Low Cost 10 Mbps POF Link for Digital Transmission

TUE-JJ-7-1

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1 Introduction

1.1 Abstract

Polymer optical fibre (POF) offers a light weight, low-cost and broad bandwidth alternative to glass optical fibres (GOF). POF technology is very popular for short-range networking and can be used for data transmission within home or room, due to several advantages such as is greater flexibility unlike GOF, operation in visible spectrum, less power requirement by transceivers etc.

In this project, we have presented design and experimental results of a low cost POF link for digital transmission across a length of about 10m and achieve data rates of 10Mbps.

LED based transmitter is designed which transmits psuedo-random bit sequence (PRBS) of length 15 bits using a 4-bit shift register. Connectors to couple LED light to the POF link are fabricated using a 3D printer and the receiver circuit consists of a trans-impedance amplifier (high speed op-amp).

1.2 Objective

The objective of this project is to establish a low-cost functional communication link using a 1mm Polymer Optical Fiber channel across a length of about 10m and achieve data rates of up to 10Mbps.

2 Design

2.1 Block diagram

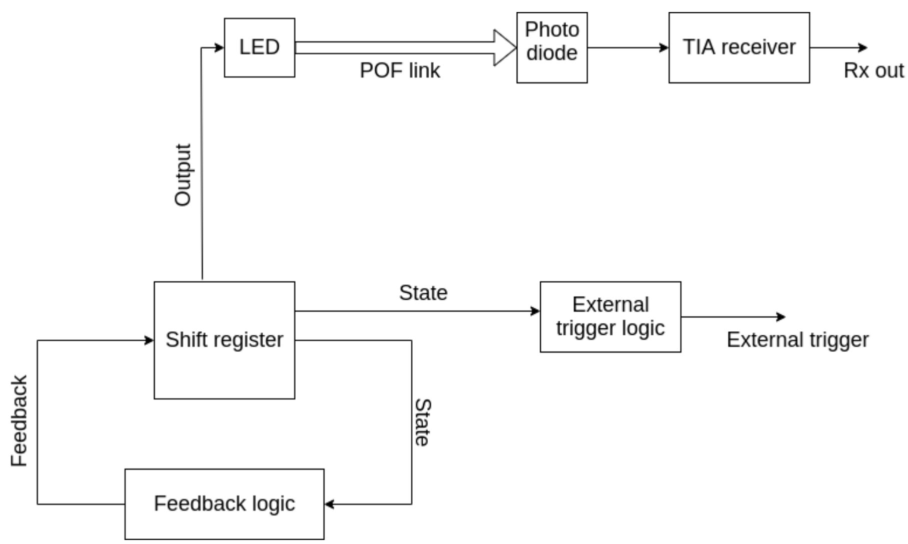


Figure 1: Block diagram showing interconnection of the subsystems

The feedback driven shift register produces a pseudo random bit sequence, and its state (which is a 4bit number) circularly rotates through all 15 non-zero values in a pseudo-random manner. The output bit is used to drive the LED that transmits across the POF. The state of the shift register also produces the external trigger. Finally, a photodiode is used to receive the light from the POF, and a trans-impedance amplifier acts as current to voltage converter.

2.2 Design approach

POF data link consists of a transmitter, receiver, cable and connectors. The data transmission can be classified into the following subsystems:

1. Transmitter - The transmitter consists of a pseudo-random bit sequence (PRBS) generator as it provides the ease of verification of the implementation of the design as input to PRBS. The electrical signal is given as input to LED and the rate of transmission is decided by the rate at which LED turns on and off. Clock signal to the transmitter circuit is given using arbitrary waveform generator.

2. Connector - A 3D printed connector at the transmitter end is used to couple the light emitted by LED with the POF link and another 3D printed connector at the receiver end is used to couple the propagating optical light with the photodetector.

3. Receiver - The receiver consists of a silicon P-I-N photodiode and trans-impedance amplifier (TIA). Silicon PIN operates in reverse biased mode. Light incident on the surface of Si PIN photodiode causes a reverse saturation current to flow through it which is converted to voltage signal using TIA.

2.3 Sub system designs

2.3.1 Transmitter

The transmitting end of the POF is a red LED that turns on/off in a pseudo-random fashion. We generate the pseudo-random sequence using a 4 bit shift register that uses the XOR of two of its output bits as input. Specifically, let the state of the shift register be (Q_a, Q_b, Q_c, Q_d). The shift register is used in 'shift' mode, and the direction of shifting is rightwards. Hence, the next state (i.e. after one clock cycle) will be $(Q_c \oplus Q_d, Q_a, Q_b, Q_c)$. We found that in this method of operation, the state of the register circularly rotates through each non-zero state in a pseudo-random order. Figure 2 illustrates the designed transmitter circuit.

However, on powering on, the shift register initializes with all 4 bits as 0 and the pseudo-random sequence is never initialized. To counter this, we modify our feedback logic to feedback '1' if the state of the shift register is

0000, and operate normally (as described above) otherwise. The exact logic can be seen in the circuit diagram of the feedback circuit Fig.3.

We have also provided an external trigger (Fig. 4) output for use in the oscilloscope, along with a clock output and ground reference.

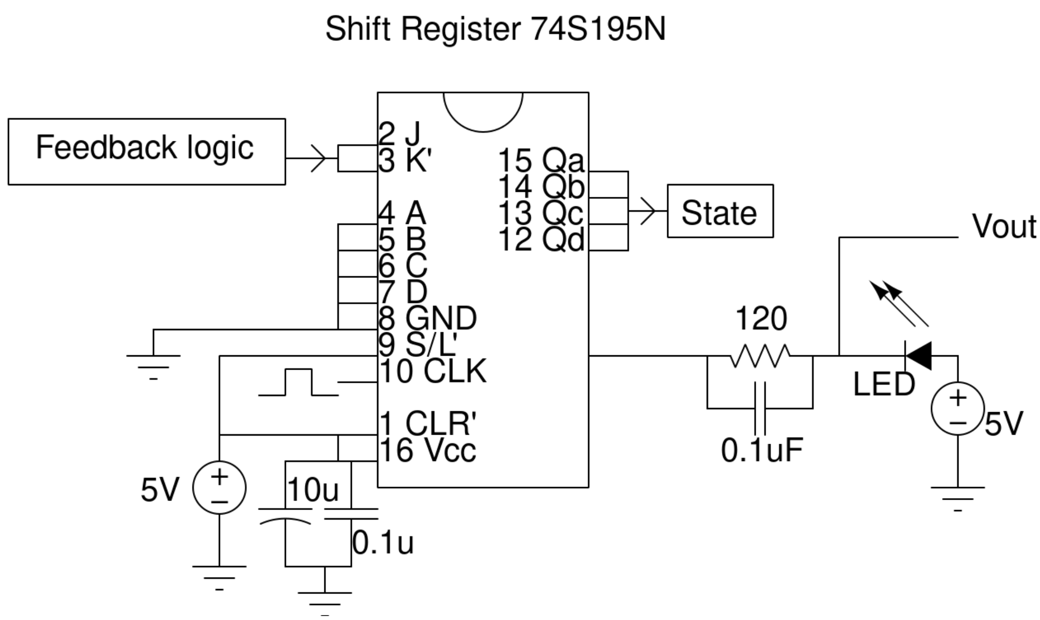


Figure 2: Configuration of the shift register

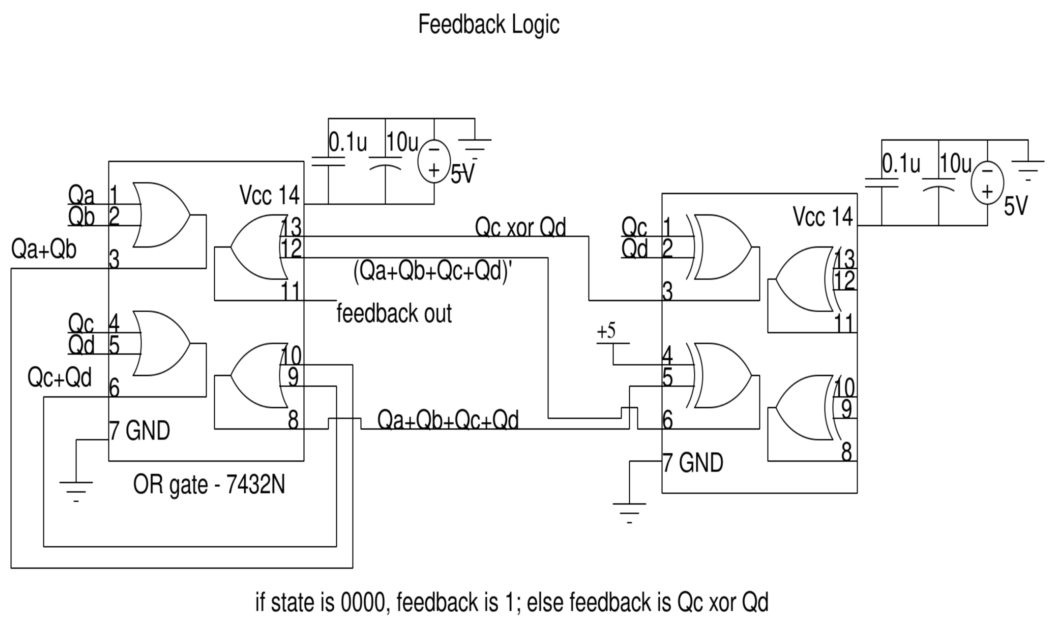


Figure 3: Modified feedback logic

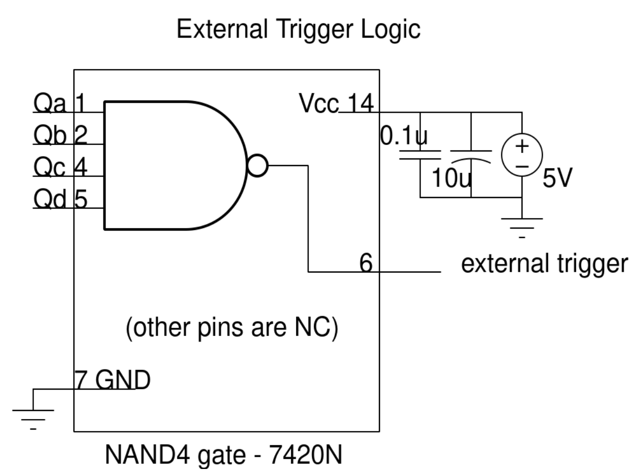
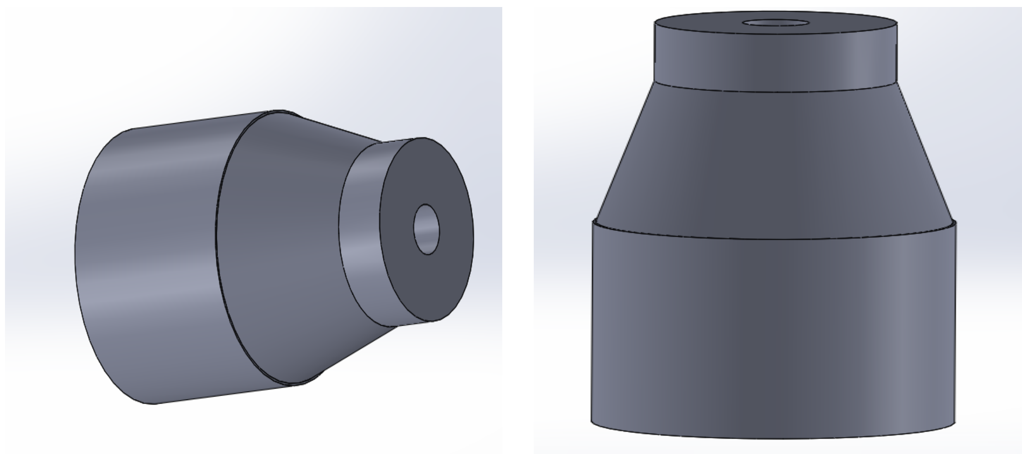


Figure 4: External trigger circuit

2.3.2 Connector

Following is the CAD model of connector. The POF link end-hole has radius as 1.1 mm whereas the LED/photodiode hole has radius of 3mm.



(a) (b)

Figure 5: (a) Connector CAD. (b) Connector side view.

2.3.3 Receiver

The task of the receiver is to convert the incoming optical signal into equivalent voltage signal for further processing by a high-speed comparator. Designing of the receiver is done in two stages. In stage-I, transmission upto 1MHz is obtained using TL082 as TIA and BPW46 as photodiode (Fig.6.

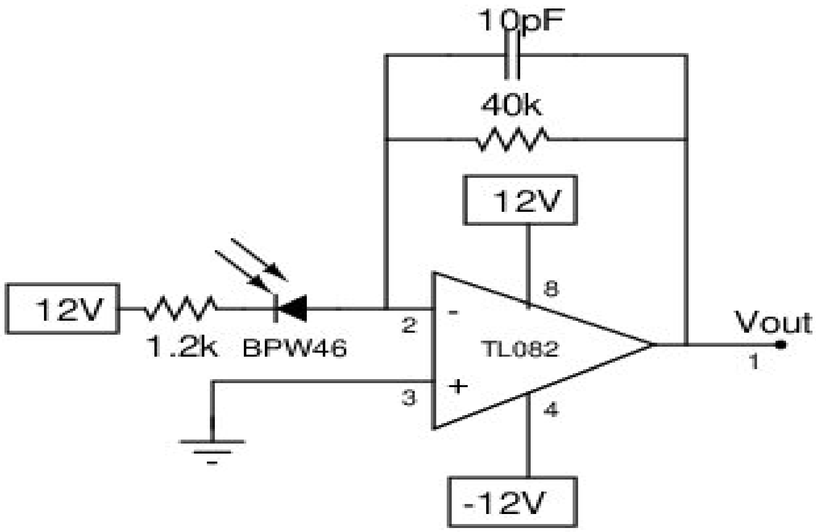


Figure 6: Receiver circuit using TL082

In stage-II, data transmission upto 10MHz is achieved using LMH6629 as TIA and SFH203P as photodiode (Fig.7). LMH6629 is a single supply op amp with very large bandwidth (upto 900MHz) and ultra low noise, thus easily suitable for our application.

$$V_{out} = V_{in+} - I_P * R_f \tag{1}$$

V_{in+} is biased at around 2.5V and I_P i.e. current in reverse saturation for SFH203P is typically 9.5μA. Thus for $R_f = 26k$ output voltage swing is expected to be from 2.25V to 2.5V. Different pair of values of R_f, C_f are tested and the values in Fig.7 gave us the best output voltage waveform.

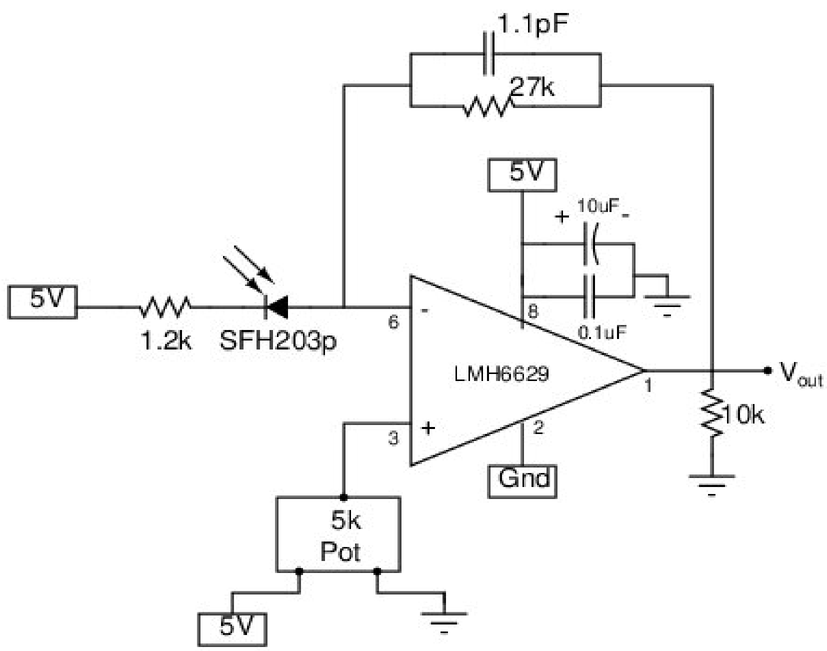


Figure 7: Receiver circuit using LMH6629

2.4 Implemented designs

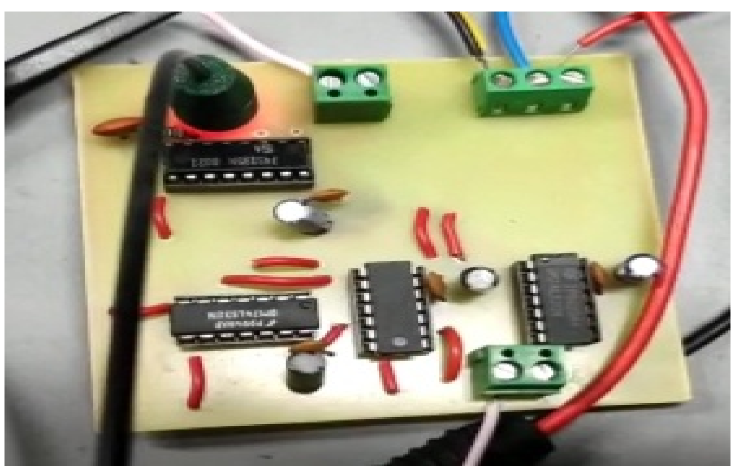
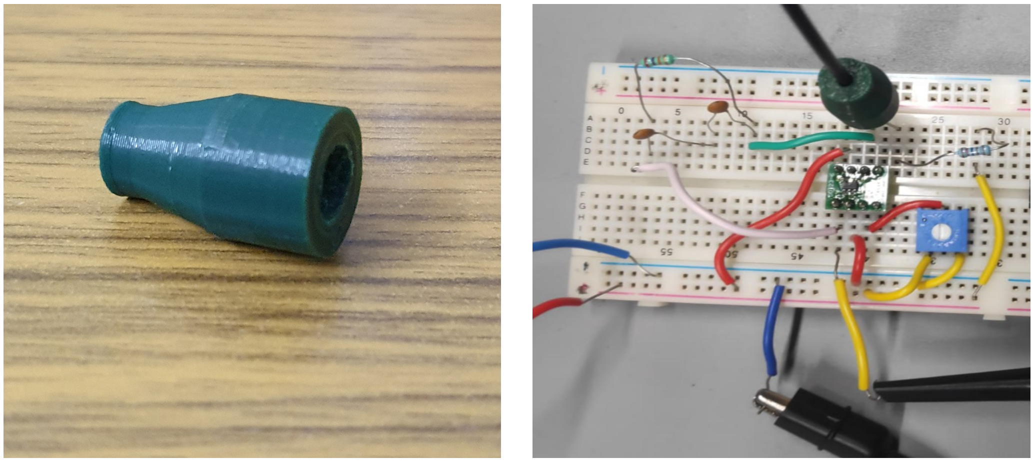


Figure 8: Transmitter on PCB



(a) (b)

Figure 9: (b) 3D printed connector. (c) Receiver on breadboard

3 Test Results

3.1 Stage - I

As described in Section 2.3.3, stage - I results are reported (Fig.10) for receiver with TL082 as TIA and BPW46 as photodiode.

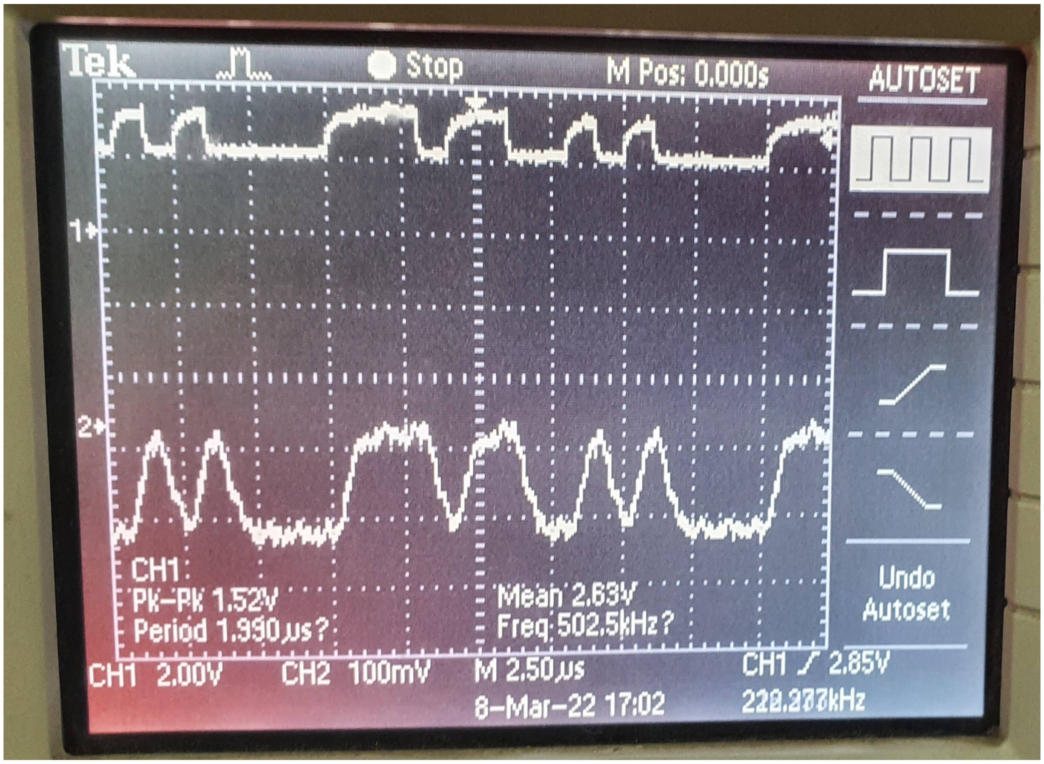


Figure 10: Channel 1 - PRBS output, Channel 2 - TL082 TIA output at 1MHz

3.2 Stage - II

In stage - II, high frequnecy op amp LMH6629 is used with fast switching SFH203P photodiode. Results obtained are as follows:

Figure 11: Channel 1 - PRBS output, Channel 2 - LMH6629 TIA output at 1MHz

Figure 12: Channel 1 - PRBS output, Channel 2 - LMH6629 TIA output at 10MHz

4 Bill of materials

Table 1: Cost of components

Component	**Cost(Rs) / WEL**
74S195N (shift register)	WEL
7432N (OR)	WEL
7486 (XOR)	WEL
7420 (NAND)	WEL
LMH6629 (TIA)	600
SFH203P (Photodiode)	100

5 Conclusion

In this project we were able to build and test POF communication link for frequency up to 10MHz. Beyond 10MHz, bandwidth limitation of DSO was also visible resulting in harmonics in PRBS and output waveform on DSO.

6 Acknowledgement

We thank Prof. Joseph John for his valuable guidance throughout this project. We would also like to thank Maheshwar sir, Shekhar sir from WEL lab for catering to our needs and their constant support.