EE 344: EDL Final Report
50 Mbps POF Link using LED

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1 Introduction

1.1 Abstract

The aim of the project is to build a 50Mbps Polymer Optical Fiber link for a length of 10-15m. The transmitter will transmit data using a PRBS generator of length 15 and the receiver will receive the data using a Transimpedence Amplifier made of using high-speed Opamp. The transmitter will use Red/ Green LED to transmit the data through POF link.
Optical Fibers are better than conventional methods of using copper wire due to its lightweight, thinness, robustness, better speed, and remarkable bandwidth. There are many types of Optical Fibers available in the market, out of these Polymer Optical fibers are lower cost than Glass optical fiber and is more bendable than the glass optical fiber.
Our project aims to achieve high speed data transmission through Polymer Optical Fiber which can efficiently work at speeds upto 50Mbps over distances ranging upto 10-15m. The transmitted signal will be sent in the form of an optical signal generated from an LED.

1.2 Project Objectives

To build a Polymer Optical Fiber link capable of transmitting data at 50 Mbps using LED as a signal source using a locally generated clock for sampling at the transmitter side.

1.3 Project Deliverables

- Transmitter and receiver PCBs doing actual transmission and reception at 50 Mbps over a 10m-15m long POF wire.
- Validate the performance using a bit error rate tester (BER $< 10^{-9}$).

1.4 Basic Block Diagram

Our design consists of a transmitter side which has a clock generating circuit to produce PRBS and feed it to LED. Then there is the channel which is 10m long POF wire connected on the other end to a photodiode. On the receiver side photodiode feeds current to tranimpedance amplifier to produce voltage signal which is finally connected to comparator circuit to obtain TTL output.

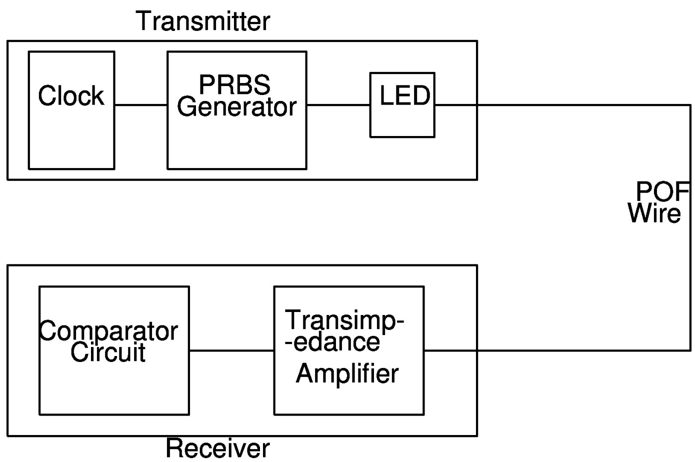

Figure 1: Block Diagram

2 Work done in Phase 1

In phase 1 we were able to achieve a 1.05 Mbps link (our own internal clock)with a 1m POF link and observed a TTL output at the receiver stage.In this stage we built our entire circuits on breadboard.

2.1 Transmitter circuit

Our transmitter circuit consists of a 15 bit **PRBS(pseudo random bit sequence generator)** which is generated using shifter IC named 74LS195. The basic design of PRBS sequence is as follows:

We use the IC in shift-er mode with the first output being set as the exclusive-or of the previous first and fourth output of the shifter IC.

Note: There is a possibility of having an alternate sequence of zeros and ones or a sequence of all zeroes as the output which is a determined sequence. To get rid of this we put a switch at input stage which can drive the first output and subsequently all outputs to 0.

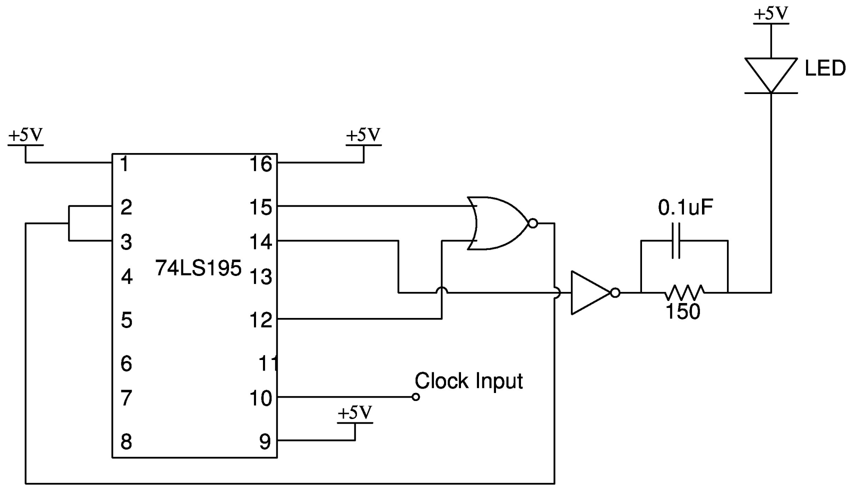

Figure 2: Transmitter Circuit Diagram for phase 1

2.2 Clock circuit

We made our own clock circuit using a NOT gate (74LS04) and changed its capacitors to vary its clock frequency. This clock circuit operates based on the transfer function of CMOS inverter.

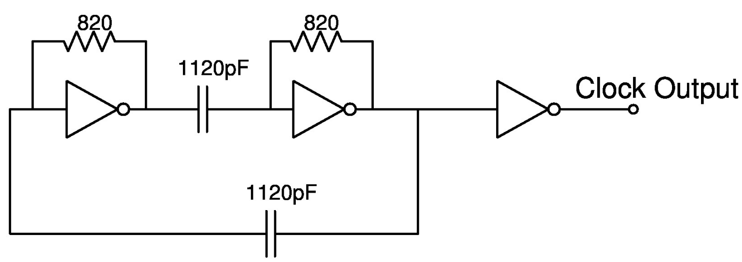

Figure 3: Clock Circuit(clock speed = 1.05MHz) Diagram for phase 1

2.3 Receiver side

We used a BPW-46 as our photodiode (reverse bias mode) and used it to drive our transimpedance amplifier.

2.3.1 Trans-Impedance amplifier

In this stage we used a TL081 based op-amp as trans-impedance amplifier and . We chose our feedback resistor and capacitor carefully so as to ensure sufficient bandwidth and at the same time had to avoid high frequency noise. Thus we had to choose appropriate bandwidth . The peak to peak output was largely decided by the feedback resistor.

2.3.2 Comparator Circuit

We made our comparator circuit using TL081 op-amp in open loop mode.We used a potentiometer to set our reference voltage as put it on the inverting terminal of our op-amp and our TIA output at non-invering terminal of the op-amp. We used power supplies of 0 and -5V at the op-amp.

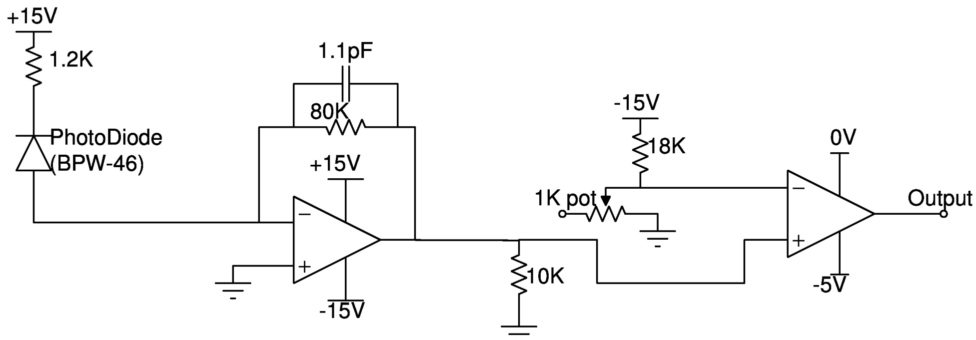

Figure 4: Receiver Circuit for phase 1

2.4 Results of Phase 1

The following image in yellow color shows the input PRBS signal to LED and the green is the final output after Comparator. The clock speed is 1.05MHz of internal clock and the POF wire length is 1m long.

Figure 5: Phase 1 Result after comparator

3 Work done in Phase 2

3.1 Changes in Transmitter circuit

- We also provided an input port for bit error rate tester which was made by another team as they needed to know the initial phase of the sequence to synchronise the time shifted received signal. So they could send their own PRBS and take the output from our receiver.
- We had put another switch for either using the clock from an an external source or using our own internally generated clock.
- We got the transmitter PCB printed with clock circuit and 74LS195 shifter IC which could generate PRBS upto 35 Mbps.
- We also changed the capacitance values in the clock circuit to make a clock of 11MHz.

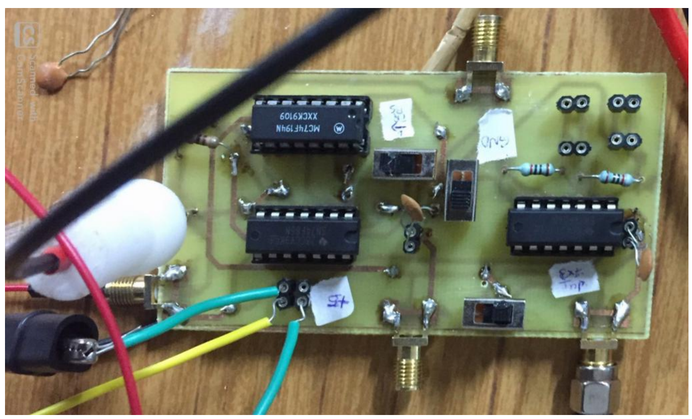

Figure 6: Transmitter PCB

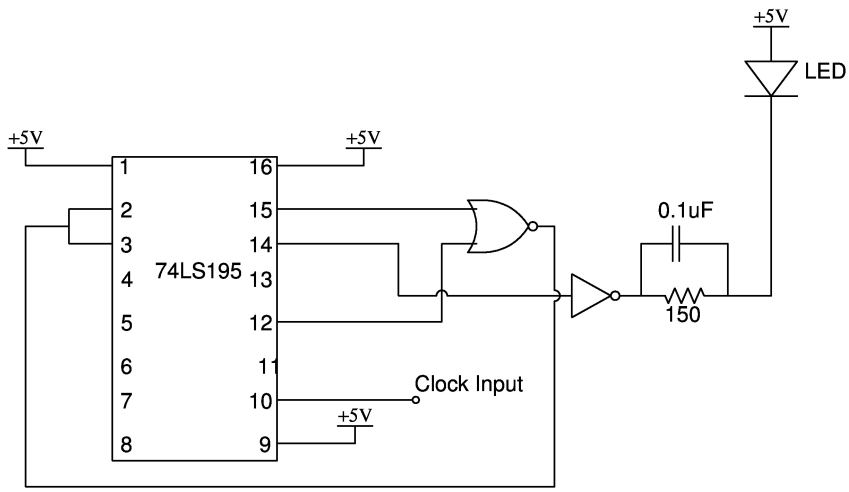

Figure 7: New Transmitter circuit diagram

3.2 Changes in Receiver circuit

- After phase 1, we replaced the photodiode BPW with high frequency photodiode SFH-203P
- Also at the receiver side we replaced the opamp which was used as a transimpedance amplifier by LMH 6624 which could work for 50 Mbps for our purpose.
- We used a 0-5V supply to this op-amp and used a reference voltage of 2.5V at non-inverting terminal using two resistor of equal values.

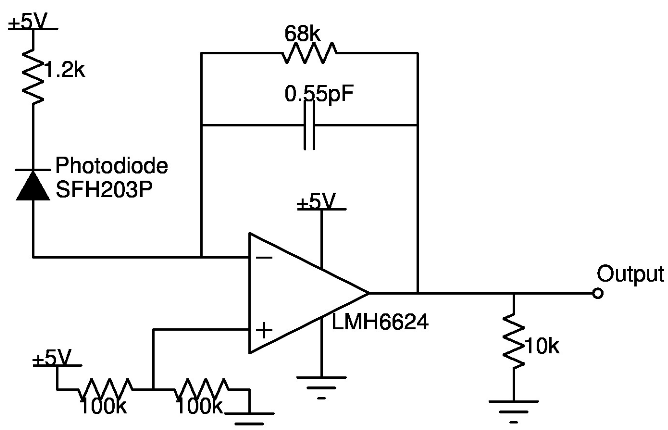

Figure 8: Receiver Circuit diagram after changes for phase 2

3.3 Connectors

To achieve higher rate of transmission we had to increase the bandwidth of the transimpedance amplifier, so the feedback resistance value had to be decreased but this reduced the gain of the output so we got 3D printed connectors to tightly couple LED and photodiode.

Figure 9: 3D Printed Coupling Connectors

3.4 Results of Phase 2

In the following image input PRBS is in yellow. It is having a peak to peak of 3.52V. The blue one is the output with 1m long POF link and it is having a peak to peak 204mV. The output is after Transimpedance Amplifier(not after comparator).

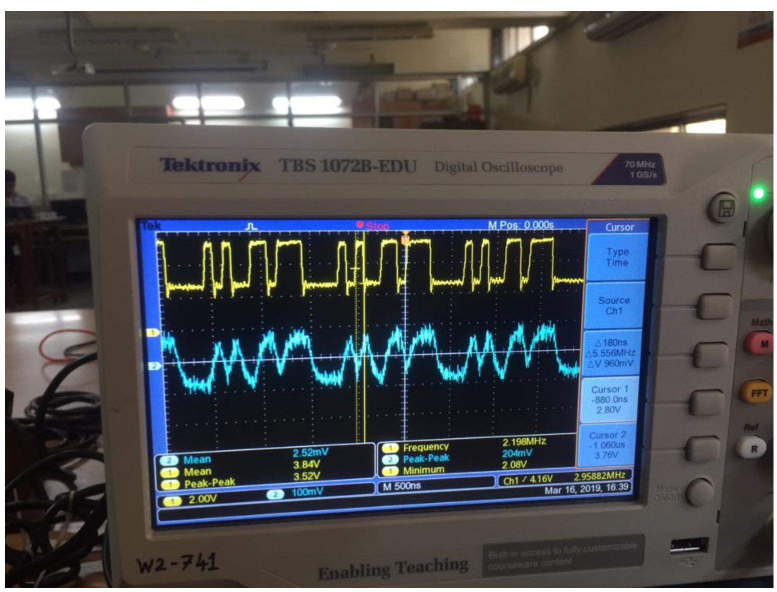

Figure 10: Transimpedance Amplifier output at 11MHz after pahse 2

4 Work done in phase 3

4.1 Final Transmitter PCB

To improve the strength of received signal we shifted from transparent LED to translucent LED and also reduced the series resistance of LED from 150 Ω to 100 Ω. This improved the strength of received signal nearly 1.5 times.

Also we changed our shifter IC from 74LS195 to 74F194 which can operate at clock frequnecies above 30MHz.We built a PCB for it and ensured that transmission occurs fine upto 50 MHz.
We placed decoupling capacitors close to power supply pin of each IC to reduce ringing at the PRBS output.
We also changed XOR gate from 74LS86 to 74F86 and NOT gate from 74LS04 to 74F04.

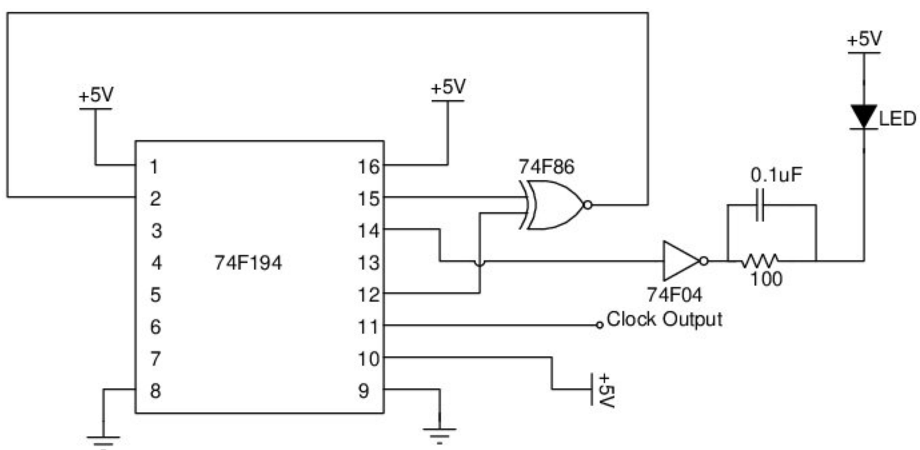

Figure 11: Final Transmitter Circuit

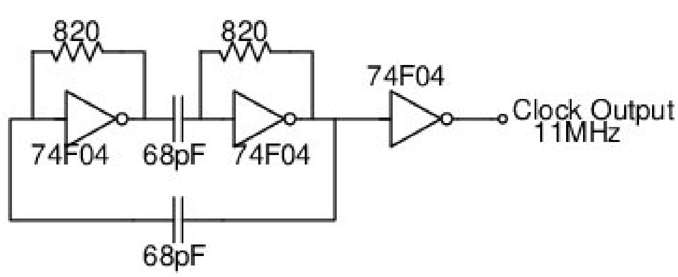

Figure 12: Final Clock Circuit Diagram

4.2 Changing comparator circuit

In this stage we decided to change our comaparator circuit to a specialised comparator IC such as LM361.We planned to use a potentiometer along with two resistor in series to set our reference voltage to comparator circuit. Set the resistor and potentiometer values accordingly to set the reference voltage to around mean of the received signal.

4.2.1 Issues faced in comparator circuit

The TIA output was becoming very noisy the moment we were connecting it to input of comparator circuit.This noise was increasing drastically the moment reference voltage is in the range of signal received at output of TIA amplifier. We tried various options (including putting a decoupling capacitor at all the supplies) but could finally resolve it only by using two separate supplies for the comparator circuit and TIA amplifier.However the ground was kept common for both.

By putting appropriate decoupling capacitor at supplies and using two separate supplies we were able to resolve the issue of noise at input and output signal.We also put a decoupling capacitor at the reference voltage of the comparator circuit(across the potentiometer and ground).

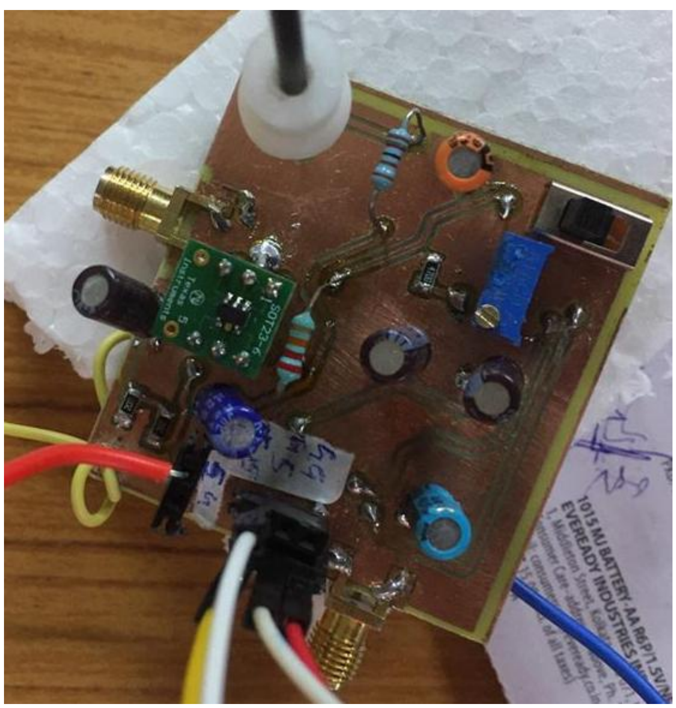

Figure 13: Final Receiver PCB

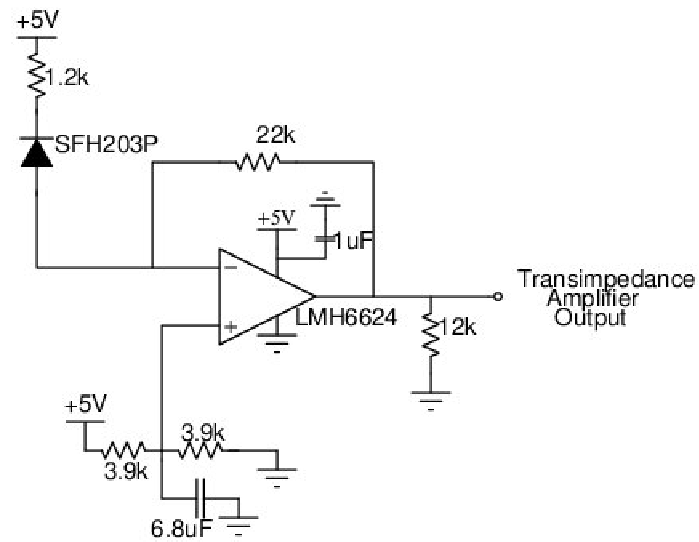

Figure 14: Final Circuit Diagram of transimpedance amplifier

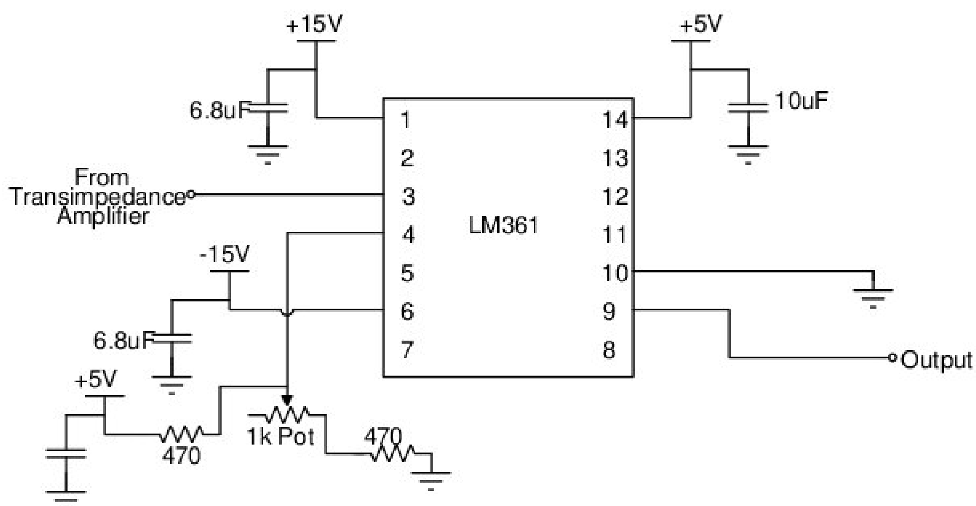

Figure 15: Final Circuit Diagram of Comparator Circuit

5 Final results

- We verified our receiver circuit on breadboard to work at 25 Mbps and got PCB printed.
- Finally the receiver PCB could work upto 35 Mbps via a 10m POF wire.

- Beyond this frequency we have inter-symbol interference between the sent signal and TIA output signal. As a result we observed bit errors in transmission above 35MHz
- We could not increase bandwidth by putting lower feedback resistance as it was decreasing the output signal strength of TIA amplifier.

Yellow in the following figure is the input signal of PRBS and the blue is output after comparator and it have peak to peak of 5-6V.

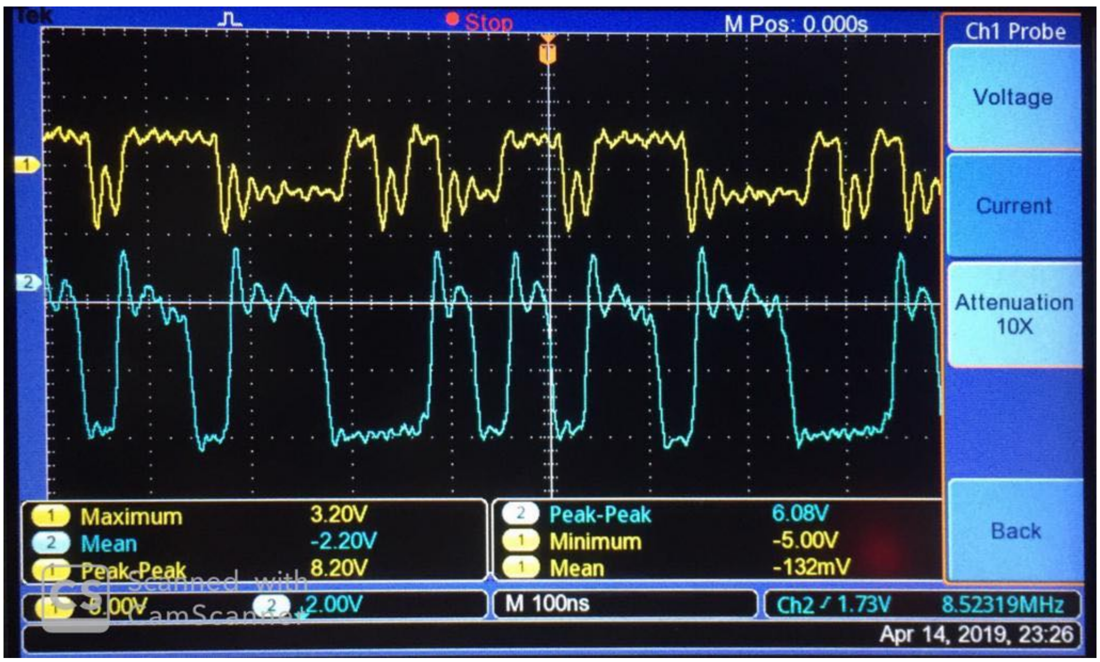

Figure 16: Final Result after comparator at 32MHz clock and 10m long POF

Figure 17: Final Result after comparator at 35MHz clock and 10m long POF