Fiber Optic Communications Educational Toolkit

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Introduction

- The main motive for this work was the need for a low cost laboratory alternative for schools teaching Fiber Optic Communications (FOC) to supplement courses offered in this field
- This FOC educational toolkit (ETK) provides both undergraduate and graduate students with a new way to study the physical layer of high speed fiber optic communications systems

FOC ETK Significance

- The Fiber Optic Communications educational toolkit (FOC ETK) provides undergraduate and graduate students with a low cost and flexible tool to study high speed fiber optic communication systems

- As an introductory tool, the FOC ETK allows for deductive approach, to investigate existing systems. Advanced students ready for an inductive approach can use the toolkit in their own projects

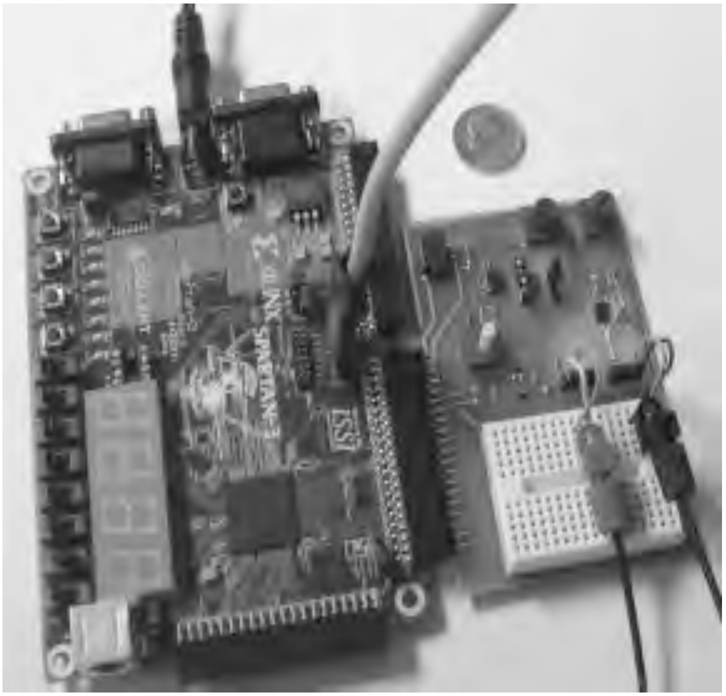
FOC ETC Design Rationale

- **To design a fiber optic toolkit that is:**
  - Able to demonstrate phenomena related to high speed data communications; issues involve bandwidth, dispersion, rise and fall time, synchronous communications involving coding and retiming with phase-lock loop
  - Uses inexpensive plastic fiber, no longer than 25m
  - Inexpensive high speed, at least 1Mb/s set-up

Fiber Optic Communications Educational Toolkit

- The FOC educational Toolkit can be used to develop low cost fiber optic communications teaching laboratories

- It is a tool that can be used to supplement courses offered in this field.



Developed Experiments

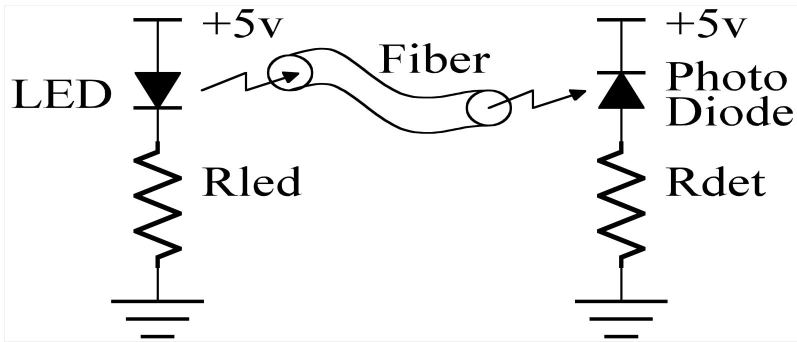
- Several Experiments were developed and implemented using the educational FOC toolkit. These experiments include:

- Fiber Optic Link Linearity.
- FOC Link Attenuation
- FOC Link Dispersion
- Data transmission

The following slides cover those experiments

Basic Fiber Optic Link

The circuit below is used to test fiber optic link linearity and attenuation in optical fiber data links



Basic fiber optic link

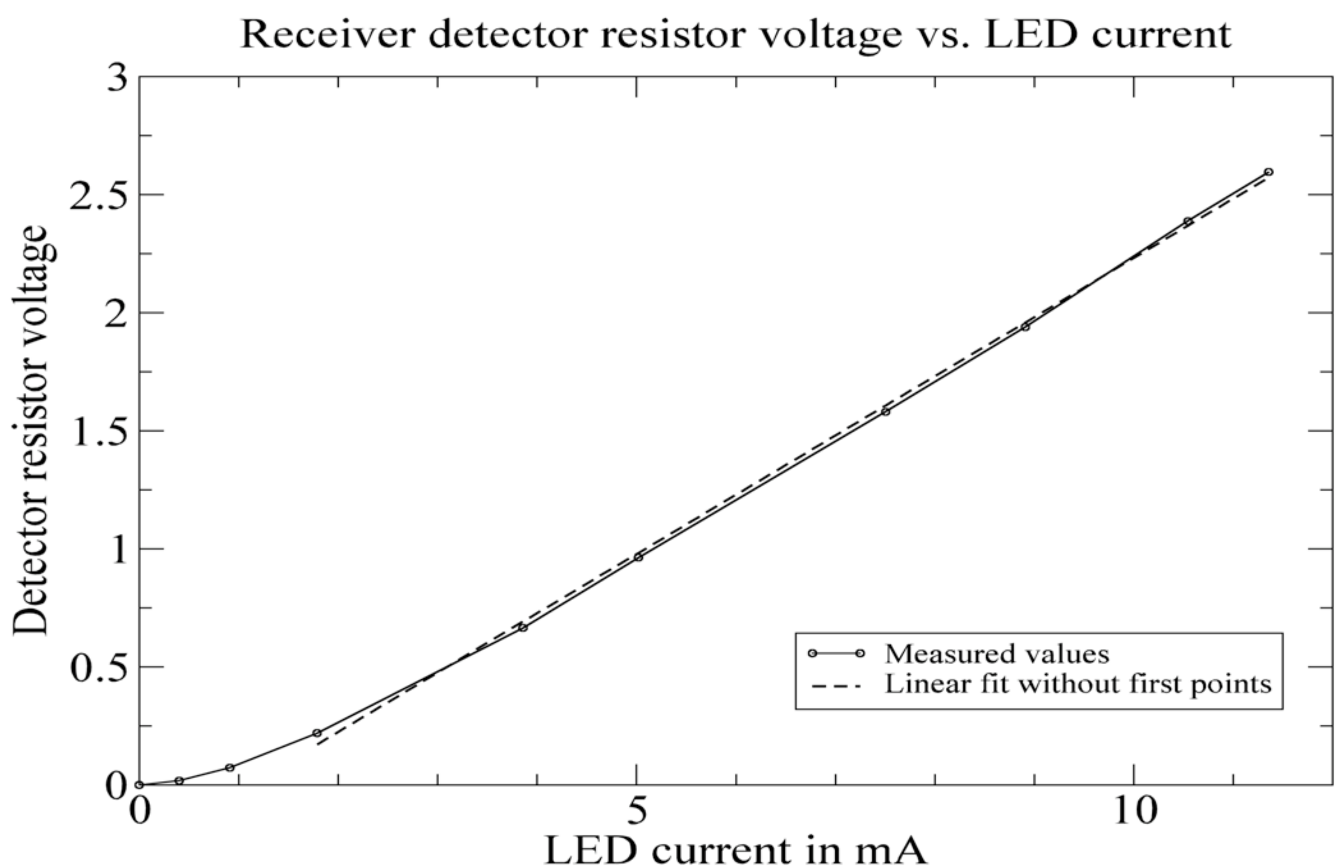
The LED load resistor is selected to adjust the LED current, and the photo diode load resistor sets the sensitivity of the receiver.

Fiber Optic Link Linearity

- Using the basic fiber optic link circuit given in the previous slide, several Experiments were developed to test the source and link linearity and fiber optic link attenuation.

- Given that the LED forward voltage is nearly constant, we expect to see a linear relationship between the transmitter and the receiver currents.

Fiber Optic Link Linearity

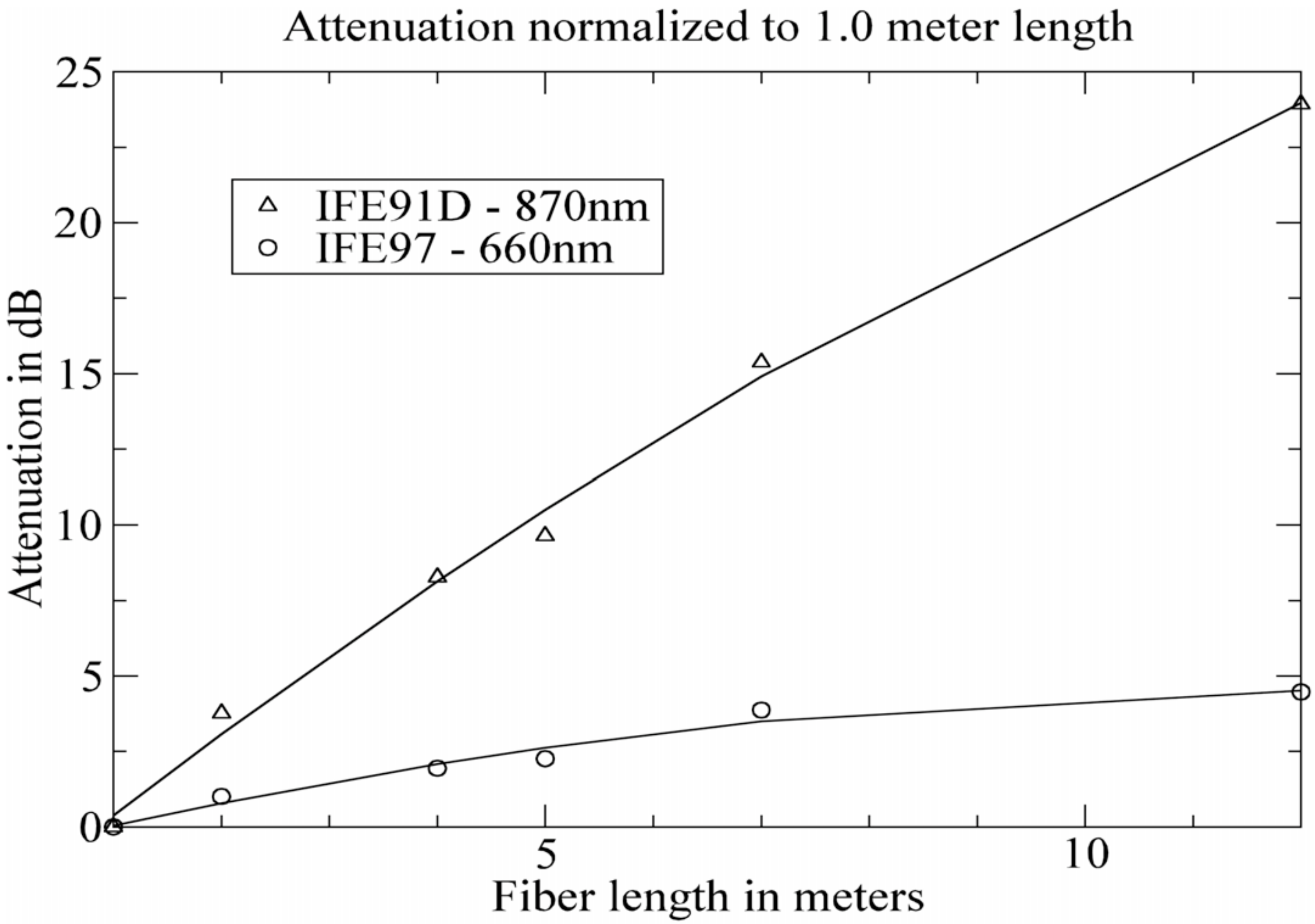


Attenuation and Power Budget

- The power budget is a useful tool for considering how optical power can be a constraining factor.
- The FOCETK can be used for Attenuation Experiments
- The difference between the transmitter power and the minimum required power at the receiver is the amount of power available to the link, which comprises the sum of all the losses and margin.

$$P_{\mathrm{tx}} - P_{\mathrm{rx}} = \sum P_{\mathrm{loss}} + P_{\mathrm{m}}$$

Attenuation and Power Budget



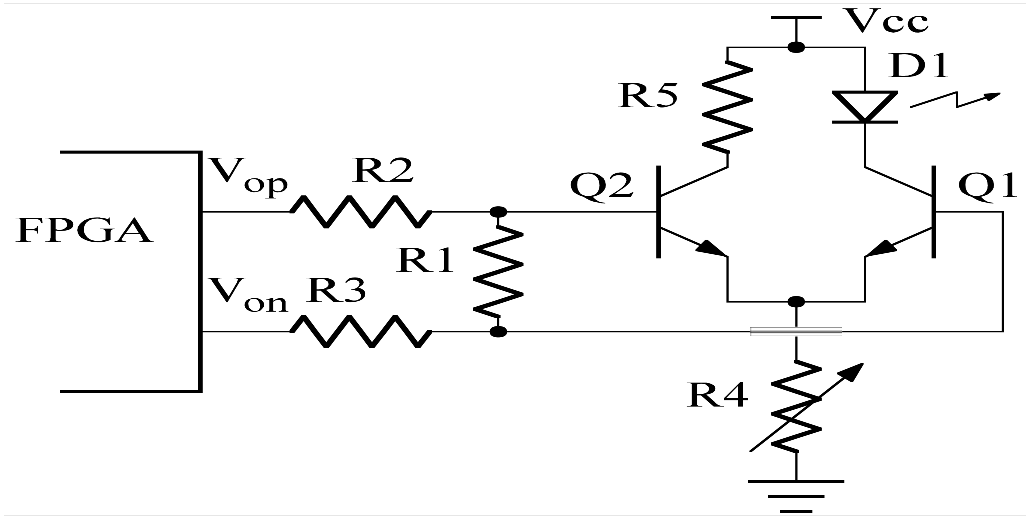
Fiber Optic Communications

FOC Involves the following:

- High speed data Transmitter
- Receiver, detector and slicer
- Dispersion & rise & fall time
- Data Encoding & decoding
- Retiming, phase-lock loop

FOC ETC Transmitter

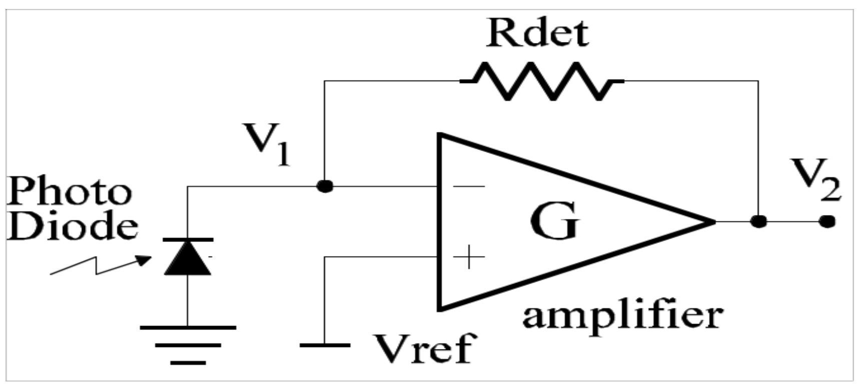
In this data transmitter circuit, the FPGA forms a low voltage differential drive signal (LVDS)



FOC Toolkit transmitter

FOC ETC Receiver

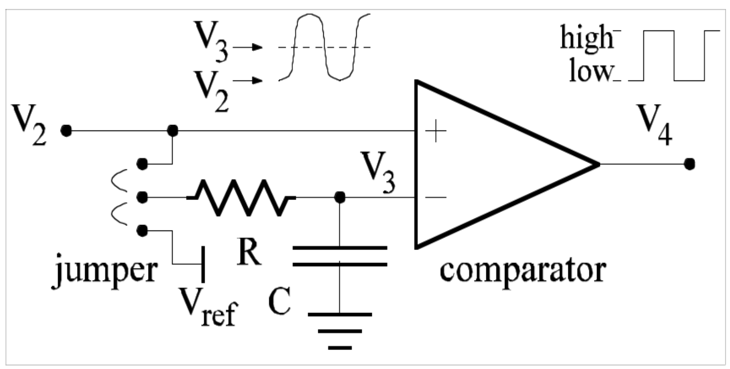
- A large resistance is selected to provide the required sensitivity. The amplifier uses negative feedback in such a way that from the photo detector the effective resistance appears very small, which allows the bandwidth and data rate to be large.



FOC Toolkit Non-inverting receiver

FOC ETC Slicing CKT

- The output of the trans-impedance amplifier is very analog and will not comply with any given logic signal standard
- The circuit below converts such a signal to digital values. Such action is called *slicing* the signal

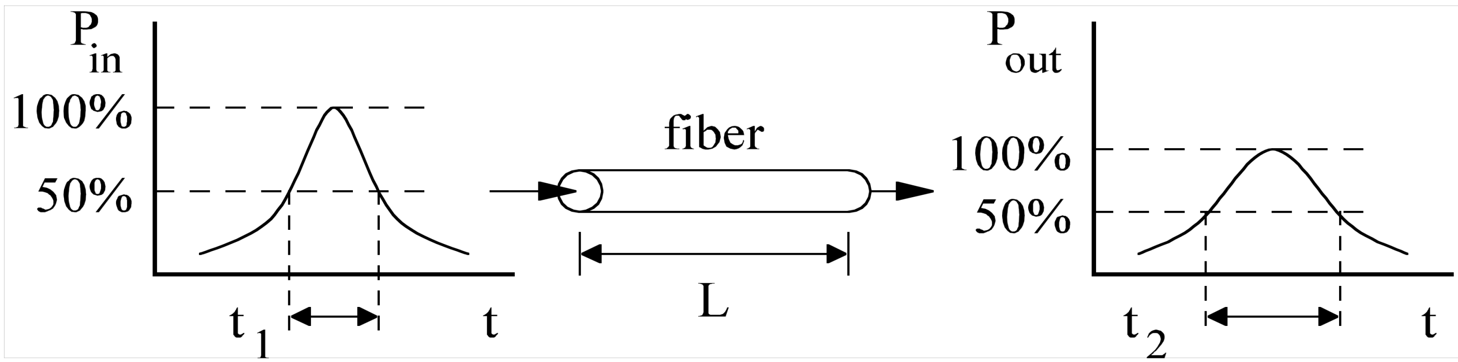


FOC Toolkit Data slicing circuit

Dispersion in Optical Fiber

Optical dispersion is the spreading that occurs to a light pulse as it travels along an optical fiber

$$T_o = \sqrt{T_{tx}{}^2 + T_f{}^2 + T_{rx}{}^2}$$



Pulse dispersion in optical fiber

Bandwidth and Rise time

A relationship between rise time and bandwidth is particularly useful. In considering the time to rise from 10% to 90% of the final value, we solve for H(s) and h(t) to find tr.

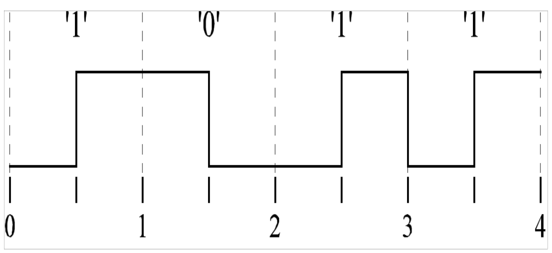
$$H(s) = \frac{K}{1+\tau s} \quad \text{; where} \quad F_c = \frac{1}{2\pi\tau}$$

$$h(t) = K\left(1 - e^{-t/\tau}\right)$$

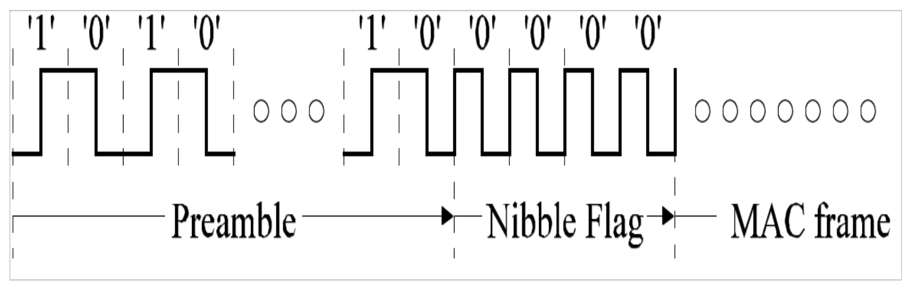
$$t_r = \frac{-\ln(0.1) + \ln(0.9)}{2\pi F_c} \approx \frac{0.35}{F_c}\,\text{sec}$$

Encoding and Message Frame

Synchronous serial communications is a widely used technique whereby the transmitter uses an encoding to convey the data and clock together



Manchester coded data

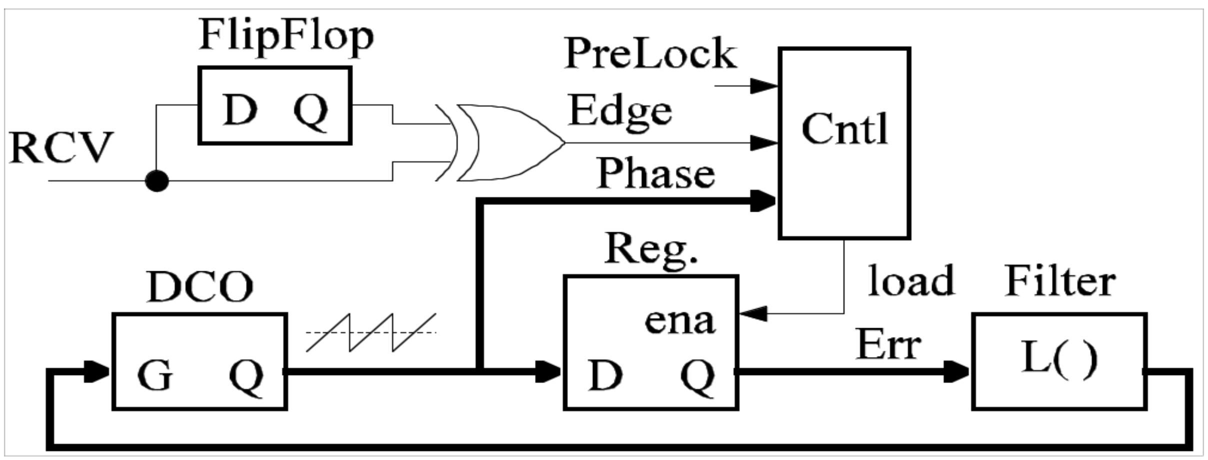


Beginning of a message

Symbol Retiming

It is common practice in communications to use a phase-lock loop to track a Manchester coded signal.

The FOC ETK can produce a preamble waveform and provides a discrete time phase-lock loop for retiming



Conclusion

- The FOC toolkit presents a low cost alternative for educators to teach the physical layer of FOC data links

- A field programmable gate array (FPGA) is used to generate the transmit data signal and also retime received signals.

- Other than the flexibility afforded by an FPGA, the accompanying development board should be particularly flexible in the discretion afforded to the instructor.