Optical Receivers

Chris Sanchez
CSU Chico
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General Outline

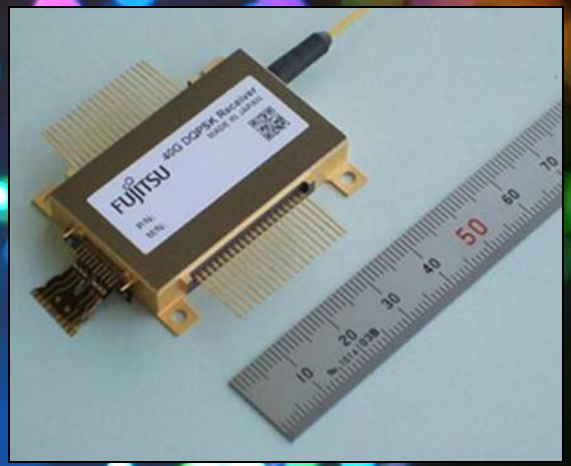
1. What is a receiver
2. Receiver configuration
    1. Front end section
    2. Linear channel section
    3. Data recovery section
    1. Types of receivers
        1. incoherent receiver
        2. Coherent receiver
    2. Differences
3. Receiver noise
4. Receiver performance

What is a Receiver?

- An optical receiver converts the optical signal received at the output end of the optical fiber back into the original electrical signal.

- Receivers consists of a few primary components:

1. Optical coupler
2. Amplifier
3. Photodetector
4. Demodulator



Receiver configuration

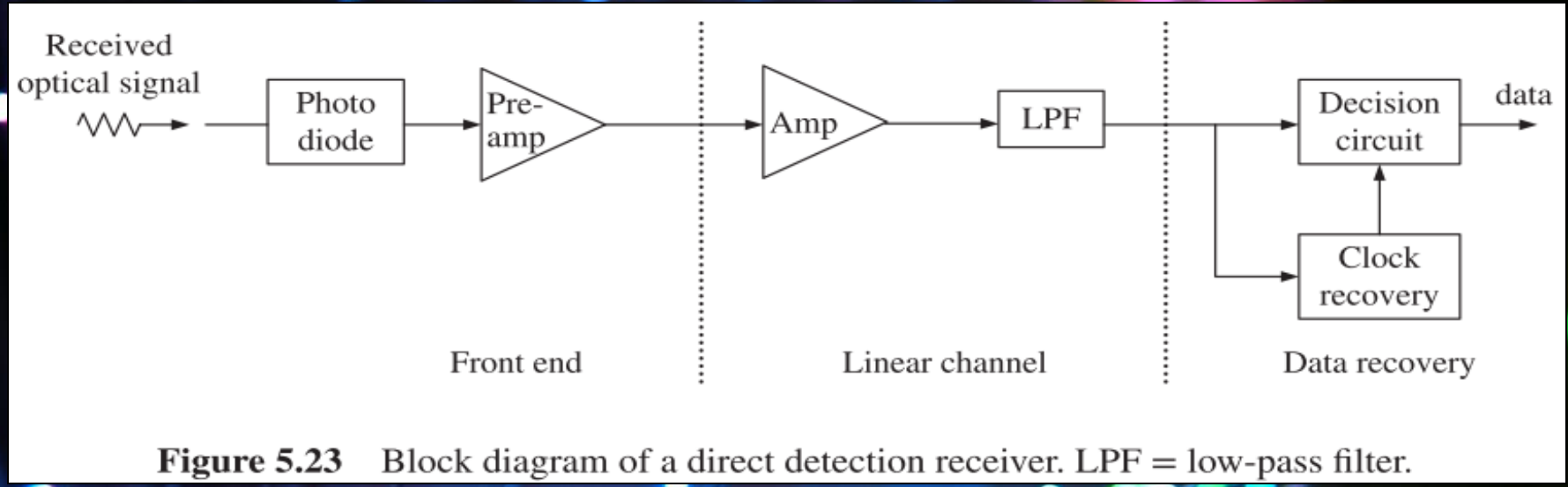
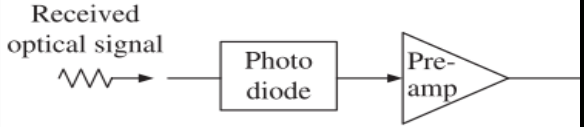


Figure 5.23 Block diagram of a direct detection receiver. LPF = low-pass filter.

Front end section

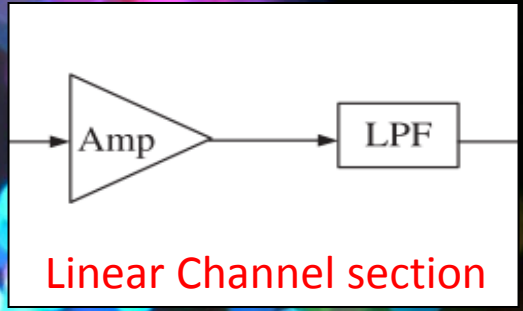
1. Coupler funnels signal into the photo detector
2. Optical data is converted to electrical data
3. Pre-amp amplifies electrical signals
   - Purpose is to reduce noise and interference and prep for further amplification



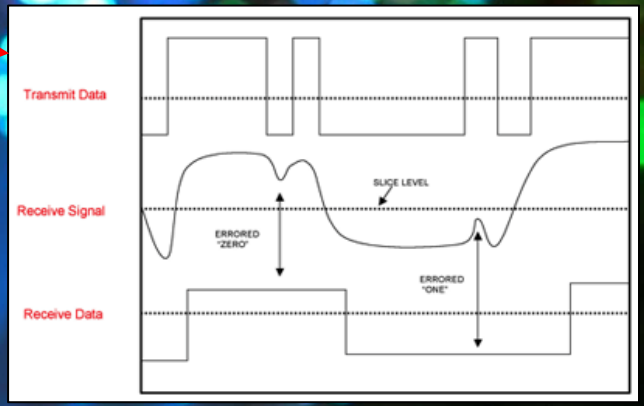
Front end section

Linear channel section

1. Amplifies signal with high gain
2. Filters out noise and reshapes signal wave
   - Shaped to mitigate intersymbol interference (ISI)
- Overall goal is to optimize signal to noise ratio (SNR)
  - Transfer function signal should match incoming signal for maximum SNR

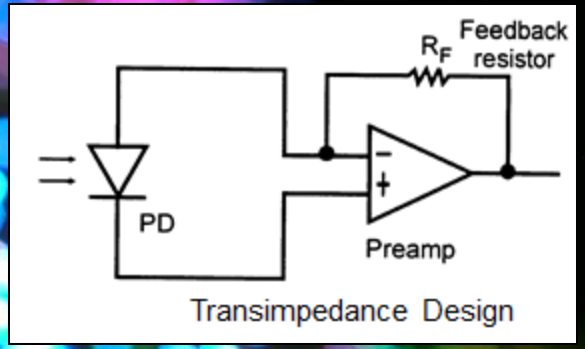


Linear Channel section

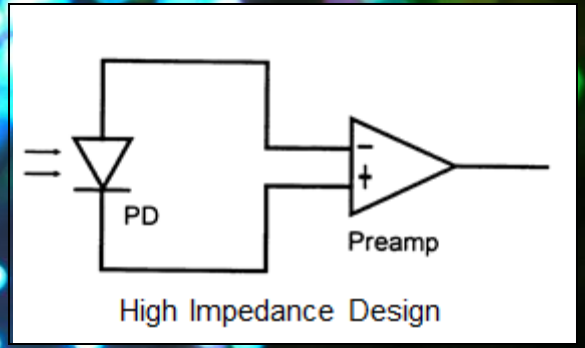


Transimpedance Amplifiers (TIA)

- TIA's provide high sensitivity and high bandwidths
- Converts current to voltage
- High impedance amplifiers (HIA) have higher thermal noise and produce low currents
  - They are typically used as the pre-amplifiers to reduce noise and prep signal for the TIA

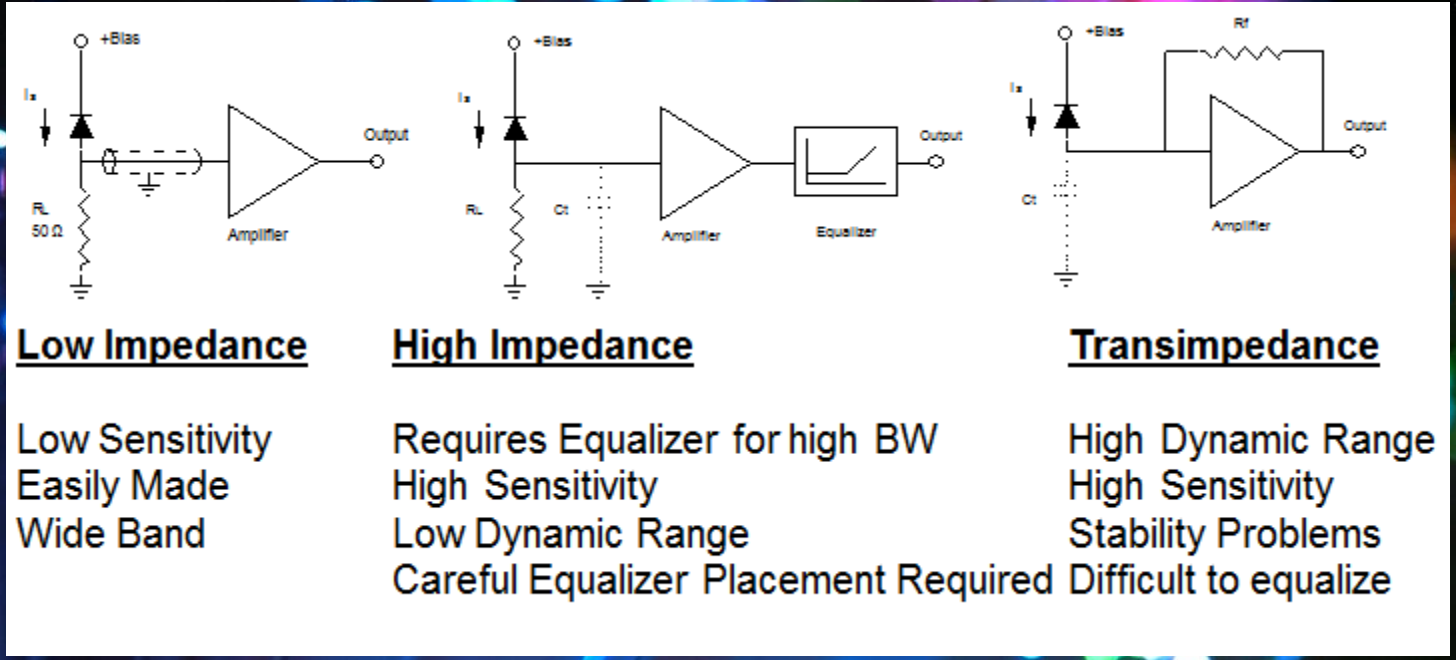


Transimpedance Design



High Impedance Design

Amplifier types cont..



Low Impedance

Low Sensitivity
Easily Made
Wide Band

High Impedance

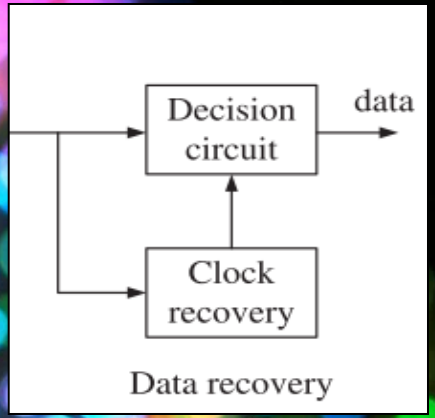
Requires Equalizer for high BW
High Sensitivity
Low Dynamic Range
Careful Equalizer Placement Required

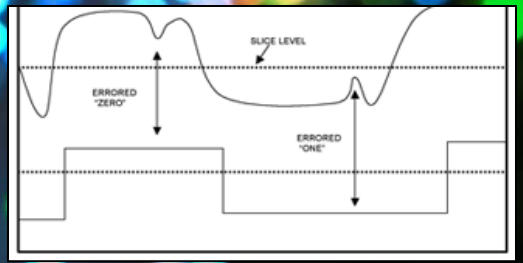
Transimpedance

High Dynamic Range
High Sensitivity
Stability Problems
Difficult to equalize

Data recovery section

- Consists of decision circuit and clock recovery circuit
- Purpose of decision circuit is to compare output to a threshold level
  - Ultimately interprets input signals and assigns 1's and 0's accordingly
- Purpose of clock recovery is to synchronize decision process
- Aftermath of noise is seen here



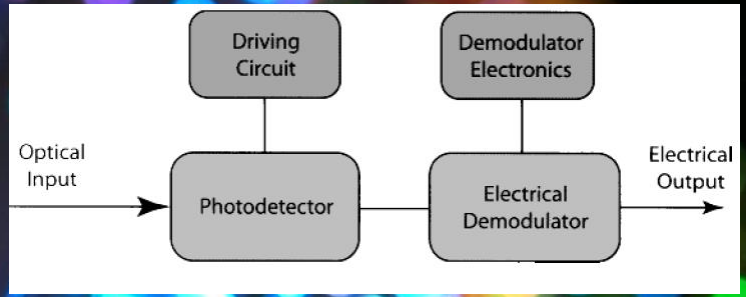


A couple of types of Receivers

1. Incoherent receivers
2. Coherent receivers

Incoherent receivers

1. Also known as direct detection receiver
2. Does not receive/interpret phase or frequency information (.: less complex)
3. Linear- Output signal is proportional to incident light
4. Higher bit error rates than coherent



Coherent receivers

1. Also known as direct detection receiver
2. Utilizes a local oscillator
3. Output signal is related to phase and amplitude
   - Phase lock loops utilized
4. Linear-Signal is proportional to incident light

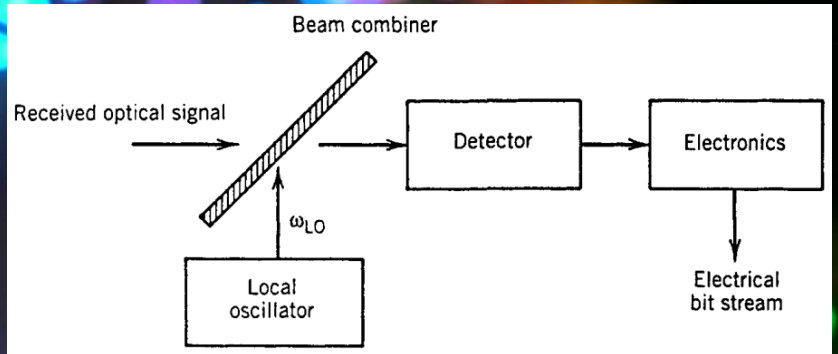


Figure 4.19: Schematic illustration of a coherent detection scheme.

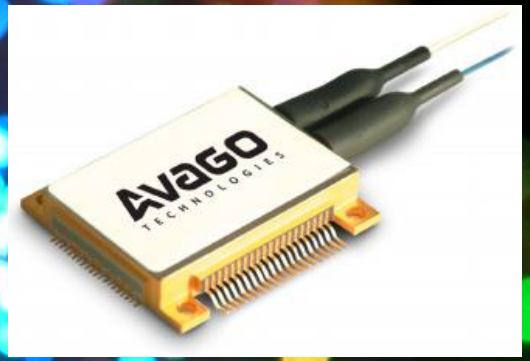
Coherent receivers cont…

- There are two coherent detection techniques:

1. Homodyne detection
   a) Local oscillator freq coincides with signal carrier freq
2. Heterodyne detection
   a) Difference between local oscillator freq and signal carrier freq lies in microwave region.
3. Both of these types can be either synchronous or asynchronous (how signal is detected)

Receiver noise

1. Shot noise
    1. Arises from the random electron generation that is produced from the optical conversion stage in photodiode.
    2. Most prevalent in avalanche photo diodes (APD)
2. Thermal noise
    1. Arises from random motion of electrons that collide with resistors



Receiver noise

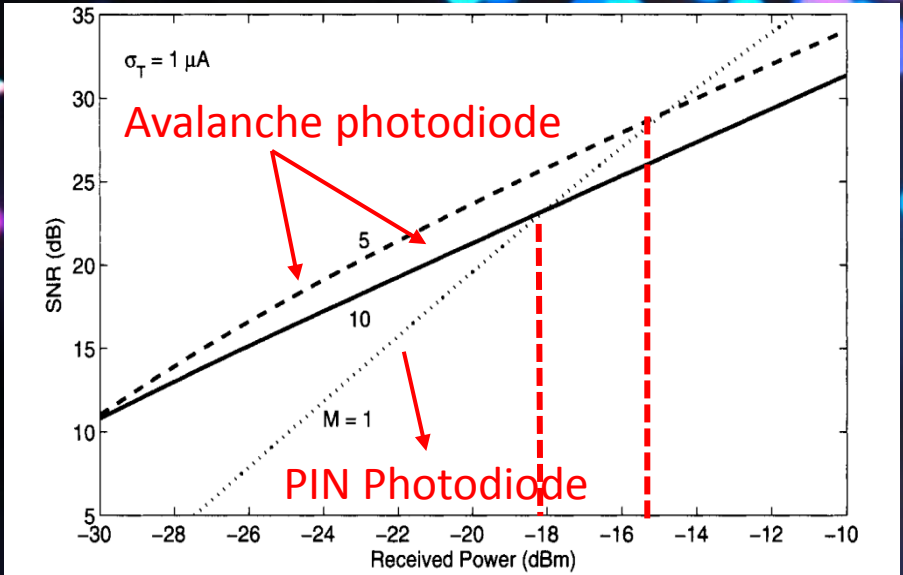
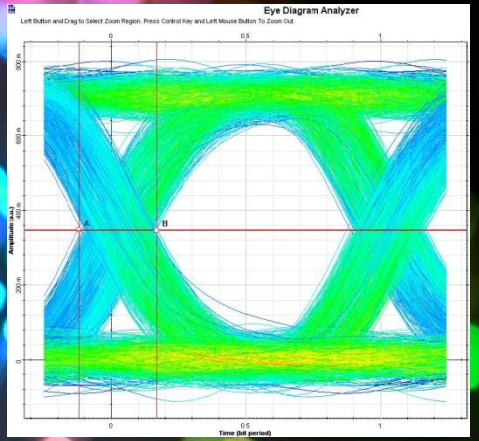


Figure 4.17: Increase in SNR with received power P_{in} for three values of APD gain M for a receiver with a bandwidth of 30 GHz. The $M = 1$ case corresponds to a *p–i–n* photodiode.

1. Note at lower power levels avalanche photodiodes have higher SNR's
2. Note at higher power levels SNR's have lower SNR's due to shot noise caused from impact ionization

Receiver performance

- Performance is measure by bit error rate which can be best visualized with eye diagrams
- Typically thermal noise and shot noise is the cause of most error



Final Summary

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