Indian Institute of Technology Bombay
Department of Electrical Engineering
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Course Project Report

Course: EE 344: Electronic Design Lab

Project Group No: TUE-JJ-7-1

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Project Title: Low Cost 10 Mbps POF Link for Digital Transmission

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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 the design and experimental results of a low cost POF link for digital transmission across a length of about 10m and achieved data rates of 10Mbps.An LED based transmitter is designed which transmits a psuedo-random bit sequence (PRBS) of length 15 bits using a 4-bit shift register. Connectors to couple the LED light to the POF link, and POF link to the receiver photodiode, are fabricated using a 3D printer.The receiver circuit consists of a trans-impedance amplifier (built using a high speed op-amp).

Contents

1 Introduction

Polymer Optical Fiber links are very popular for short-range networking applications (eg. in a home) because of the relatively high data rates that are achievable. The project aims to establish a functional communication link using a 1mm Polymer Optical Fiber channel across a length of about 10m and achieve data rates of 10Mbps.

The project involves designing an LED based transmitter which transmits pseudo random bit sequence (PRBS), 3D connector to couple LED emissions with POF link at transmitter end, a 3D connector to couple optical light carried in the guided medium with a silicon PIN photodiode at the receiver end and a receiver.

2 System Overview

2.1 The complete system

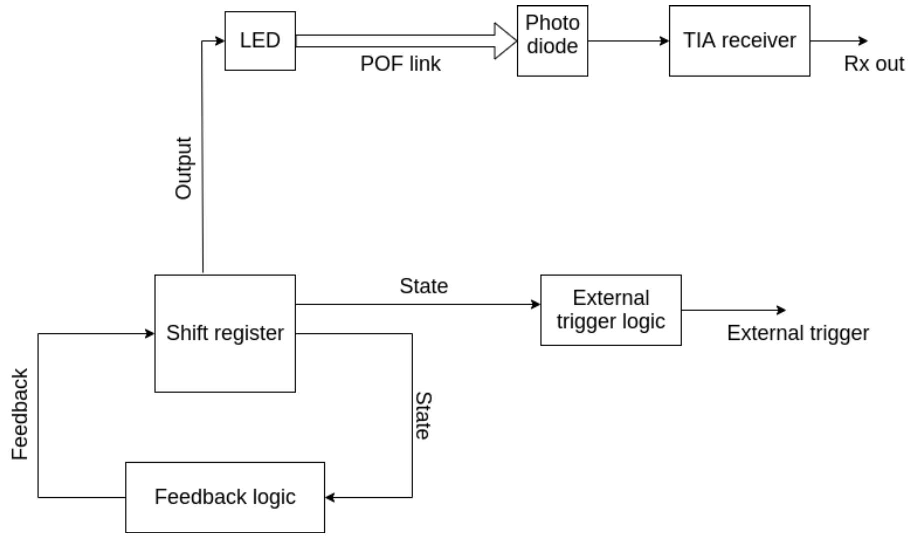


Figure 1: Block diagram showing interconnection of the subsystems

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 Breaking into sub-sytems

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.

3 Project Implementation

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.

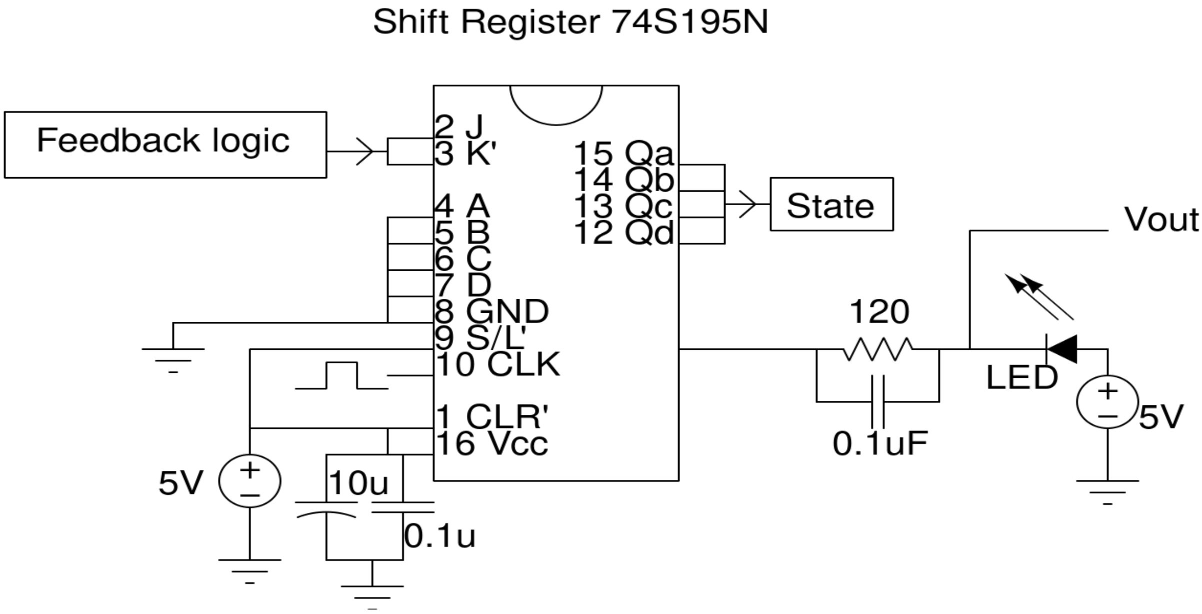


Figure 2: Configuration of the shift register

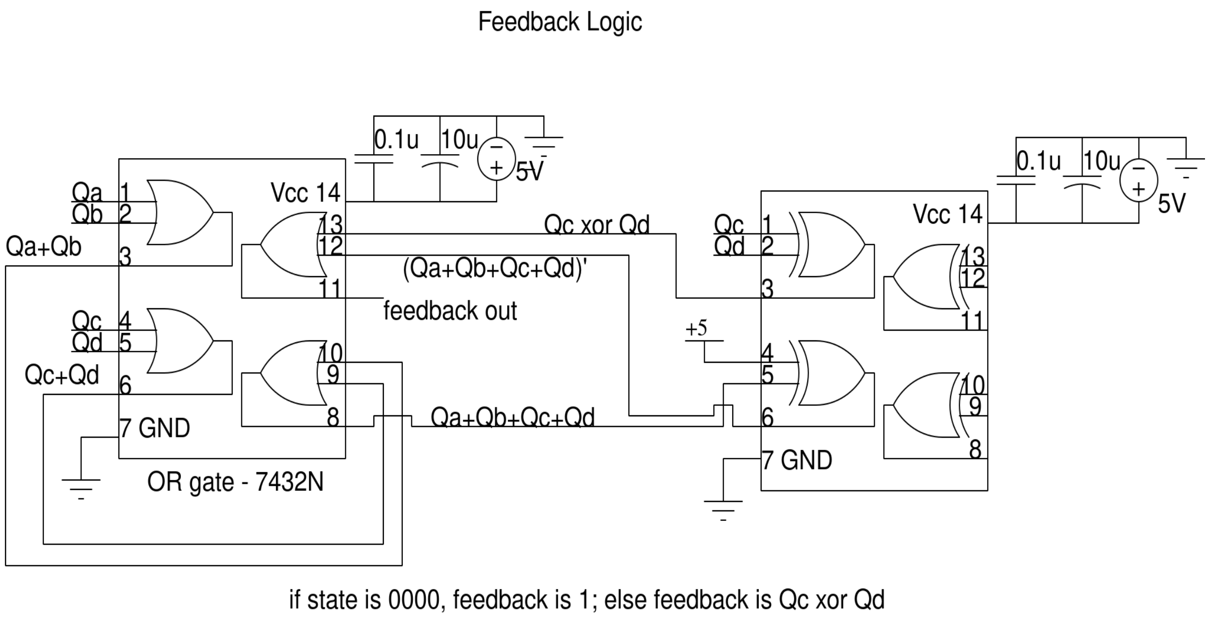


Figure 3: Modified feedback logic

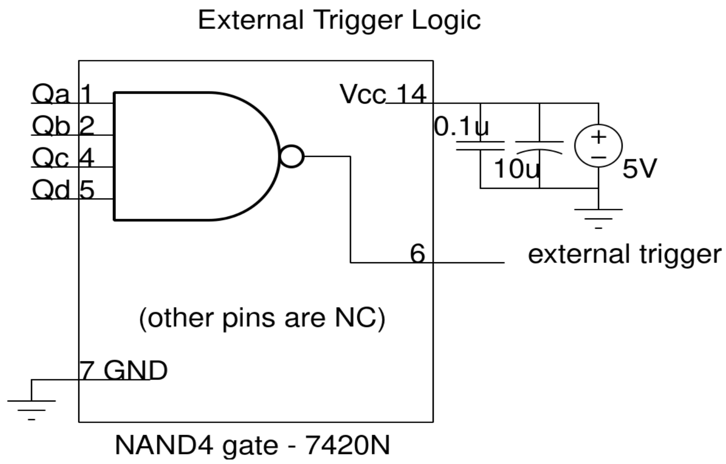
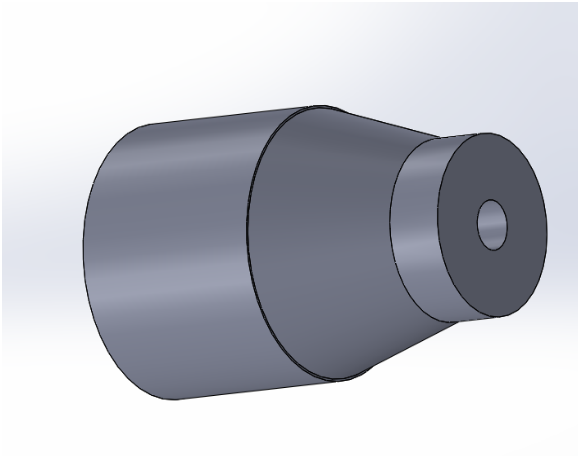


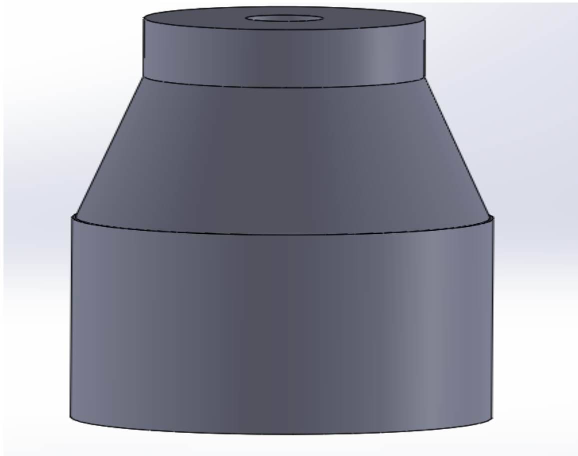
Figure 4: External trigger circuit

3.2 Connector

Following is the CAD model of connector. The POF link end-hole has radius as 1.2 mm whereas the LED/photodiode hole has radius of 2.8 mm. We had to manually drill the holes to make them slightly broader and ensure that the photodiode and LED fit well. The lengths of the POF and diode ends are both 10mm.



(a)



(b)

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

3.3 Receiver

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

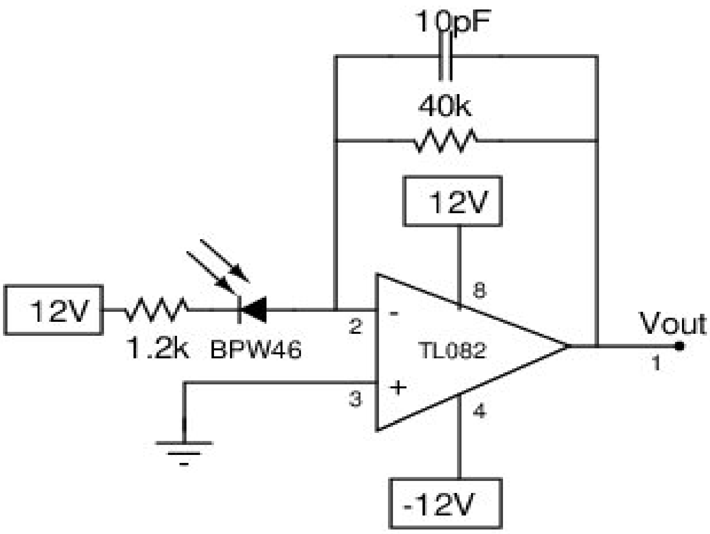


Figure 6: Receiver circuit using TL082

In stage-II, data transmission upto 10MHz is achieved using LMH6629 as the TIA and SFH203P as the photodiode (Fig.7). LMH6629 is a single supply op amp with very large gain-bandwidth product (upto 900MHz) and ultra low noise, and is thus well-suited 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.

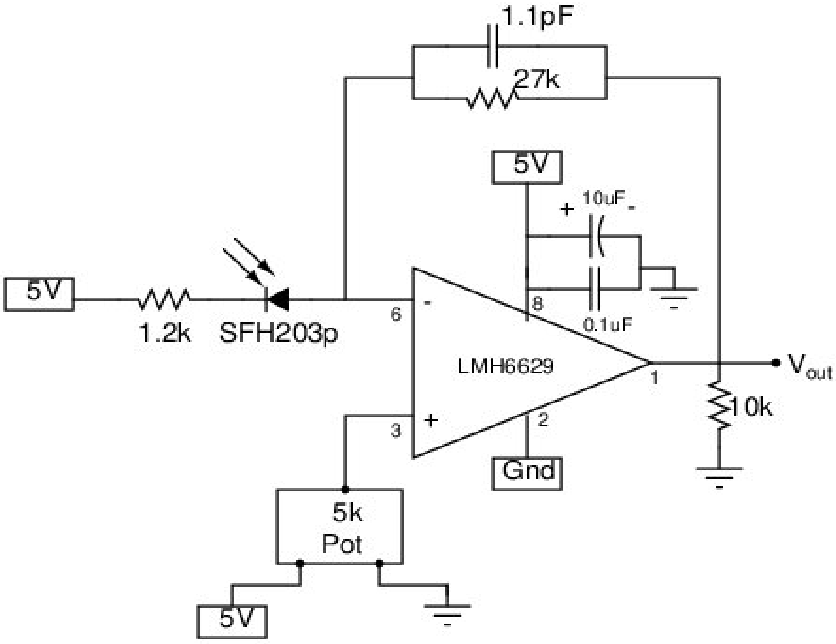


Figure 7: Receiver circuit using LMH6629

4 Testing and Evaluation

Testing and evaluation was an instrumental step in our process, and the steps involved were as follows:

- First, we performed component-wise testing. Eg. looking at the output of the PRBS block on an oscilloscope to verify that it matches our analysis, and so with the output of the TIA and even photodiodes etc. We then tested individual subsystems, especially the Tx block to ensure it is completely bug free, since this would greatly help us test the Rx too.
- The testing was done via oscilloscopes and DMMs. AG was used to provide the clock, and a osilloscope was used to look at the outputs at desired locations. We ensured that the expected value of voltage appeared at specific points via the DMM.
- The DMM was also used to test all soldered joints, and traces to ensure that all paths of the PCB functioned as expected.
- Finally, basic precautions were checked. These included ensuring that the LED had a protecting resistor, that there were DC blocking capacitors where needed, and that ICs had decoupling capacitors.
- We realized that our systems were fairly low risk, and they did not need high-end resources, apart from the 3D printer which was a one time necessity, and the POF link/photodiode which was already provided to us.
- For evaluating our final system, we compared the generated signal at the Tx and the interpreted signal at the Rx on an oscilloscope. Resistors and capacitors were aptly tuned to allow for high frequency operation.

5 Experimentation and Results

5.1 Stage - I

As described in Section 3.3, stage - I results are reported (Fig.8) for receiver with TL082 as TIA and BPW46 as photodiode.

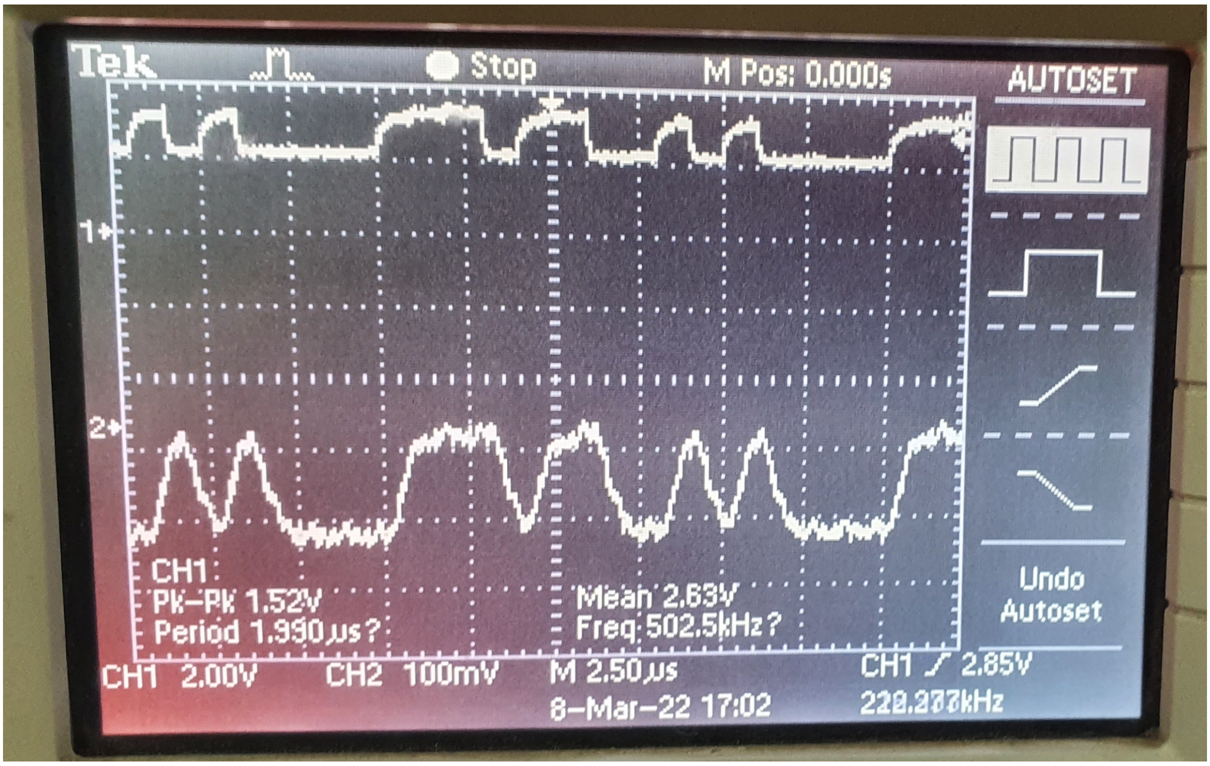


Figure 8: Channel 1 - PRBS output, Channel 2 - TL082 TIA output at 1MHz

5.2 Stage - II

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

Figure 9: Channel 1 - PRBS output, Channel 2 - LMH6629 TIA output at 1MHz

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

6 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.

7 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

Acknowledgements

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