-1	-1	-1	1	-1	1	1	1
θ_k	π	0	0	π	π	π	0	π	0	0	0
$\theta_k - \theta_{k-1}$		π	0	π	0	0	π	π	π	0	0
Detected bits		1	0	1	0	0	1	1	1	0	0