②→2(4)

DEPARTMENT
OF
ELECTRONICS AND COMMUNICATION ENGINEERING

FIBER OPTICS COMMUNICATION LABORATORY

LAB INSTRUCTIONS FOR CARRYING OUT PRACTICAL

ON

MEASUREMENT OF NUMERICAL APERTURE (NA) OF A MULTIMODE FIBER

BIRLA INSTITUTE OF TECHNOLOGY
MESRA, RANCHI

EXPERIMENT NO. 4

NAME
Measurement of Numerical Aperture (NA) of a multimode fiber.

OBJECTIVE
The objective of this experiment is to measure the numerical aperture of the plastic fiber provided with the kit using 660 nm wavelength LED.

THEORY
Numerical aperture refers to the maximum angle at which the light incident on the fiber end is totally internally reflected and is transmitted properly along the fiber. The cone formed by the rotation of this angle along the axis of the fiber is the cone of acceptance of the fiber. The light ray should strike the fiber end within its cone of acceptance, else it is refracted out of the fiber core.

CONSIDERATION IN NA MEASUREMENT:

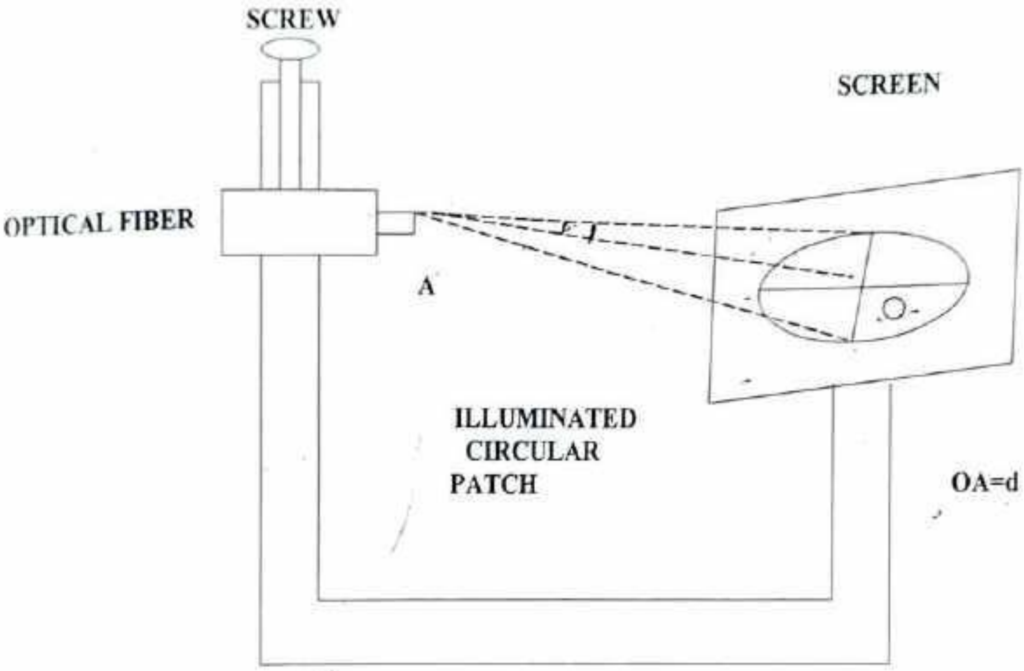
1. It is very important that the optical source should be properly aligned with the cable & the distance from the launched point & the cable be properly selected to ensure that the maximum amount of optical power is transferred to the cable.
2. This experiment is best performed in a less illuminated room.

EQUIPMENTS
Transmitter Box
1 meter fiber cable
Fiber holding fixture
Ruler

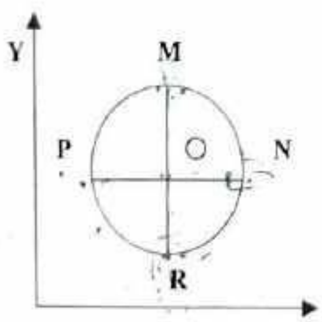
PROCEDURE
1. Slightly unscrew the cap of LED SFH 756V in Transmitter box. Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tighten the cap by screwing it back.
2. Now short the jumpers as shown in jumper diagram.
3. Connect the power cord to the kit & switch on the power supply.
4. Apply TTL high input to the LED from EXT-TTL terminal.
5. Insert the other end of the fiber into the numerical aperture measurement jig. Hold the white sheet facing the fiber. Adjust the fiber such that its cut face is perpendicular to the axis of the fiber.
6. Keep the distance of about 10 mm between the fiber tip and the screen. Gently tighten the screw and thus fix the fiber in the place.
7. Now observe the illuminated circular patch of light on the screen.
8. Measure exactly the distance d and also the vertical and horizontal diameter MR and PN as indicated in the fig.
9. Mean radius is calculated using the following formula
   $r = (MR + PN) / 4$
10. Find the numerical aperture of the fiber using the formula
    $NA = \sin \theta_{max} = r / \sqrt{d^2 + r^2}$

Where θ_{max} is the maximum angle at which the light incident is properly transmitted through the fiber.

BLOCK DIAGRAM FOR NUMERICAL APERTURE MEAUSREMENT

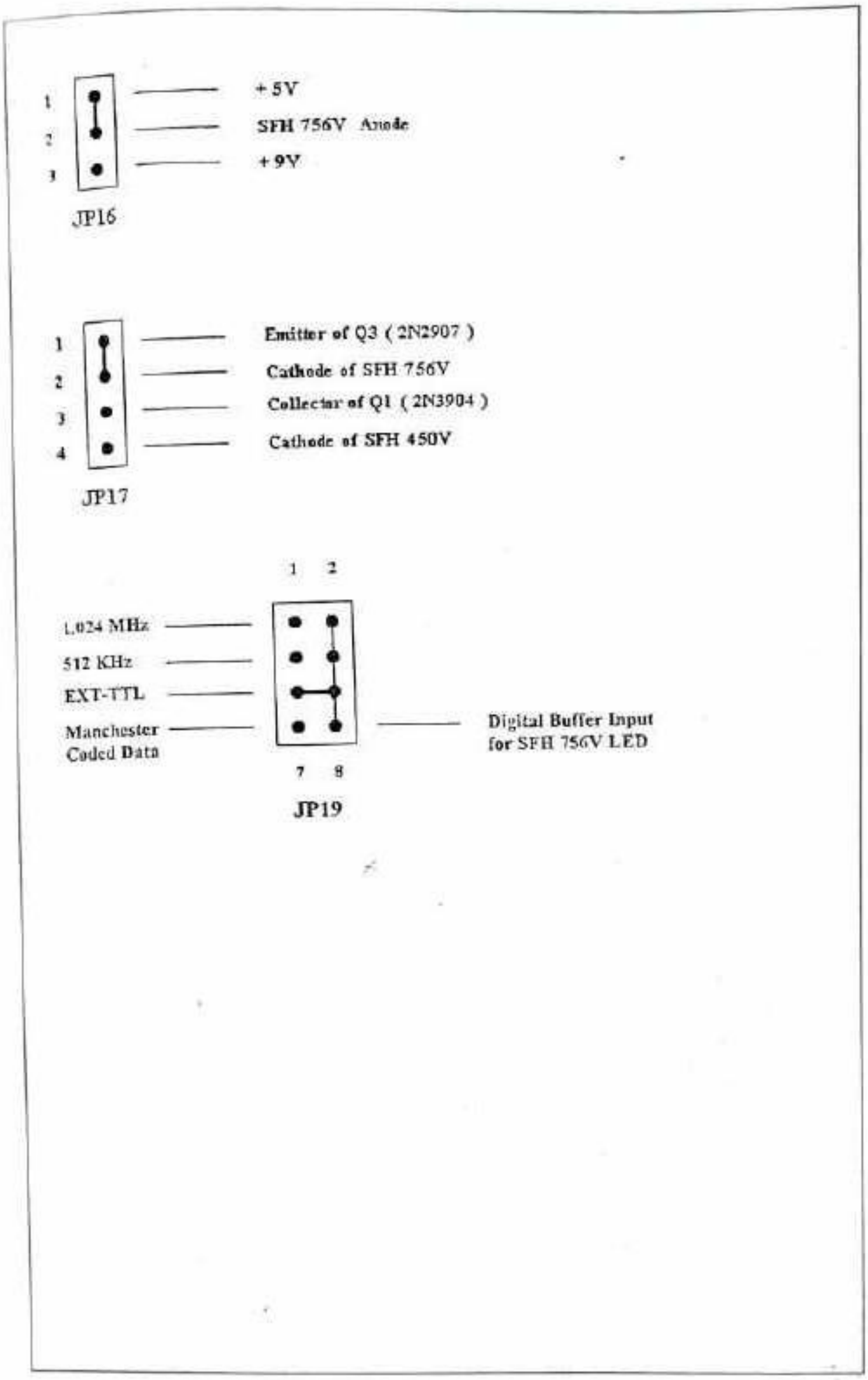


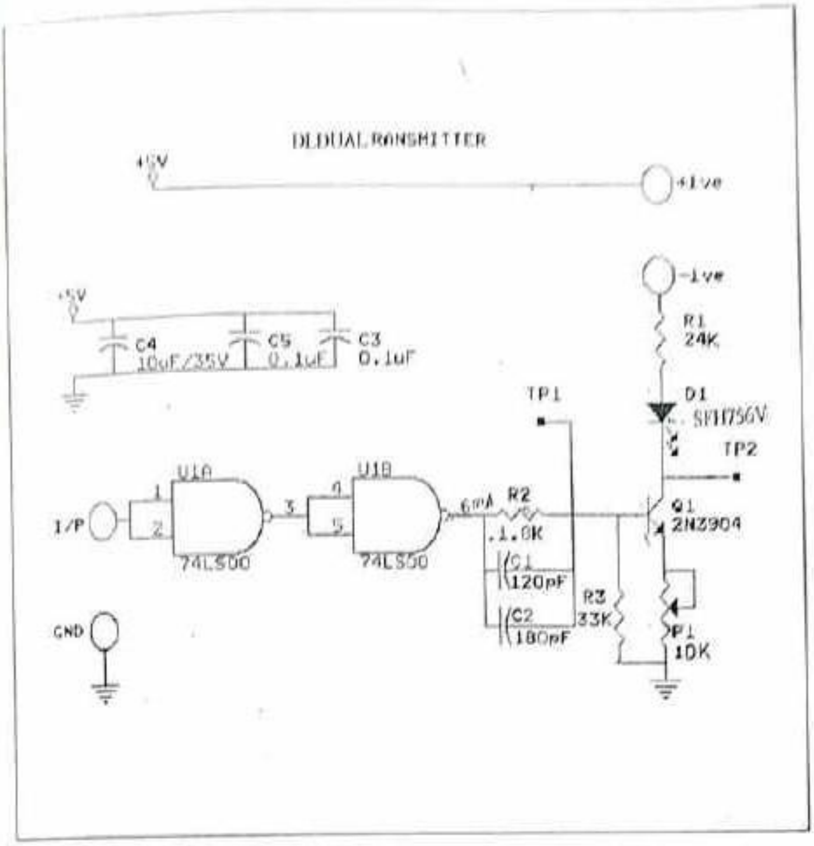
NUMERICAL APERTURE MEASUREMENT SETUP



$r = (MR + PN)/4$

JUMPER SETTING DIAGRAM




DLDUALRANSMITTER
+5V
+ive
-ive
R1
24K
D1
SFH756V
TP1
TP2
C4
10uF/35V
C5
0.1uF
C3
0.1uF
U1A
U1B
1
2
3
4
5
6
1/P
74LS00
74LS00
R2
1.8K
Q1
2N3904
C1
120pF
C2
180pF
R3
33K
P1
10K
GND

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LAB INSTRUCTIONS FOR CARRYING OUT PRACTICAL

ON

MEASUREMENT OF FIBER ATTENUATION OF A PLASTIC FIBER USING MODICOM KIT

BIRLA INSTITUTE OF TECHNOLOGY
MESRA, RANCHI

EXPERIMENT NO.3

MEASUREMENT OF FIBER ATTENUATION OF A PLASTIC FIBER USING MODICOM KIT.

APPARATUS/COMPONENTS REQUIRED:

MODICOM 6 Fiber Optic Trainer (LG Electronics)
Power Supply Unit with +/-5 V and +/-12 V output
Oscilloscope
Plastic fiber cables (0.5 m, 5 m, 10 m, 20 m)

INSTRUCTIONS:

1. Connect the fiber 0.5 m between emitter and detector.
2. Apply 1 KHz signal from Function Generator to the emitter circuit and observe the output at the fiber end.
3. Observe the waveform on the oscilloscope by connecting the probe at the appropriate pin.
4. Measure the peak-to-peak amplitude of the signal displayed on the oscilloscope.
5. Repeat steps 1-4 for other fiber lengths.
6. Plot the graph peak-to-peak voltage Vs length and find out the fiber attenuation using the relations given in the manual.

For procedural and component details refer the attached manual.

BJECTIVES

To investigate the transmission of light 'pulses' through an optic fiber, and their detection at the far end;

To deduce the relationship between cable attenuation and cable length for polymer fiber optic cable.

QUIPMENT REQUIRED

ower Supply Unit ±5V and ±12V outputs (e.g. I.C. Power 60).
ODICOM 6 Transmitter/Receiver module
t of 4 mm leads for electrical connections
5m, 5m, 10m and 20m lengths of fiber optic cable
ual trace Oscilloscope

XPERIMENTATION

Connect supplies to the MODICOM 6 Transmitter/Receiver module, as shown in Figure 14.

Ensure that all switched faults on the Transmitter/Receiver Module are Off.

Ensure that all switched faults on the Transmitter/Receiver module's EMITTER CIRCUITS block, ensure that the driver circuits in the Transmitter/Receiver module are in digital mode. Do this by putting the MODE switch, just below each of both Emitter LED's are in digital mode. Do this by putting the MODE switch, just below each emitter's DRIVER symbol, in the DIGITAL position.

This causes the LED's to switch on and off quickly in response to fast-changing digital input signals.

On the Transmitter/Receiver module, connect the FUNCTION GENERATOR block's 1 KHz square wave output to the IN1 input of EMITTER 1, as shown in Figure 16 at the end of this chapter.

Turn on power to the Transmitter/Receiver module.

Using your oscilloscope, examine the signal at Emitter 1's input (test point 5). Note that this is a square wave of frequency 1 KHz and 50% duty cycle.

This square wave will be used to switch Emitter 1's LED on and off, in order to generate 'pulses' of light. The LED is turned on when the square wave's level is high, and off when its level is low.

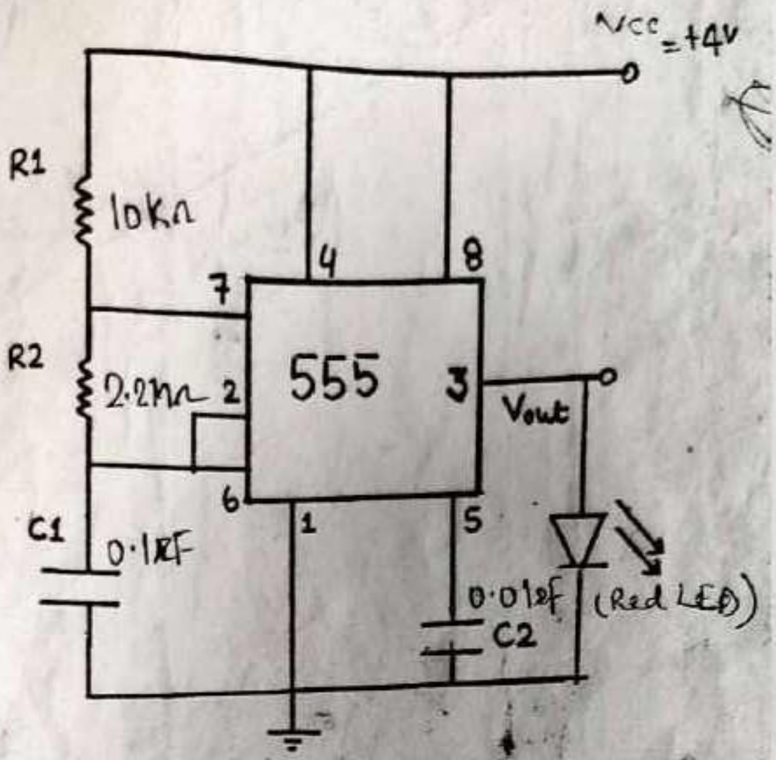
7. If you look into Emitter 1's LED housing, you will see that the LED appears to be producing continuous red light. In fact, the LED is only on for half of the time, because it is continuously being switched on and off by the 1 KHz square wave.

This switching rate is so fast that your eye cannot respond to the changes in the LED's brightness, and so the LED appears to your eye to be permanently on.

8. We will now transmit these 'pulses' of light over a short length of optical fiber.

Take a 0.5m length of fiber optic cable, and connect one end into Emitter 1's LED housing. Do this by pushing one of the cable's end connectors into the housing, until it snaps securely into place.

9. If you now examine the 'free' end of the cable, you will again see red light. This is because the light from the LED is being 'launched' into the cable, and is being transmitted down the fiber, to the end that you are viewing.



$R_1 = 10K$

$R_2 = 2.2M\Omega$

$C_1 = 0.01\mu F$

$C2 = 0.001\mu F$

LED TRANSMITTER.CIRCUIT.

...ry putting a large loop into the cable, as shown in Figure 15, and examine the 'free' cable end ...e again. Note: Take care when bending the cable, that the radius of the bend does not become ...ss than 15mm. Otherwise, the cable may be permanently damaged.

...ote that the LED's light output still reaches the cable's free end, even though there is no direct ...path for the rays to take. This proves that total internal reflection is taking place inside the cable.

Although the light output from the cable appears be uniform in its intensity, remember that the LED is being continuously switched on and off at a 1 KHz rate. What you are seeing at the fiber's end are transmitted 'pulses' of light, but once again they are too fast for your eye to detect.

To prove that what you are seeing are in fact 'pulses' of light, we will now convert the light output from the cable back into an electrical signal, by using one of the detector circuits on the Transmitter/Receiver module. To do this, connect the free end of the fiber optic cable into Detector 1's PIN diode housing, once again ensuring that the cable's end connector snaps securely into place.

Emitter 1 and Detector 1 should then be linked via the 0.5m fiber optic cable, as shown in Figure 17 at the end of this chapter.

Using your oscilloscope, monitor the input signal to Emitter 1 (at t.p.5) and the output signal from Detector 1 (at t.p.10), triggering the scope from t.p.5.

The signal at Detector 1's output is an amplified version of the output signal from the detector's PIN diode. Consequently, the output voltage at t.p.10 is directly proportional to the optical power of the light falling onto the PIN diode. The greater the variation in the received optical power, the greater the amplitude of the signal voltage at the detector's output.

Note that in this case the signal at the detector's output is a square wave, of the same frequency and phase as that at the emitter's input. The only obvious difference between the two signals is that the detector's output amplitude is considerably smaller than that of the emitter's input signal.

The 'pulses' of light falling on the detector's PIN diode have been converted into a tiny electrical signal. Which has been amplified to produce the quare wave at the detector's output.

To confirm that the waveform at t.p. 10 is caused by the received 'pulses' of light, try disconnecting the fiber-optic at either the emitter or detector end, and note that the square wave at Detector 1's output (t.p. 10) disappears.

Reconnect the fiber optic cable before continuing.

13. Measure the peak-to-peak voltage of the square wave at Detector 1's output (TP 10) with the 0.5m cable connected between Emitter 1 and Detector 1, and record this figure.
Disconnect both ends of the fiber-optic cable from the Transmitter/Receiver module, before continuing.

14. Repeat the previous step for 5m, 10m and 20m lengths of fiber-optic cable connected between Emitter 1 and Detector 1. In each case record the peak-to-peak voltage at t.p. 10.

Notice that the detector's output amplitude **decreases** as the cable length **increases.** This is because the amount of light reaching the detector is dependent on the length of fiber optic cable, since transmission loss through the cable (i.e. the cable's **attenuation**) increases with increased cable length.

5. Using log/linear graph, plot the peak-to-peak detector voltage against cable length (in meters), for 0.5m, 5m, 10m and 20m cables. The detector voltage should be on the log scale.

6. You should be able to draw a straight line which runs through, or very close to, the points that you have plotted. Draw the straight line which runs closest to all the plotted points.

Note that not all plotted points will necessarily fall exactly on the line that you have drawn. These variations from the ideal are due to slight differences in the quality of the polished fiber ends, from one cable to another.

7. The final stage is to calculate the cable attenuation in dB's per meter.

To do this, select two points on your graph which are a reasonable distance apart. Let us suppose that the detector voltages at these two points are V1 and V2 (where v1 is the larger of the two voltages), and that the change in cable length between the two points is L meters.

The cable attenuation in dB's per mete, for red light, is then given by the formula:

$$\text{Cable Attenuation (dB/m)} = \frac{10\log_{10}(V1/V2)}{\Delta L}$$

0.25 0.3 dB/m

64

Experiment - 2(A)

Aim: Measurement of fiber attenuation of a plastic fiber using Modicom kit.

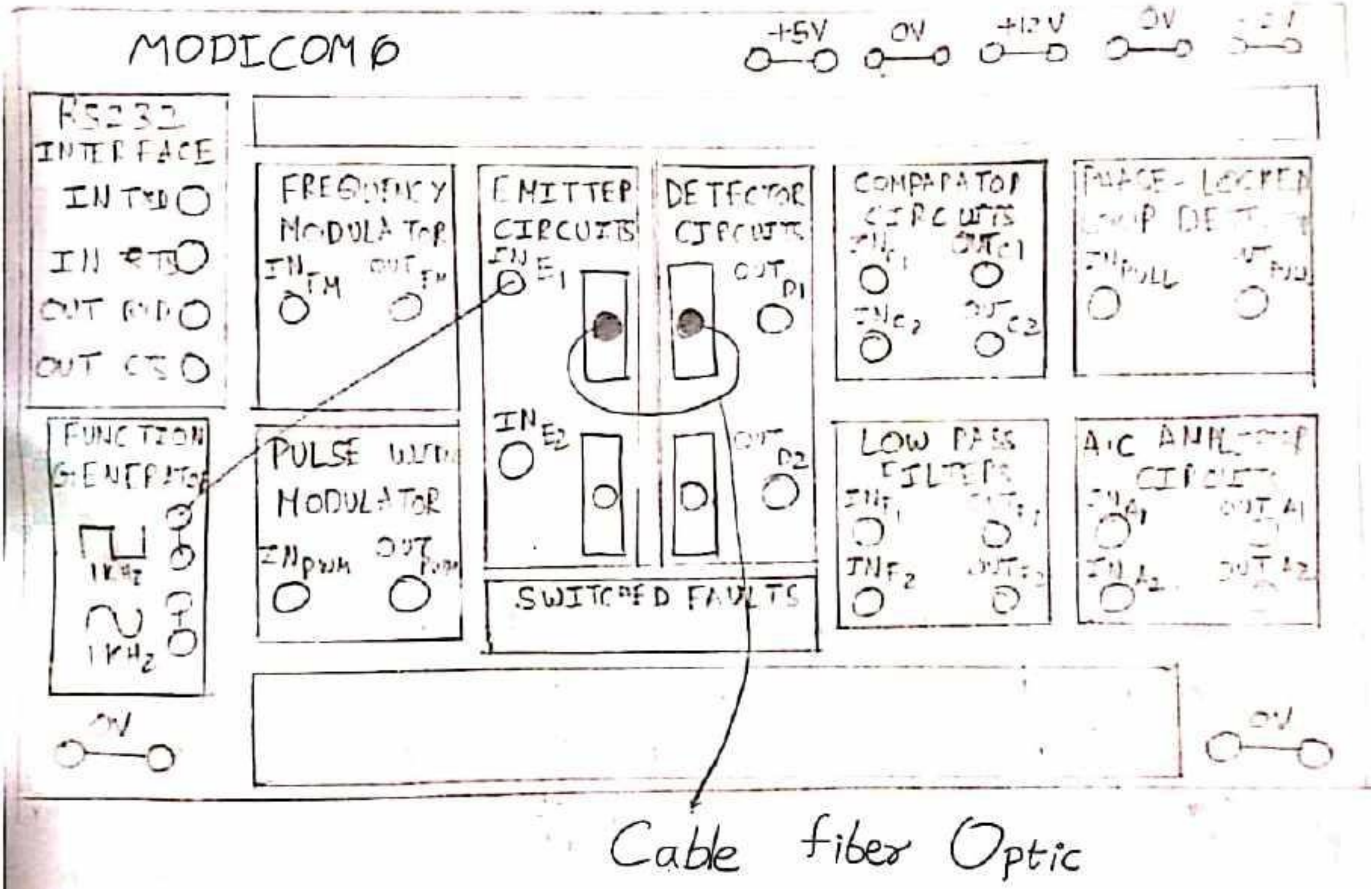
Aim 1: Measurement of fiber attenuation

Apparatus / Components Required:-
1) MODICOM 6 fiber Optic Trainer
2) Power Supply unit with ±5V & ±12V
3) Oscilloscope
4) Plastic fiber cables

Theory :-

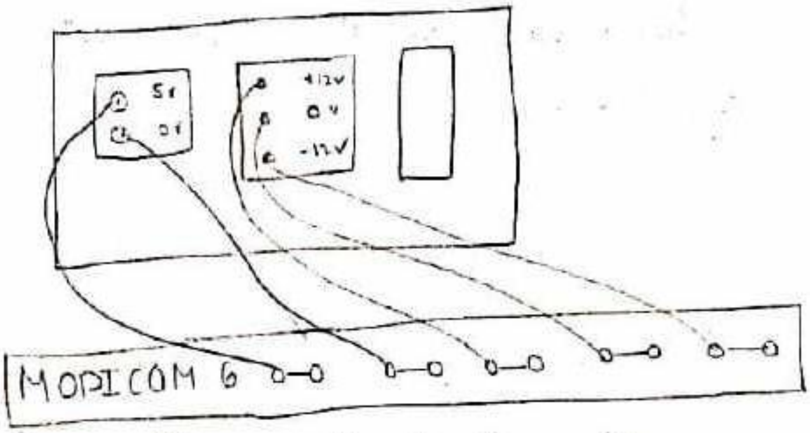
Attenuation means loss of flux intensity through a medium. for instance, dark glasses attenuate sunlight, lead attenuates X-rays, -- In optical fibers attenuation is the rate at which the signal decreases in Intensity. plastic fiber has a higher attenuation and used for shorter range. fiber optic cable

Moreover it is immune to noise. Hence, it can be run along side of power cables. It is more rugged and more flexible. Hence, it is easier to install them. It is light in weight and can withstand stress.

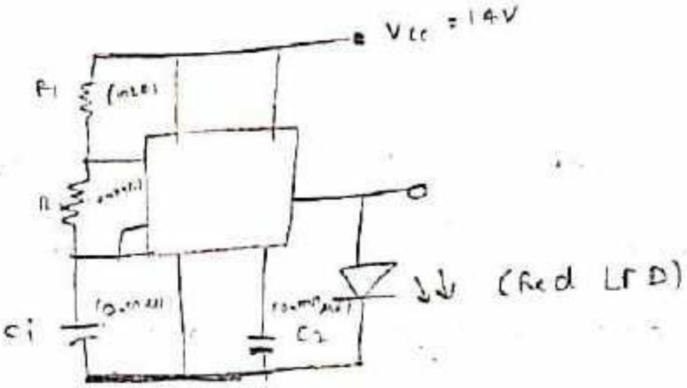


Connection of fiber optic Cable
B/w Emitter & detector

Circuit Diagrams:



Power Supply Connections



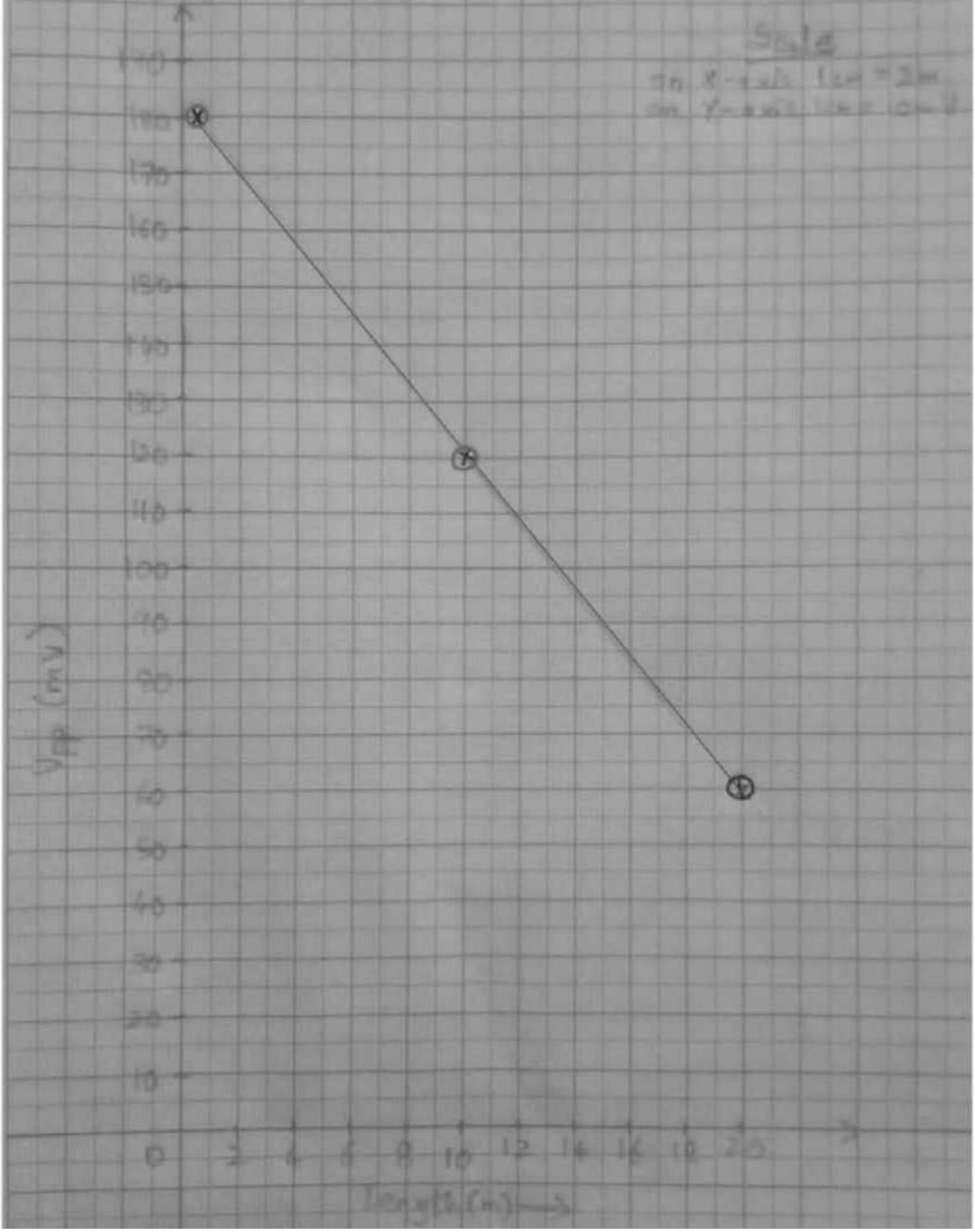
LED Transmitter Circuit.

Observation Table:-

length of optical fiber (m)	Peak to Peak Voltage (V)
0.5	1.8
10	1.2
20	0.6

Conclusion:- In this experiment we observed the peak to peak voltage when the length of the optical fiber is changed

① Fiber Attenuation



Experiment - 2 (B)

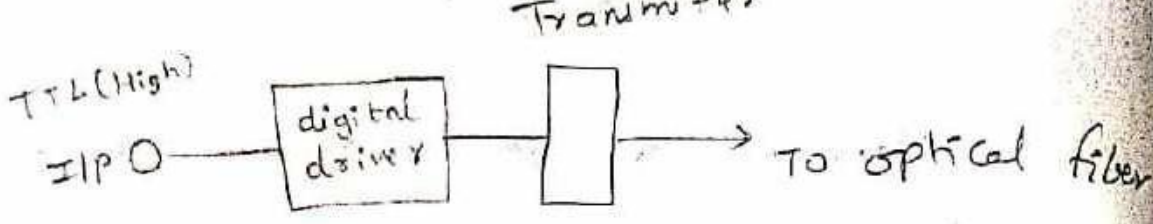
Aim: Measurement of numeric aperture of a multimode fiber

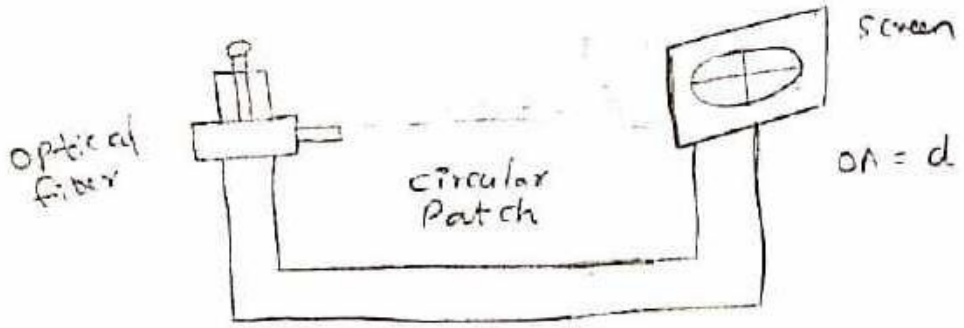
Equipments:
1) Transmitter Box
2) Fiber holding fixture
3) Ruler
4) 1m fiber cable

Theory:- Numerical aperture refers to the maximum angle at which the light incident on the fiber end is total internally reflected and is transmitted properly. along the fiber. The light ray should strike the fiber end within its cone of acceptance, else it is refracted out of the fiber core.

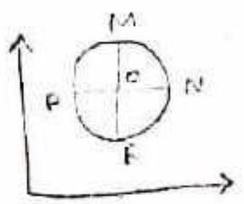
(NA) has no dimensions. It is used by fiber manufactures to specify the acceptance angle of an optical fiber and is defined as, In Step Index fibers with a large core, the NA can be calculated directly using the equation

Circuit Diagram:-



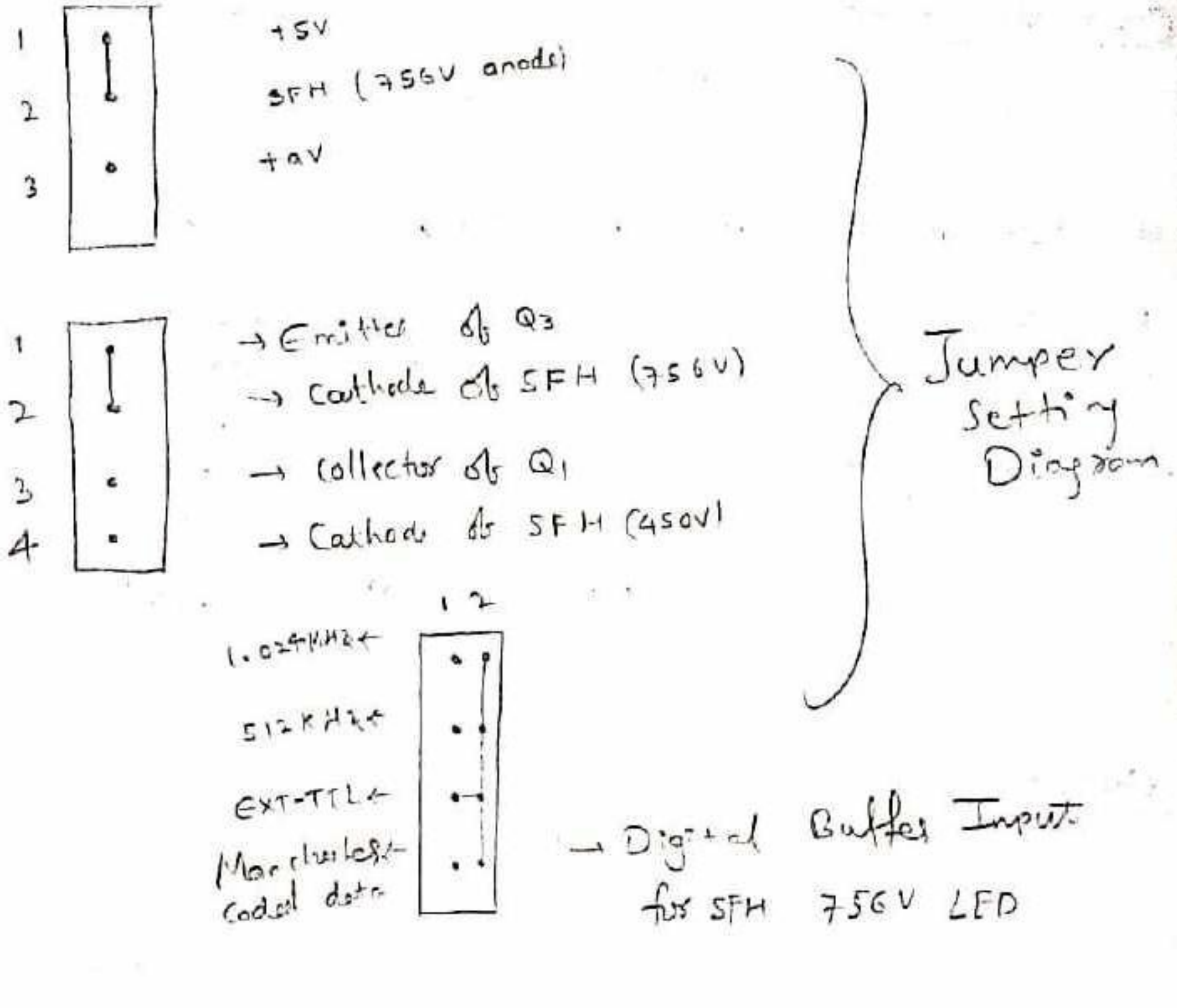


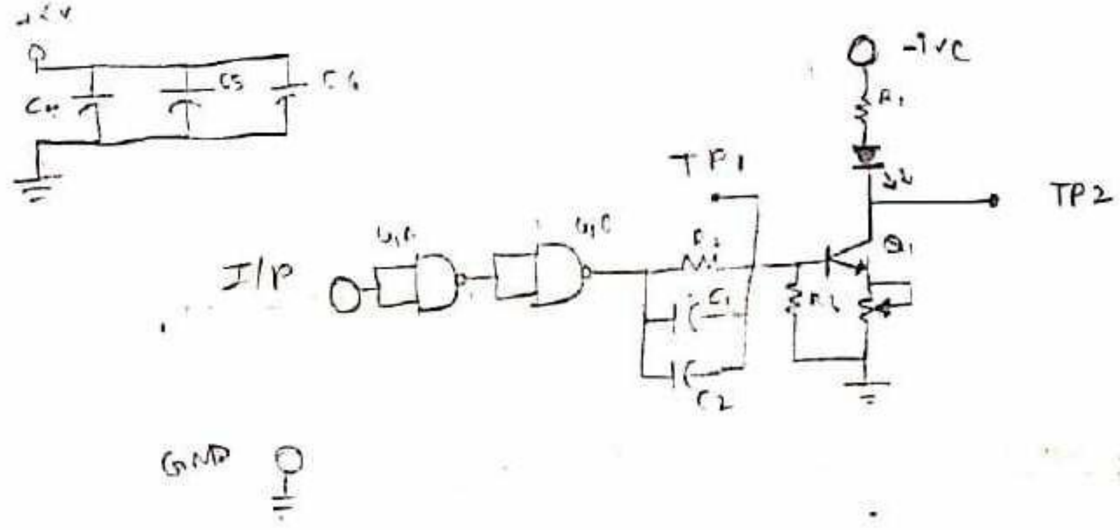
Numerical aperture measurement Setup



$r = \frac{MR + PN}{4}$

It is very important that the optical source should be properly aligned with the cable and the distance from the launched point and the cabel be properly selected to ensure that the maximum amount of optical fiber power is transferred to the cable.





DL Dual transmitter

Observation table:-

$$NA = \frac{r}{\sqrt{d^2+r^2}}$$

S.No	d(cm)	MR(cm)	PN(cm)	$r = (MR+PN)/4$	NA	$\theta = \sin^{-1}(NA)$
1	1.2	1.1	1.2	0.575	0.432	25.6°
2	1.8	1.5	1.4	0.725	0.373	21.94°
3	2.2	1.75	1.8	0.8771	0.372	21.95°
4	2.5	2.25	2.2	1.112	0.406	23.97°
5	2.7	2.3	2.25	1.138	0.389	22.87°
				Avg ⇒	0.3944	23.25°

Calculation

for, $d = 1.2$, $MR = 1.1\,cm$, $PN = 1.2\,cm$

$$\Rightarrow r = \frac{PN+MR}{4} = \frac{1.2+1.1}{4} = \frac{2.3}{4} \Rightarrow 0.575\ cm$$

$$\Rightarrow NA = \frac{r}{\sqrt{d^2+r^2}} = \frac{0.575}{\sqrt{(1.2)^2+(0.575)^2}} = 0.432$$

$$\theta = \sin^{-1}[NA]$$

$$\therefore \theta = \sin^{-1}(0.432) \Rightarrow \boxed{\theta \simeq 25.6^\circ}$$

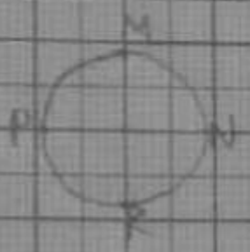
Conclusion: In this experiment we observed and measured the numerical aperture (NA) of a multimode fiber

② Numerical Aperture

Scale
On X-axis 1cm = 1 cm
On Y-axis 1cm = 1 cm

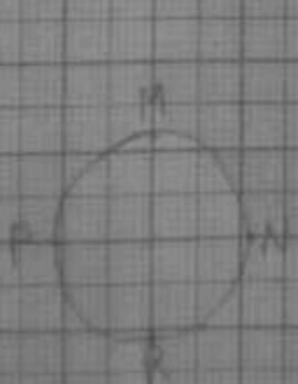
d = 1.2cm MR = 1.1cm PN = 1.2cm

d = 1.8cm MR = 1.5cm PN = 1.6cm



d = 2.2cm MR = 1.75cm PN = 1.8cm

d = 2.5cm MR = 2.25cm PN = 2.2cm



d = 2.7cm MR = 2.3cm PN = 2.25cm

converter (O/E)

(iii) Optical fiber as

(iv) Connector, couplers &

(v) line coder & deco

(vi) Timing recovery ci

The recov

for transmission is esse

timing recovery depends

"0" to "1" & "1" to

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data bit is "1", the

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'0' data bit, the fi

cell will be zero.

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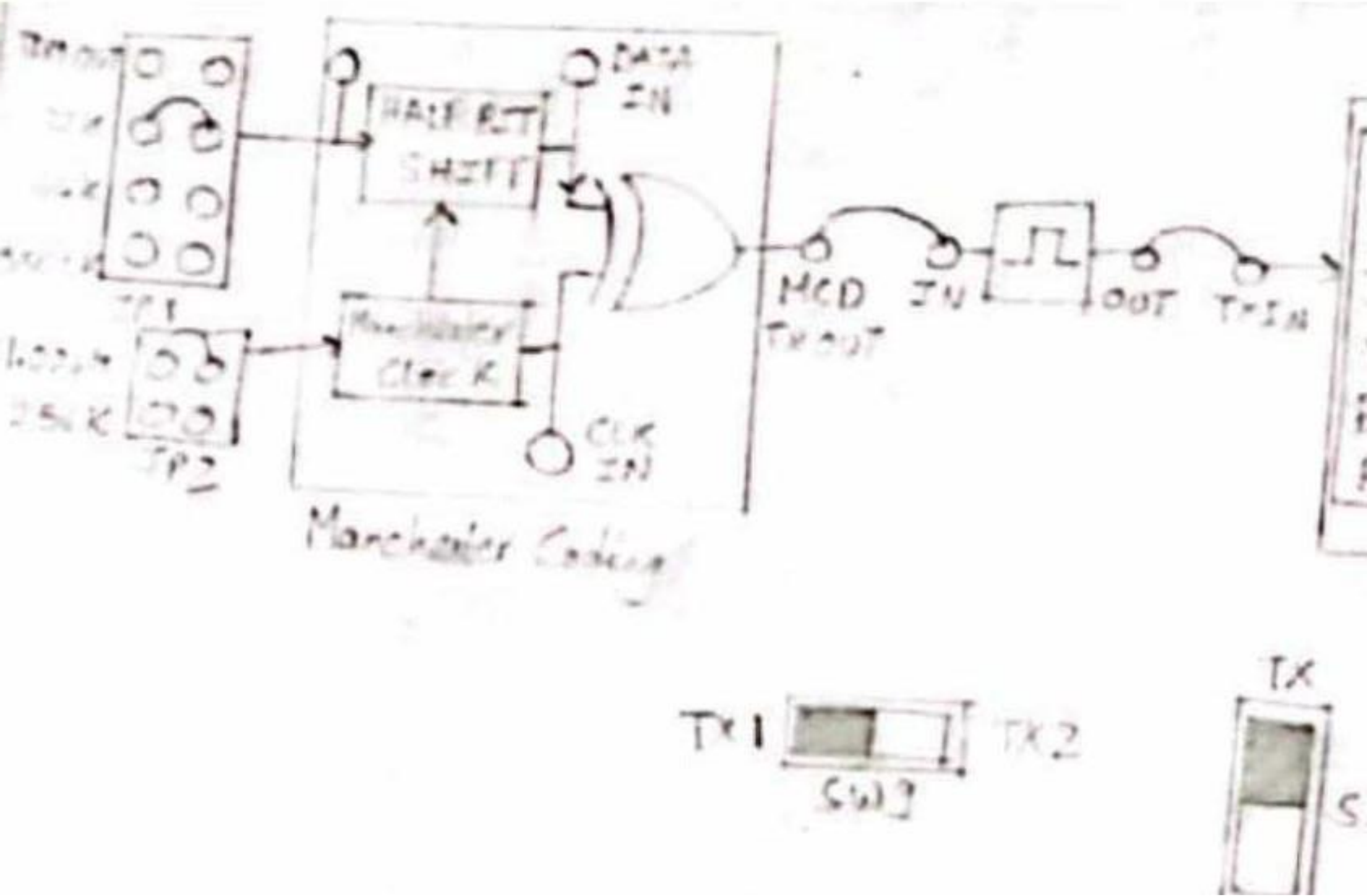
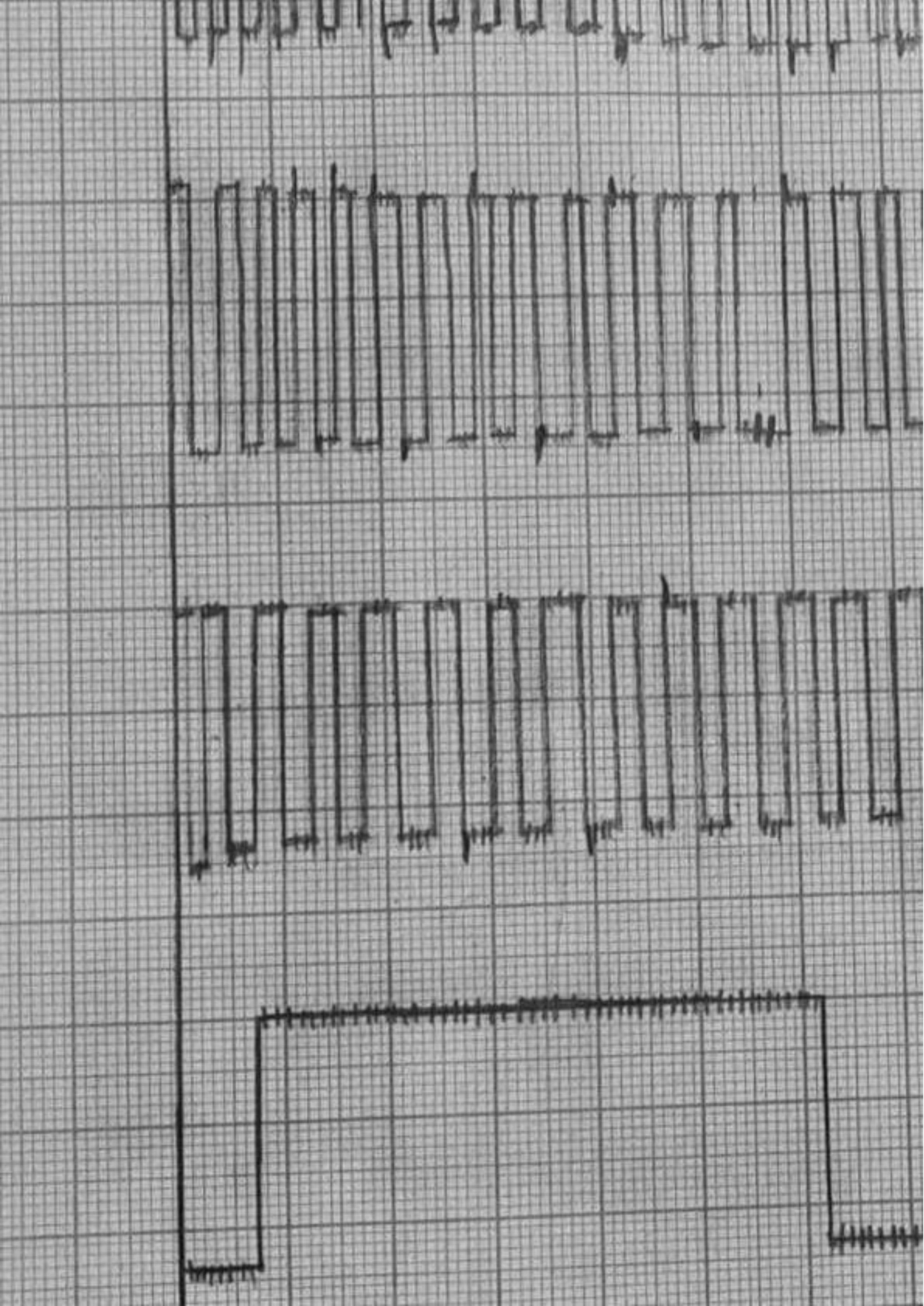
of whether the

Conclusion: We ha

man chester coding and


HALF BIT
SHIFT
Manchester
Clock
DATA
IN
CLK
IN
TP1
TP2
25K
MCD
TX OUT
IN
OUT
TXIN
Manchester Coding
TX1
TX2
SW3
TX



(6)

DEPARMENT

OF

ELECTRONICS AND COMMUNICATION ENGINEERING

FIBER OPTICS COMMUNICATION LABORATORY

LAB INSTRUCTIONS FOR CARRYING OUT PRACTICAL

ON

MANCHESTER CODING & DECODING IN OPTICAL FIBER LINK

BIRLA INSTITUTE OF TECHNOLOGE

MESRA, RANCHI

EXPERIMENT NO. 8

NAME

Study Of Manchester Coding & Decoding

OBJECTIVE

The objective of this experiment is to study the techniques of Manchester coding & decoding in digital communication.

THEORY

A fiber optic digital communication system usually consists of the following:

- Optical transmitter including electrical to optical converter (E/O)
- Optical receiver including optical to electrical converter (O/E)
- Optical Fiber as data transmission medium
- Connectors, Couplers & Splicers
- Line Coder
- Line Decoder
- Timing recovery unit

In digital communication the recovery of the clock used for transmission is essential. The Technique of timing recovery depends on the no. of "0" to "1" & "1" to "0" transitions. At times, one cannot ensure that the data to be transmitted has such transitions. To introduce the transitions in such a case, line coding is used. For low bit rate fiber optic transmission, the commonly used line coding technique is known as Manchester Coding, whereas for higher bit rates various coding schemes like mBnB coding schemes are used. Thus line coding is implemented in digital communication for the following reasons.

- For ease of timing recovery at the receiver
- To shape the spectrum of the signal as required by various elements in the communication system

The recovery of synchronous clock, synchronous both in terms of phase & frequency, at the receiver is a must for any synchronous digital link. A long string of zeros & ones, i.e. lack of transitions in data, could make the receiver clock lose synchronization. Line coding introduces sufficient transitions in the data for ease of clock recovery. Also a certain pattern of data, like a long string zeros or one, would result in a strong DC component in the transmitted signal. Such a DC component is often not desirable; line coding shifts the spectrum & avoids the DC component. Several methods of coding digital transmission for unique effects are possible each type of coding has inherent advantages. We will consider the simplest line coding technique as Manchester Coding. The data waveform is composed of a binary bit stream with each bit forming a cell, one clock period in length.

The Manchester coded waveform is generated in the following manner. If the Data bit is '1', the waveform will be positive for the first half of the bit cell. For a '0' data bit, the first half of the bit cell will be a zero. A transition always occurs in the center of the bit cell, regardless of whether the bit is '1' or '0'.

EQUIPMENTS

FO-A-P Kit with power supply
Patch chords
20 MHz Dual Trace Oscilloscope
1 Meter fiber cable

NOTE: Keep All Switch Faults In Off Position.

PROCEDURE

- Make connections as shown in diagram.
- Keep jumper & switch settings as shown in fig.
- Observe the Test points of DATA IN & MCDTX OUT. The **MCDTX OUT** shows that when Data is "1" the first half bit of data is high whereas the second half is zero. While for Data as "0" the first half is a "0" level & second half is "1" as shown in the waveforms.
- Select the fiber optic transmitter TX1 SFH756 using jumper & switch settings as shown in fig.9.2.
- Slightly unscrew the cap of SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the one-meter fiber into the cap. Now tighten the cap by screwing it back.
- Slightly unscrew the cap of RX1 Photo Transistor with TTL logic output SFH551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.
- Observe the test points of **INT OUT, ET OUT**. The decoded output is obtained at **RX DATA** test point & the decoding clock at **DATA CLK** test point.FIG.8.2 shows Manchester coded & decoded signals for 32 KHz data input.
  (After inserting the fiber on both sides, align the fiber properly inside both SFH devices if required to get proper indication of o/p LEDs.)
- Observe the waveforms for other data by shifting **JP1** to **64 KHz & MX CLK.**
- Also observe the effect of changing Manchester clock by keeping **JP2** position at **256 KHz.** Now the Manchester coded output will be exact but the Manchester decoded output & clock may not match the data as the decoded clock circuit is tuned to 1.024MHz clock & not 256Khz.So for this observe only the Manchester coded data.

SWITCH FAULTS

NOTE: Keep the connections as per the procedure. Now switch **ON** corresponding fault switch button to **ON** position & observe the different effects on the output. The faults are normally used one at a time.

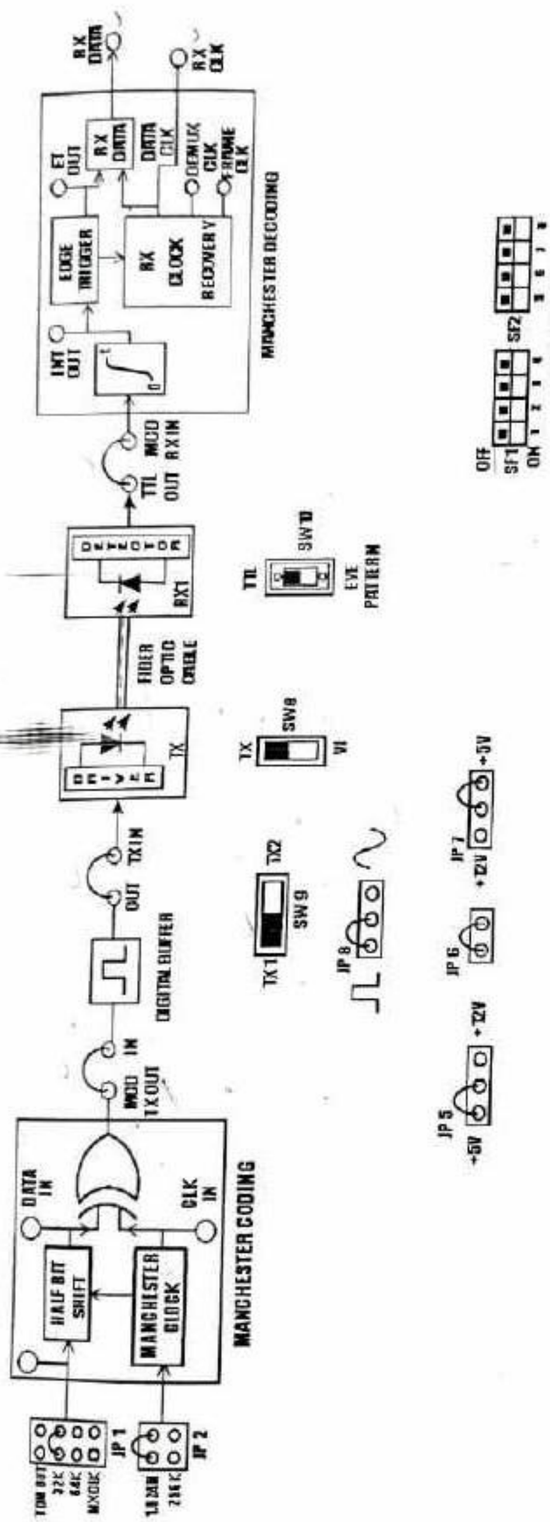


FIG. 8.1 STUDY OF MANCHESTER CODING AND DECODING.

- Put switch **5 (SF2)** in Switch Fault section to **ON** position. This will open pin 2 MCDCLK of U19 (74HC86). This will affect the Manchester coding and the Manchester coded o/p will be in a wrong format.
- Put switch **6 (SF2)** in Switch Fault section to **ON** position. This will disturb the Manchester decoding o/p and data will be disturbed. R71 comes in parallel to PR1 & hence the RC time constant changes & RX CLK gets disturbed.

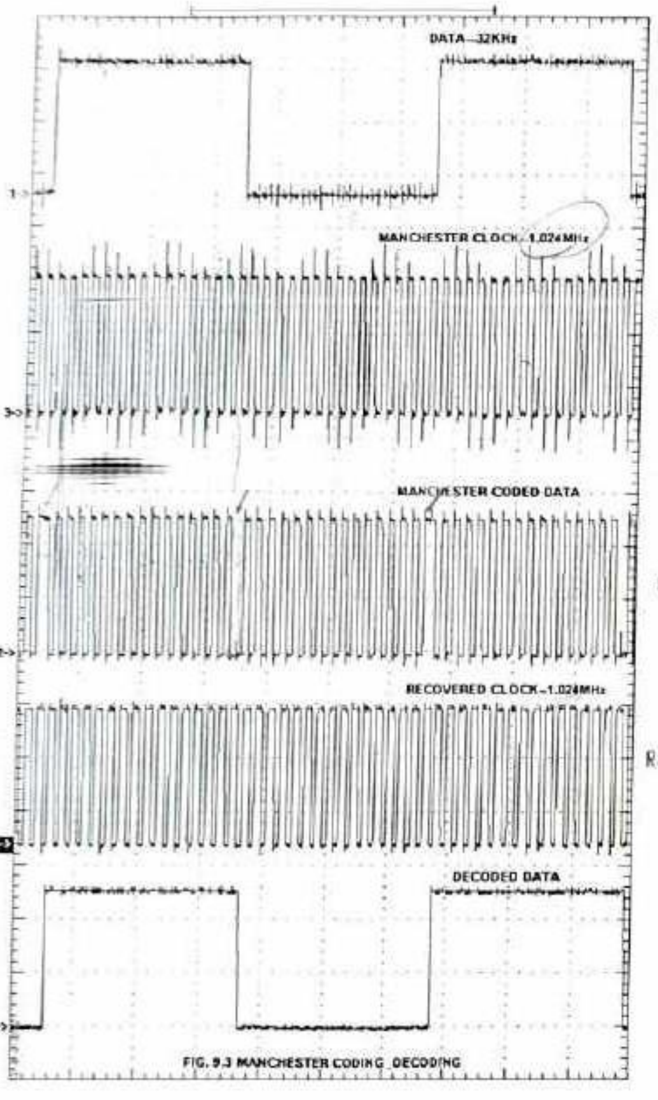


FIG. 9.3 MANCHESTER CODING DECODING

Experiment-4

Name: Study of simple time division multiplexing

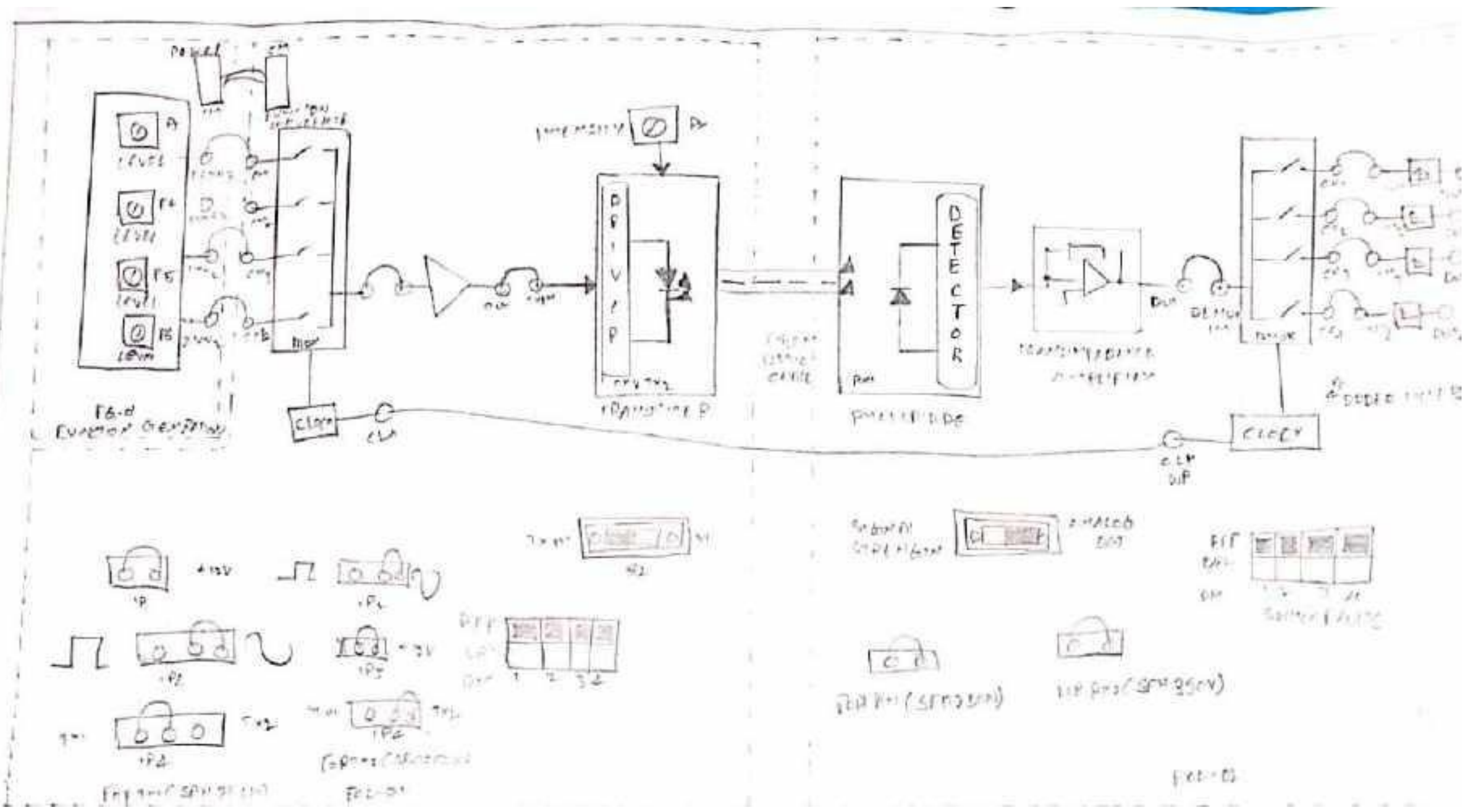
Aim: To Study time division multiplexing for 4 analog channels fiber optic analog link.

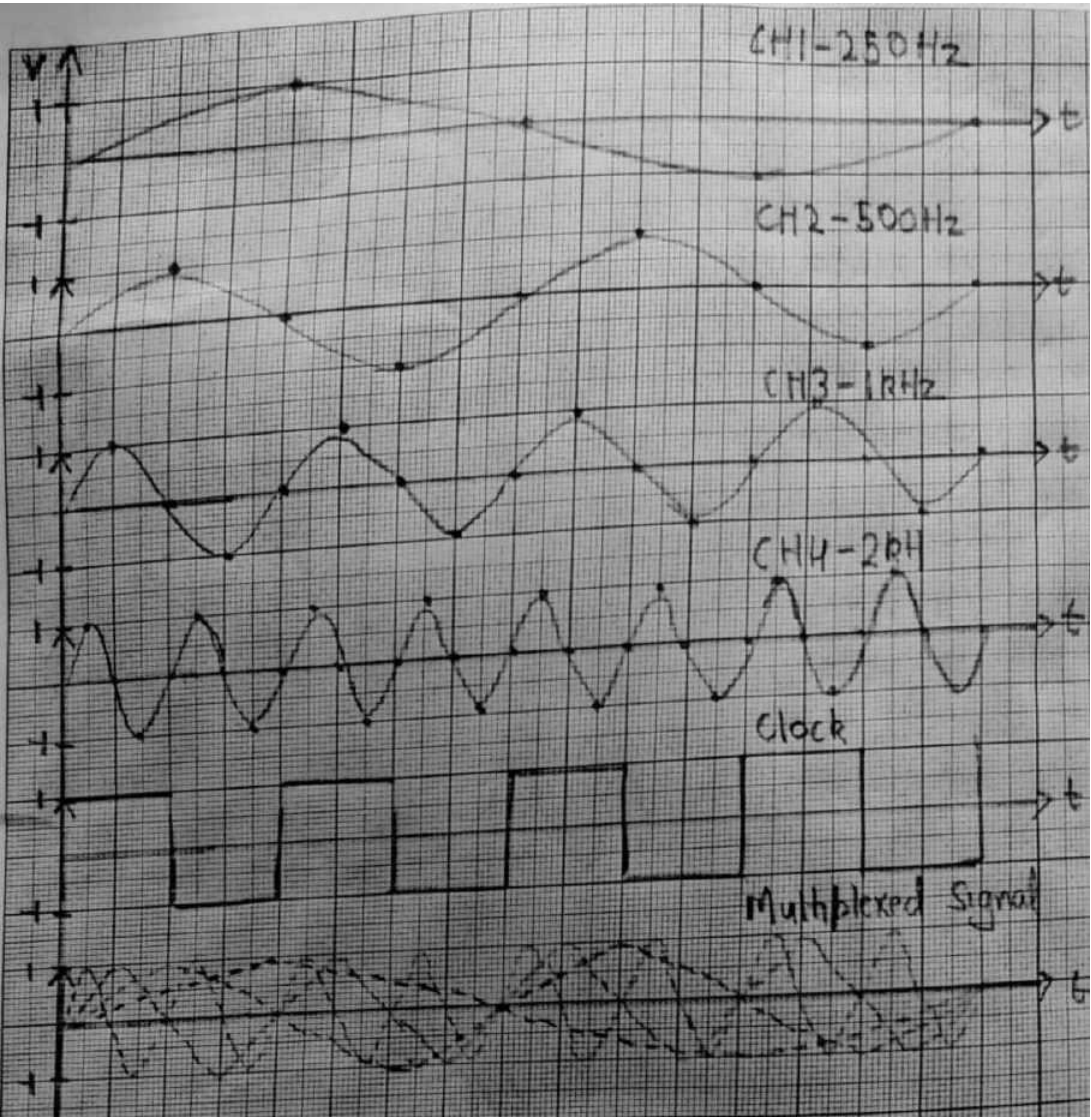
Equipments:
1) FCL-01, FCL-02
2) FG-01 with power cable
3) 20MHz dual channel oscilloscope
4) Patch chords
5) 1 Meter fiber cable
6) Power Supply

Theory: This technique enables simultaneous transmission of number of signals along the same communication channel. The signals from different sources are multiplexed by allowing only a specific time slot for each signal. At the receiver side, the multiplexed data is distributed to the corresponding channels.

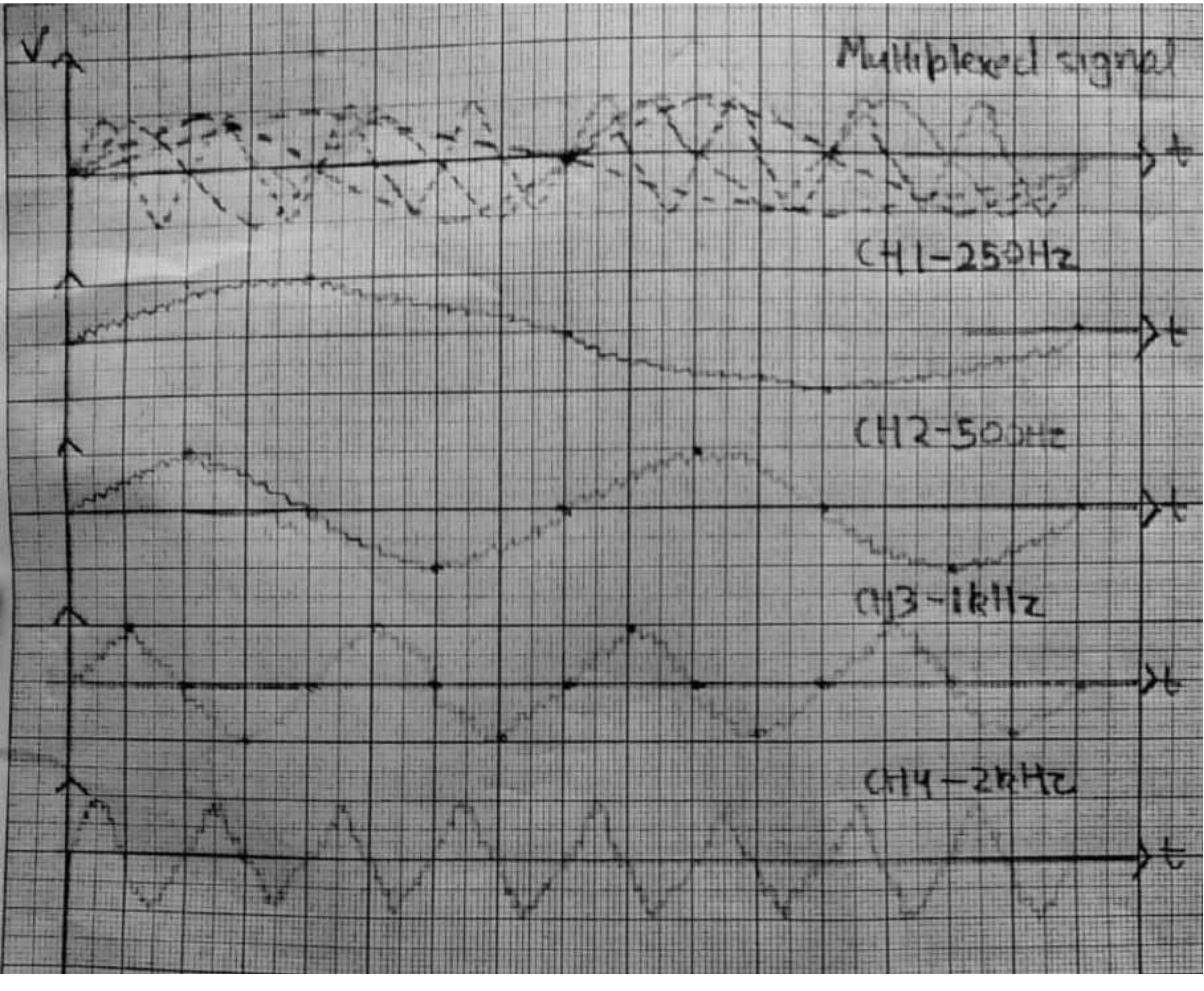
The block diagram shows different parts used in the TDM circuit. The circuit consists of the following parts:-

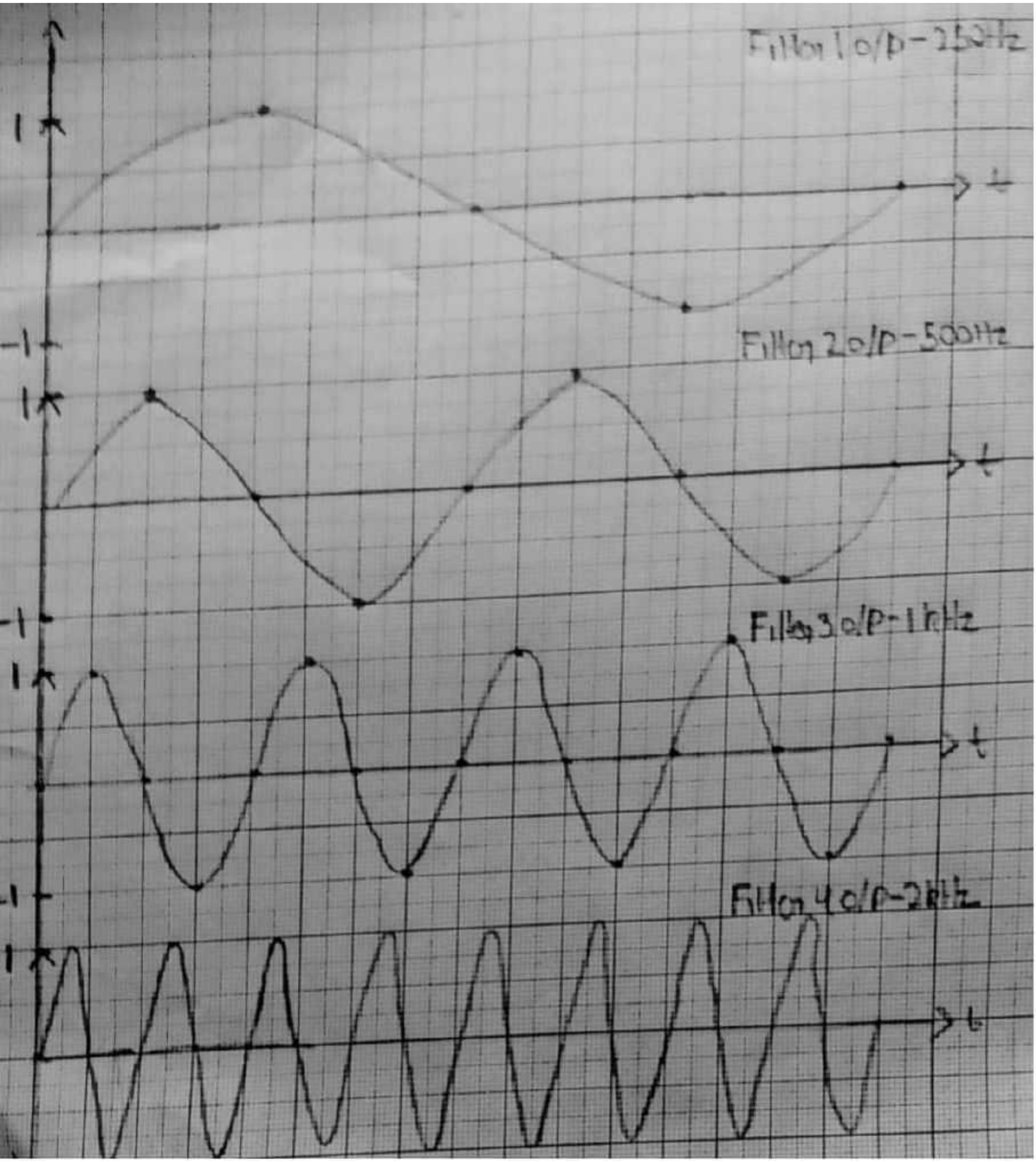
a) clock Pulse Generator
b) 4 Stage Up/down binary counter
c) Analog multiplexer


POWER
DETECTOR
CLOCK



CH1-250Hz
CH2-500Hz
CH3-1kHz
CH4-2kH
Clock
Multiplexed Signal


V
Multiplexed signal
t
CH1-250Hz
t
CH2-500Hz
t
CH3-1kHz
t
CH4-2kHz
t



Filter 1 o/P - 250Hz
Filter 2 o/P - 500Hz
Filter 3 o/P - 1kHz
Filter 4 o/P - 2kHz
t
1
-1

EXPERIMENT NO: ~~10~~ 5

NAME

Study of Simple Time Division Multiplexing (Analog)

OBJECTIVE

The objective of this experiment is to study of Time Division Multiplexing for 4 analog channels fiber optic analog link.

THEORY

This technique enables simultaneous transmission of number of signals along the same communication channel. The basic concept behind this is that the signals from different sources are multiplexed by allowing only a specific time slot for each signal. At the Receiver side, the multiplexed data is distributed to the corresponding channels. The block diagram shows different parts used in the TDM circuit. The circuit consists of three parts:

A. Clock Pulse Generator.
B. Four stage Up/Down Binary Counter.
C. Analog Multiplexer.

EQUIPMENTS

- FCL-01 & FCL-02
- FG-01 with power cable
- 20 MHz Dual Channel Oscilloscope
- 1 meter Fiber cable
- Patch chords
- Power supply (Use only one provided)

NOTE: Keep All Switch Faults In Off Position.

PROCEDURE

- Refer to fig 10.1 and make the following connections.

- Connect the power supply with proper polarity to FCL-01 and FCL-02. While connecting this, ensure that the power supply if OFF.
- Connect Function Generator FG-01 to FCL-01 using power cable.
- Keep the jumpers **JP1**, **JP2**, **JP3** &**JP4** on FCL-01 as shown in fig.10.1.
- Keep the jumpers **JP1** &**JP2** on FCL-02 as shown in fig.10.1.
- Keep switch **S2** in **TX IN** position on FCL-01.
- Switch on the power supply.
- Connect four sinusoidal signal of different frequencies as **250 Hz**, **500 Hz**, **1 KHz**&**2 KHz** generated on FG-01 to **CH1**, **CH2**, **CH3**&**CH4** inputs of Time Division Multiplexing section on FCL-01 respectively. The amplitude of these signals can be varied with the help of potentiometers **P3**, **P4**, **P5** and **P6**. Observe these signals on Oscilloscope and adjust their amplitude to 2 Vp-p.
- Observe the TDM output at **OUT** post of Time Division Multiplexing section as shown in Fig. 10.1.
- Connect the output of Time Division Multiplexing section post **OUT** to post INof Analog Buffer on FCL-01.
- Connect the output of Analog Buffer post **OUT** to post **TX IN**.
- Connect post **CLK** on FCL-01 to post **CLK I/P** on FCL-02.
- Slightly unscrew the cap of LED SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the 1 meter fiber into the cap. Now tighten the cap by screwing it back.
- Slightly unscrew the cap of Photo Diode SFH250V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.
- Keep switch **SW2** in **ANALOG OUT** position on FCL-02.
- Connect the output of Photo Diode detector post **OUT** to post **DEMUX IN** of Time Division Demultiplexing Section.
- Connect the output of Time Division Demultiplexing Section **CH1**, **CH2**, **CH3**&**CH4** to input of 4^{th} order low pass filters **IN1**, **IN2**, **IN3**&**IN4** respectively.
- Observe four different reconstructed signals at the output channels marked as **OUT1**, **OUT2**, **OUT3**&**OUT4** of 4^{th} order low pass filters in FCL-02 as shown in fig 10.3.
- Perform the above procedure again for all the combinations of Transmitter & Receiver.

SWITCH FAULTS

NOTE: Keep the connections as per the procedure. Now switch **ON** corresponding fault switch button to **ON** position & observe the different effects on the output. The faults are normally used one at a time.

- Put switch **3** of **SF1** in Switch Fault section of FCL-01 to ON position. This will short capacitor C63 & C64 in Time Division Multiplexing section. Synchronization pulse duty cycle get increases. TDM output distorts and similarly Demodulator output also gets distorted.

- Put switch **4 of SF1** in Switch Fault section of FCL-01 to ON position. This will short CH3 & CH4 signals going for TDM. Mixed signal appears for CH3 & CH4 positions at Multiplexer and de-multiplexer outputs.
- Put switch **2 of SF1** in Switch Fault section of FCL-02 to ON position. This will open capacitors C37 from fourth filter. Fourth filter output gets distorted.
- Put switch **4** of **SF1** in Switch Fault section of FCL-02 to ON position. This will open decoder pulse for CH3 in Time Division Demultiplexing section. Output for third channel will be absent.

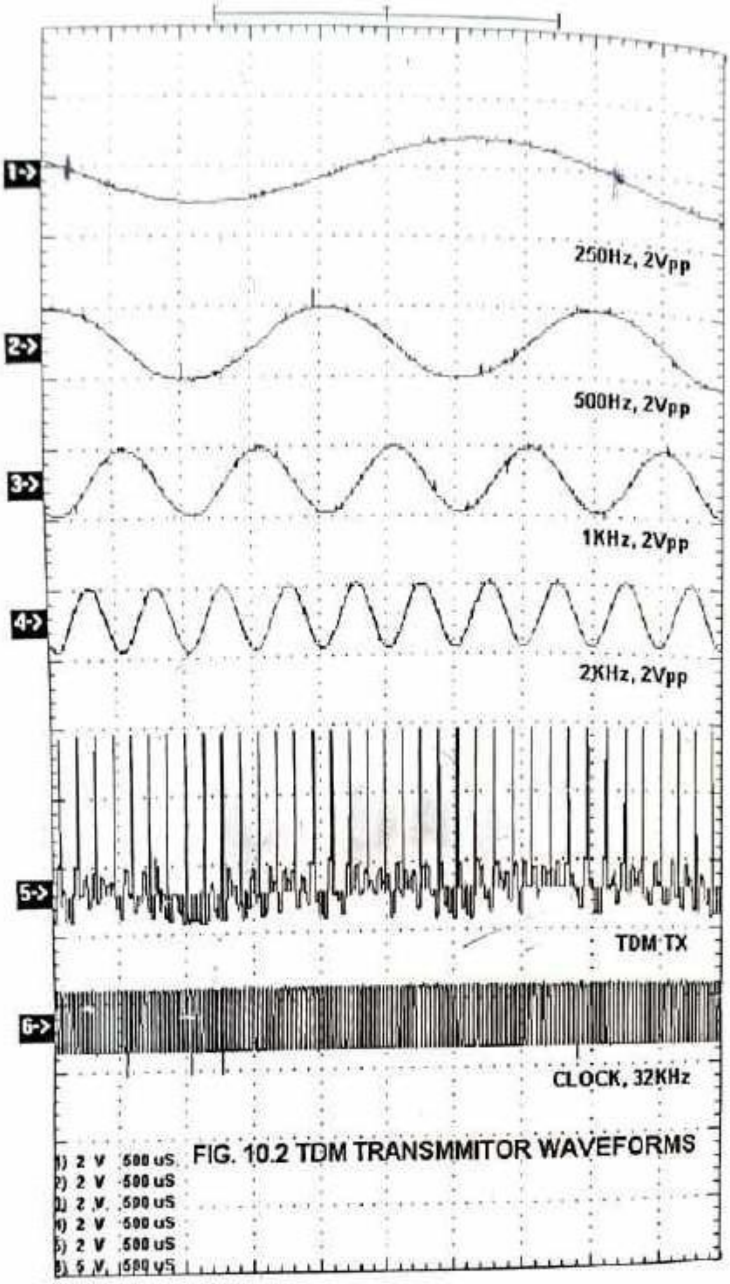


FIG. 10.2 TDM TRANSMMITOR WAVEFORMS

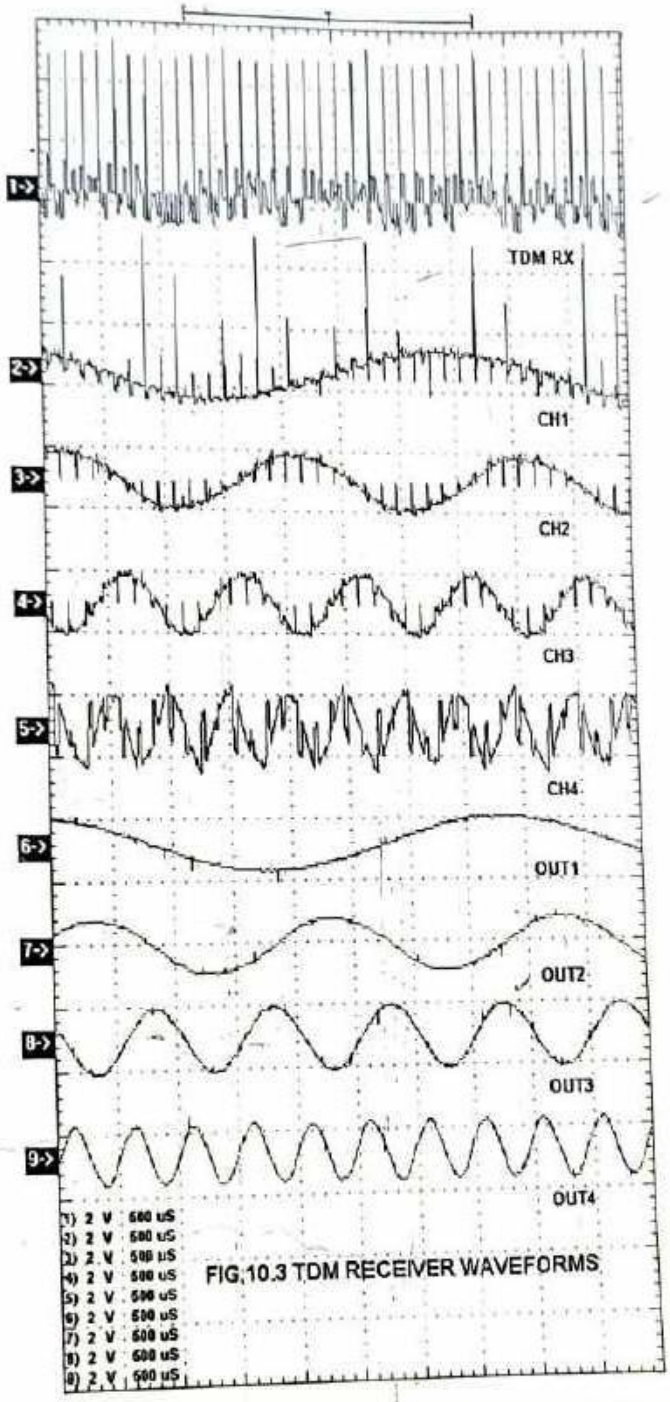


FIG.10.3 TDM RECEIVER WAVEFORMS

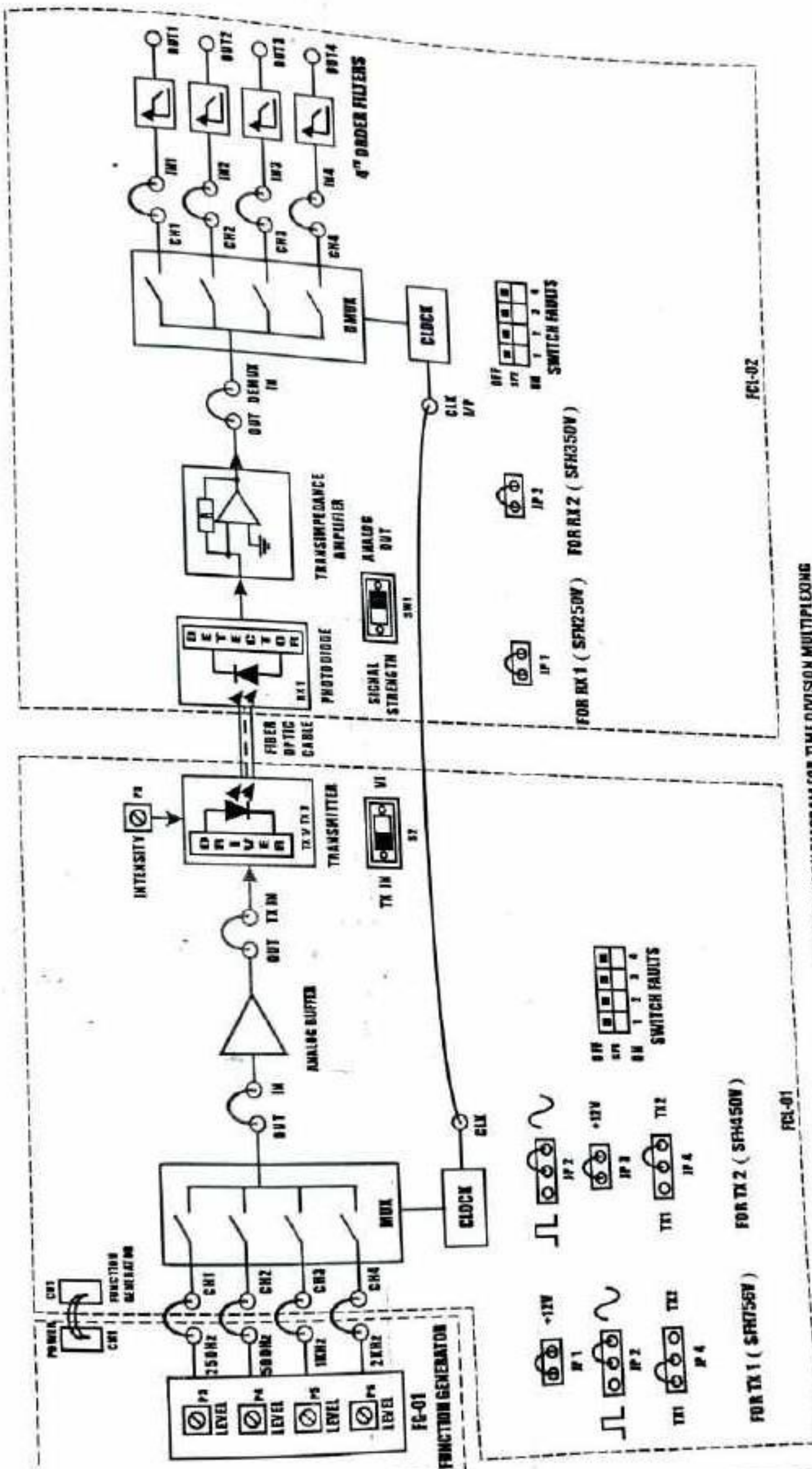


FIG 10.1 BLOCK DIAGRAM FOR TIME DIVISION MULTIPLEXING

1

EXPERIMENT NO.1

NAME:

Setting Up a Fiber Optic Analog Link

OBJECTIVE:

The objective of this experiment is to study a 660 nm/ 950 nm Fiber Optic Analog Link. In this experiment you will study the relationship between the input signal & received signal.

THEORY:

Fiber Optic Links can be used for transmission of digital as well as analog signals. Basically a fiber optic link contains three main elements, a transmitter, an optical fiber & a receiver. The transmitter module takes the input signal in electrical form & then transforms it into optical (light) energy containing the same information. The optical fiber is the medium, which carries this energy to the receiver. At the receiver, light is converted back into electrical form with the same pattern as originally fed to the transmitter.

Transmitter

Fiber optic transmitters are typically composed of a buffer, driver & optical source. The buffer electronics provides both an electrical connection & isolation between the transmitter & the electrical system supplying the data. The driver electronics provides electrical power to the optical source in a fashion that duplicates the pattern of data being fed to the transmitter. Finally the optical source (LED) converts the electrical current to light energy with the same pattern. The LED SFH756V supplied with the kit operates inside the visible light spectrum. Its optical output is centered at near visible wavelength of 660 nm. The emission spectrum is broad, so a dark red glow can usually be seen when the LED is on. The LED SFH450V supplied with the kit operates outside the visible light spectrum. Its optical output is centered at near infrared wavelength of 950 nm.

Receiver

The function of the receiver is to convert the optical energy into electrical form, which is then conditioned to reproduce the transmitted electrical signal in its original form. The detector SFH250V used in the kit has a diode type output. The parameters usually considered in the case of detector are its responsivity at peak wavelength & response time. SFH250V has responsivity of about 4 μA per 10 μW of incident optical energy at 950 nm and it has rise& fall time of 0.01 μ sec.

PIN photodiode is normally reverse biased. When optical signal falls on the diode, reverse current starts to flow, thus diode acts as closed switch and in the absence of light intensity, it acts as an open switch. Since PIN diode usually has low responsively, a trans impedance amplifier is used to convert this reverse current into voltage. This voltage is then amplified with the help of another amplifier circuit. This voltage is the duplication of the transmitted electrical signal.

UIPMENTS:

- FOL-B-P kit
- Dual Channel Oscilloscope
- 1 Meter Fiber cable
- Power Supply

ROCEDURE:

Slightly unscrew the cap of LED SFH 756V TX1 (660 nm) from kit. Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap and assure that the fiber is properly fixed. Now tight the cap by screwing it back. Keep INTENSITY pot P3 at minimum position i.e. fully anticlockwise.

Make the connections and Jumper settings as shown in **FIG. 1.1**. Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF.

Switch on the power supply.

Select the frequency range of Function Generator with the help of Range Selection Jumper**J2**, frequency can be varied with Pot **FREQ**. Adjust the voltage level of the Sine Wave with Pot **LEVEL** as per following setting FREQUENCY: 1KHz, LEVEL: 1Vp-p.

Connect **SINE** post of the Function Generator section to **IN** post of Analog Buffer Section.

Connect **OUT** post of the Analog Buffer Section to **TX IN** post of TRANSMITTER.

Connect the other end of the fiber to detector SFH 250V (RX 1) in kit very carefully as per the instructions in step 1.

Check the output signal of the Analog Buffer at its OUT post in Kit. It should be same as that of the applied input signal.

Observe the output signal from the detector at **ANALOG OUT** post on DSO by adjusting **INTENSITY** (Optical Power Control) Pot **P3** in kit and you should get the reproduction of the original transmitted signal.

To measure the analog bandwidth of the link, connect the external Signal Generator with **1**Vp-p sine wave to **IN** post of Analog Buffer Section and vary the frequency of the input signal from 100Hz onwards. Measure the amplitude of the received signal for each frequency reading.

Plot a graph of gain / Frequency. Measure the frequency range for which the response is flat.

Repeat the procedure **1** to **11** for IR LED 450V (950 nm) TX2.

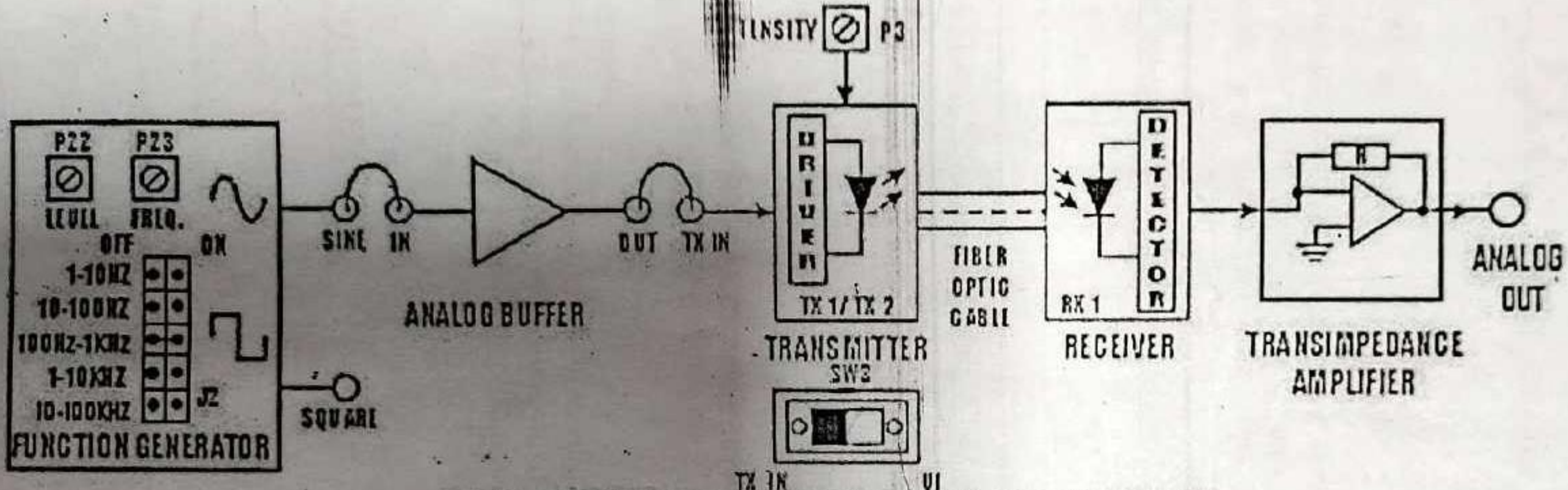
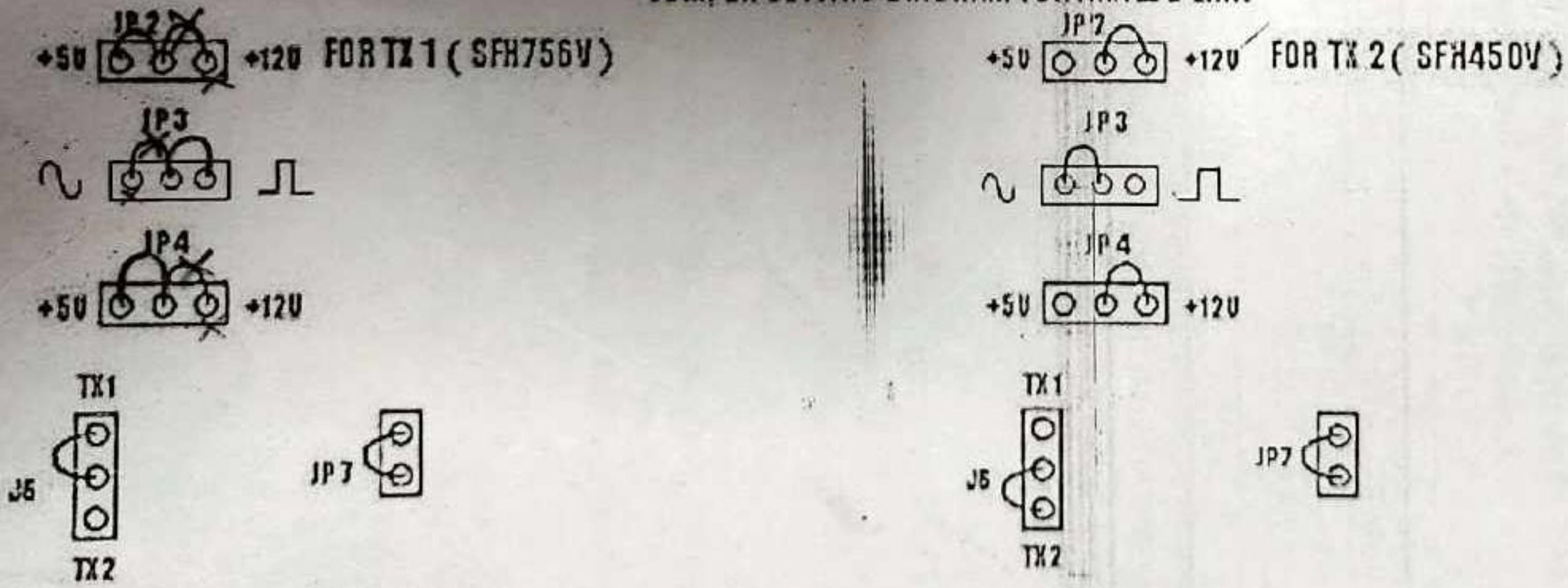


FIG. 1.1 BLOCK DIAGRAM FOR SETTING UP FIBER OPTIC ANALOG LINK

JUMPER SETTING DIAGRAM FOR ANALOG LINK



DEPARTMENT
OF
ELECTRONICS AND COMMUNICATION ENGINEERING

EC352
Fiber Optic Communication Lab

LAB INSTRUCTIONS FOR CARRYING OUT PRACTICAL

ON

Characterization of Erbium Doped Fiber Amplifier (EDFA)

BIRLA INSTITUTE OF TECHNOLOGY
MESRA RANCHI

Name of the Experiment:

Characterization of Erbium Doped Fiber Amplifier (EDFA)

AIM: 1: Setting up the fiber optic link with EDFA.
2: Measurement of Gain of EDFA.

APPARATUS REQUIRED:

1. EDFA-kit containing,
   i) 980 nm and 1550 nm laser sources,
   ii) WDM multiplexer and demultiplexer,
   iii) EDF
   iv) Photodetector
2. SC-SC single mode fiber optic patch chords
3. Fiber Optic Power Meter

THEORY

Erbium-Doped Fiber Amplifier (EDFA) is an optical amplifier used in the C-band and L-band, where loss of telecom optical fibers becomes lowest in the entire optical communication bands. Invented in 1987, EDFA is now most used to compensate the loss of an optical fiber in long-distance optical communication. Another important characteristic is that EDFA can amplify multiple optical signals simultaneously, and thus can be easily combined with WDM technology.

Before the invention of EDFA, a long optical fiber transmission line required a complicated optical-to-electrical (O-E) and E-O converter for signal regeneration. The use of EDFA has eliminated the need for such O-E and E-O conversion, significantly simplifying the system. This is especially of use in a submarine optical transmission, where more than a hundred EDFA repeaters may be needed to construct one link. The TPC-5CN (Trans-Pacific Cable 5 Cable Network), started its operation in 1996, is the first submarine optical fiber network which employed EDFA.

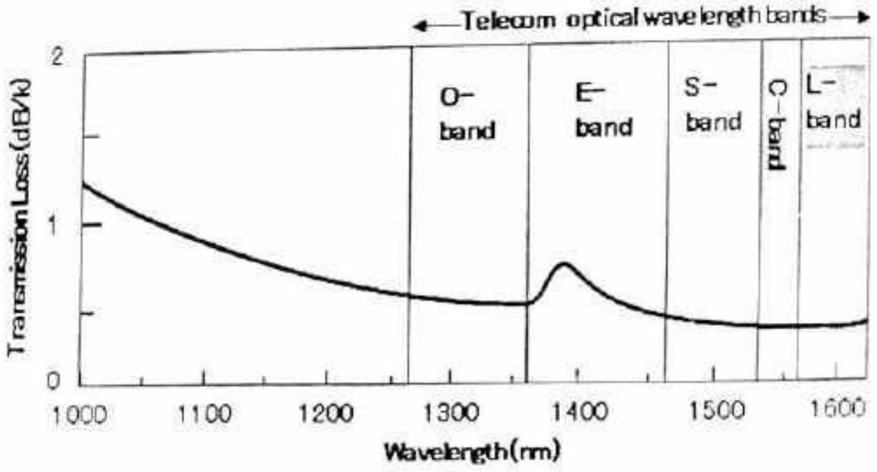


Figure 1: Optical telecommunication optical bands (EDFA operates in the C- and L-band).

Working Principle of EDFA

The EDFA works on the principles of optical pumping and stimulated emission. Commonly, 980 nm or 1480 nm lasers are used to optically pump Er^{3+} ions to higher energy bands. The purpose of optical pumping is to achieve a population inversion, where there are more ions in a higher energy band than there are in the ground energy band. It is necessary for optical gain; otherwise, the rate of optical signal photons absorbed by the erbium-doped fiber will be greater than the rate generated by stimulated emission. Figure 2 illustrates a simplified energy diagram of Er, showing how amplification takes place at 1550 nm. Two typical wavelengths to pump an EDFA are 980 or 1480 nm.

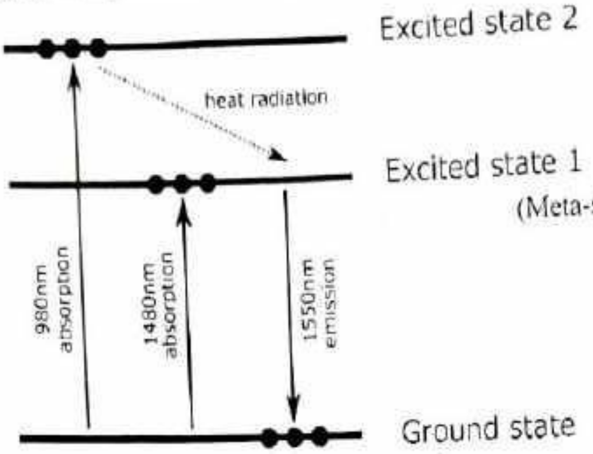


Figure 2: Energy diagram of Erbium.

When an EDFA is pumped at 1480 nm, Er-ion doped in the fiber absorbs the pump light and is excited to an excited state (Excited state-1 in Figure 2). When sufficient pump power is launched to the fiber and population inversion is created between the ground state and Excited state-1, amplification by stimulated emission takes place at around 1550 nm. When an EDFA is pumped at 980 nm, Er-ion absorbs the pump light and is excited to another excited state (Excited state-2 in Figure 2). The lifetime of the Excited state-2 (meta-stable state) is relatively short, and as a result, the Er ion is immediately relaxed to the Excited state-1 by radiating heat (i.e., no photon emission). This relaxation process creates a population inversion between the ground level and Excited state- 1. Once population inversion is achieved, optical gain or amplification is possible via stimulated emission. The Stimulated emission is the process by which an incoming photon of a specific wavelength can interact with an excited atomic electron, causing it to drop to a lower energy level. The liberated energy transfers to the electromagnetic field, creating a new photon with a frequency, polarization, and direction of travel that are all identical to the photons of the incident wave. This is in contrast to spontaneous emission, where photons are emitted spontaneously due to transition of atomic electrons from higher to lower energy state regardless of the external photon. After stimulated emission, the new photons can then continue down the fiber to stimulate the emission of more photons with the same optical phase and direction. Therefore, the optical signal will be amplified many times larger. This is explained in Figure-3.

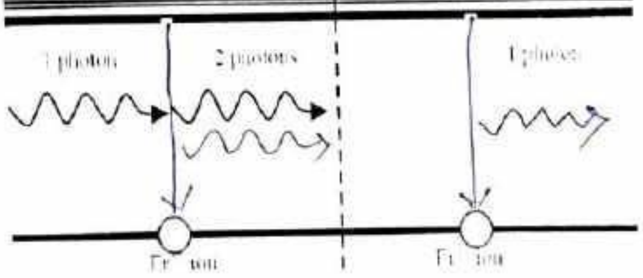


Figure 3. Photons emitted by excited erbium ions through (a) stimulated emission by another photon, and (b) spontaneous decay

The EDFA can be characterized by two parameters

(A) Measurement of the small signal gain:

The gain of an amplifier is defined as the ratio of output signal power to input signal power, with the output signal power corrected for the ASE noise of the EDFA, where P_{in} and P_{out} are the respective input and output signal powers in Watts, and P_{ASE} is the ASE noise power in Watts at the signal wavelength. The small-signal gain region is considered the range of input signal powers where the signal amplification does not significantly reduce the gain of the amplifier. In this situation, it is assumed that the rate of erbium ions excited into the metastable energy level is greater than the rate of stimulated emission. Therefore, the gain will remain constant as the input signal power is increased.

(B) Measuring Gain Saturation

Gain saturation is experienced when the metastable energy level population is severely depleted by a high rate of stimulated emission, as when the input signal power is sufficiently high. For a fixed pump power, the rate of erbium ions excited for population inversion will be constant. As the input signal power is increased past the small-signal region, the more photons will enter the erbium-doped fiber stimulating emission of photons and depleting the metastable energy level faster than it can be filled. Therefore, the amplification will reach a limit and the gain will decrease with increasing input signal power.

PROCEDURE

(A) Measuring Small-Signal Gain

1. Turn on power supply.
2. Switch ON the system from the back panel. Connect Shielded USB cable from system to the PC. Check if the USB connection is detected at PC end.
3. Run FOL-EDFA Software installed in PC.
4. When asked for the COM-Port, select the appropriate COM-Port assigned by the driver and click "OK".
5. Go to the Continuous Wave Mode and Turn the power supply ON.
6. Turn on the 1550 nm signal source and 980 nm Pump source. Press Run.
7. You will find that the two sliders in the right panel for 1550 nm and 980 nm are enabled.
8. Now you can vary the slider and change the signal source current as well as pump source current.
9. Connect the signal source @ 1550 nm and Pump source @ 980 nm to input of the WDM1. Common output of WDM1 should be connected to one of the ports of EDF. The other end of EDF should be connected to common port of WDM2.
10. Output signal power @ 1550 nm and pump power @ 980 nm after passing through EDF can be measured using power meter at 1550 nm and 980 nm ports of WDM2.
11. To set the approx. 13 mW of Pump power at WDM1 common port slide 980 nm slider to 46 count position.
12. For small signal gain measurement, we need to vary the signal power from 100 nW to 100 μW. For this, initially set 1550 nm slider at 51 count where power is approx. 150 nW.
13. The gain equation is

$$\text{Gain} = (P_{out} - P_{ASE}) / P_{in}$$

[Note: ASE power at 13 mW of Pump power is practically calculated using spectrum analyzer over a wavelength range of 1551 nm to 1552 nm, which is 2.911 μW]

14. To calculate the amplified output power of 1550 nm use 2nd WDM and connect the EDFA output to common port of WDM2 and read the output power at 1550 nm port of WDM2.
15. Use the input, output, ASE powers from above measurements to calculate the gain.

16. Repeat the gain measurement procedure for incremental values of input signal power.
17. Plot the graph for the gain. You will find that Gain remains approximately constant for input signal power range of 100 nW to 100 μW. Plot Gain Vs. Pin (dB)

(B) Measuring Gain Saturation

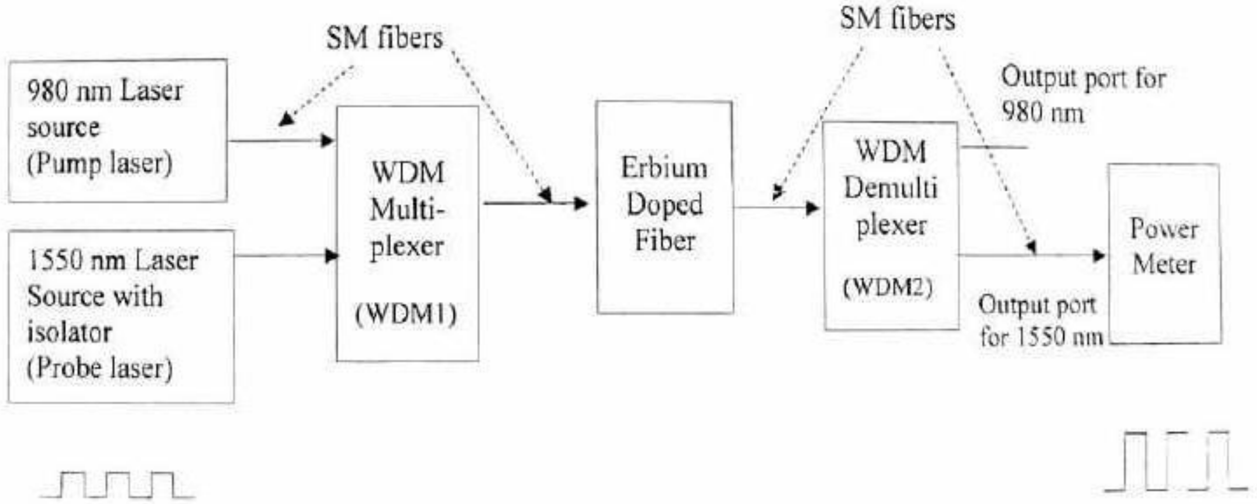
1. Turn on power supply.
2. Switch ON the system from the back panel. Connect Shielded USB cable from system to the PC. Check if the USB connection is detected at PC end.
3. Run FOL-EDFA Software installed in PC.
4. When asked for the COM-Port, select the appropriate COM-Port assigned by the driver and click "OK".
5. Go to the Continuous Wave Mode and Turn the power supply ON.
6. Turn on the 1550 nm Signal source and 980 nm Pump source. Press Run.
7. You will find that the two sliders in the right panel for 1550 nm and 980 nm are enabled.
8. Now you can vary the slider and change the signal source current as well as pump source current.
9. Connect the signal source @ 1550 nm and Pump source @ 980 nm to input of the WDM1. Common output of WDM1 should be connected to one of the port of EDF. The other end of EDF should be connected to common port of WDM2.
10. Output signal power @ 1550nm and pump power @ 980 after passing through EDF can be measured at 1550 nm and 980 nm ports of WDM2.
11. To set the approx. 13 mW of Pump power slide 980nm slider to 46 count position.
12. For measuring gain saturation, we need to vary the signal power from 100 nW to 100 μW. For this, initially set 1550nm slider at 51 count where power is approx. 150 nW.
13. The gain equation is

$$\text{Gain} = (P_{out} - P_{ASE}) / P_{in}$$

[Note: ASE power at 13 mW of Pump power is practically calculated using spectrum analyzer over a wavelength range of 1551 nm to 1552 nm, which is 2.911μW]

14. To calculate the amplified output power of 1550 nm use 2nd WDM and connect the EDFA output to common port of WDM2 and read the output power at 1550nm port of WDM2.
15. Use the input, output, ASE powers from above measurements to calculate the gain.
16. Repeat the gain measurement procedure for incremental values of input signal power.
17. Plot the graph for the gain. You will find that Gain reduces even after increase in the input signal power. *[Remember we need to increase the input signal power past the small-signal region]*

EXPERIMENTAL SETUP



(Modulating signal for 1550 nm)

(Amplified signal)

Observation and Calculation

A) Measuring Small-Signal Gain

Set, Pump Power @ 980 nm =40 mW / Count=51 by Power meter set at $\lambda = 980$ nm — 300 mW

$\underline{52} \rightarrow 387$ μmW

↳ 46 mW / Count = 49

Vary source power @ 1550 nm from 100 nW (count=50) ↳ by power meter (same), $\lambda = 1550$ nm 105.9

Assume, P_{ASE}=1 mW

P_{ASE} = 1 mW always

Sl. No.	Source 1550 nm		O/p Power at 1550 nm (P_{out}) (mW)	Gain P_{out}/P'_{in} $(P_{out}-P_{ASE})/P_{in}$	Gain in dB
	Count	Power (P_{in}) (nW)			
1	50	105.9 nW	1.402 mW	1.402 − 1.00 = 0.402 mW	0.
2	51	127.3 "	1.410		
3	52	152.0 "	1.419		
4	53	180.7	1.462		
5	54	225.6	1.475		
6	55	267.3	1.462		
7	56	314.0			
8	57	370.6			
9	58	439.5			
10	~~30~~ 59	579.9			

Plot Gain (dB) vs. P_{in}

A) Measuring Gain Saturation

Set, Pump Power @ 980 nm =40 mW / Count=51

Vary source power @ 1550 nm past the small signal region

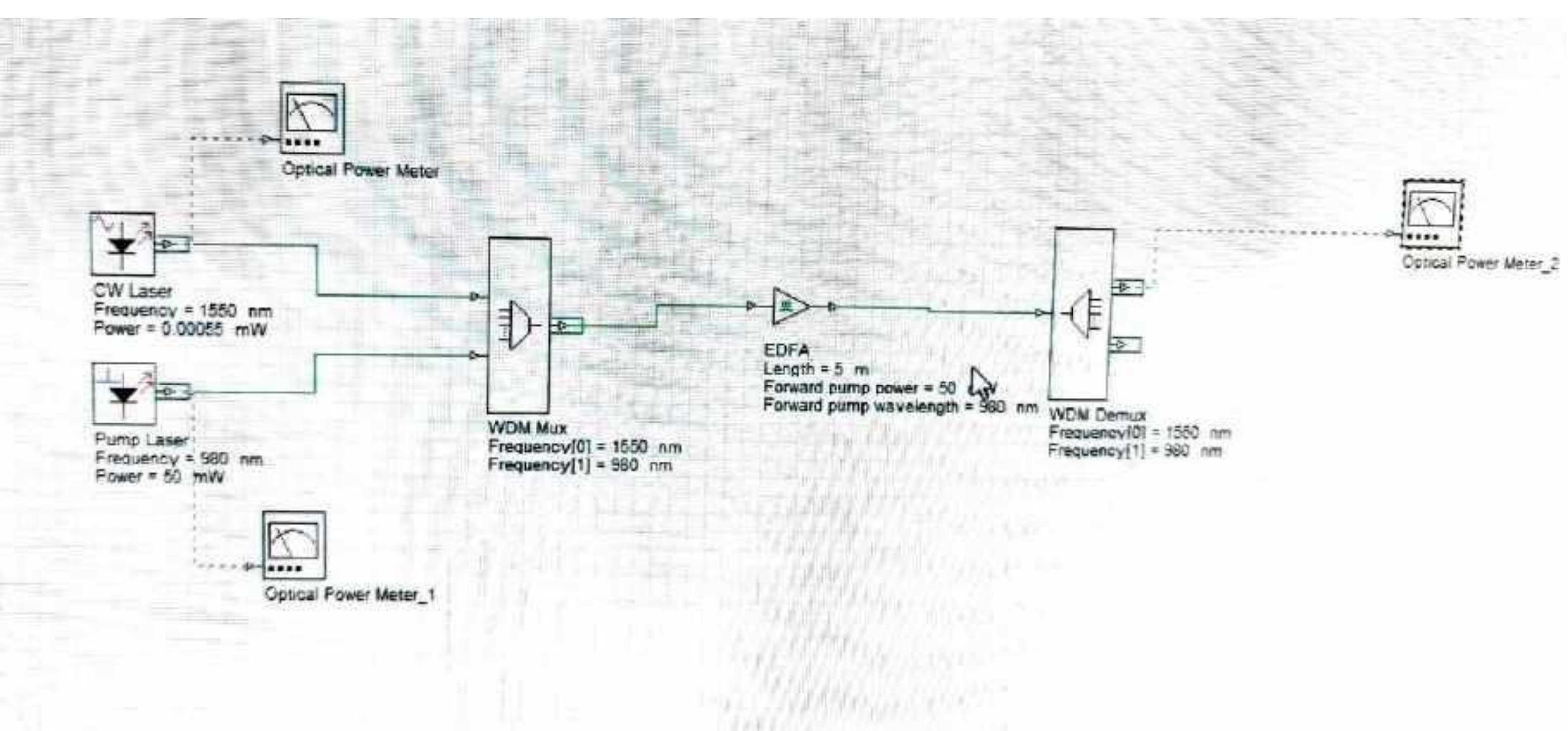
Assume, P_{ASE}=1 mW

When 1550 nm removed, P_{out} = 1.30 mW @ 51 count for 980

P_{ASE} = 1.00 mW

Sl. No.	Source 1550 nm		O/p Power at 1550 nm (P_{out})	Gain $(P_{out}-P_{ASE})/P_{in}$	Gain in dB
	Count	Power (P_{in})			
1	60.	623.7			
2	61	732.8			
3	62	879.0			
4	63	1.035 mW			
5	64	1.205 "			
6	65	1.412 "			
7	66	1.702 "			
8	67	1.849 "			
9	68	14.0			
10					

Conclusion:



Optical Power Meter
CW Laser
Frequency = 1550 nm
Power = 0.00055 mW
Pump Laser
Frequency = 980 nm
Power = 50 mW
Optical Power Meter_1
WDM Mux
Frequency[0] = 1550 nm
Frequency[1] = 980 nm
EDFA
Length = 5 m
Forward pump power = 50 mW
Forward pump wavelength = 980 nm
WDM Demux
Frequency[0] = 1550 nm
Frequency[1] = 980 nm
Optical Power Meter_2

not least is the security aspect. It is very, very difficult to tap into a fiber cable to read the data signals.

You will learn soon that fiber optic communication is indeed a simple technology, closely related to electronics. In fact, it was research in electronics that set the stage for fiber optics to develop into the communication giant that it is today.

What is fiber-optic communication?

A fiber-optic communication system is a communication system in which the transmitter and receiver are linked by fiber-optic cable. At the transmitter, light is shone into the cable. This travels down the fiber-optic cable, and can be detected at the receiver.
If we change the brightness of the light beam at the transmitter, we can detect this change in brightness at the receiver-this allows us to send information over the fiber-optic link.

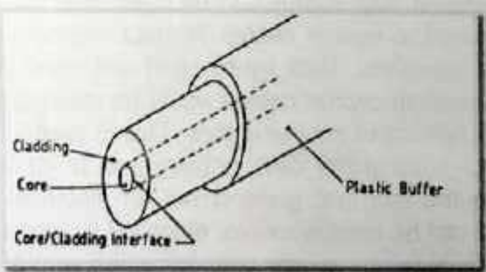
Why use light?

Fiber-optic cables have a number of advantages over metal cables when it comes to communication systems. They:

- Have smaller diameters
- Are lighter in weight and more flexible
- Allow much greater distance to be covered without any amplifiers / electronics
- Have extremely large bandwidths
- Provide electrical isolation between transmitter and receiver
- Naturally insulate between any electromagnetic wave energy i.e. it is extremely difficult to eavesdrop)
- Are immune to interference due to other people's electrical equipment.

What is an optical fiber?

An optical fiber is basically a light wave-guide, which transmits energy at optical frequencies. It consists of a central transparent core down which the light travels, surrounded by a layer of transparent cladding, which creates an optical interface at the core/cladding boundary as shown in Figure.

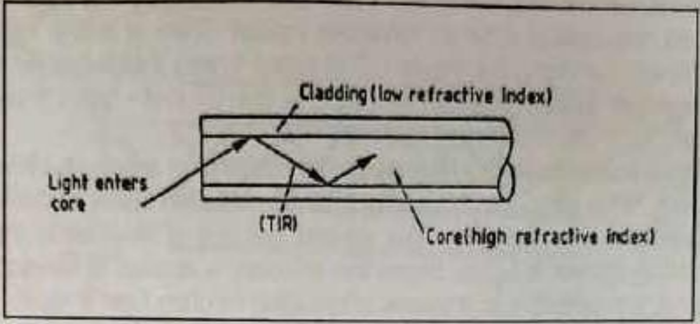


Construction of a fiber Optic cable

The core and cladding may be made from either **glass** or **plastic**, and non-transparent **plastic buffer** to provide environmental protection surrounds the cladding.

How does light travel down an optical fiber?

Light is transported through the fiber-optic core by continuously being reflected off the Core/cladding interface. This is called **total internal reflection (TIR)**, and is shown in Figure below:

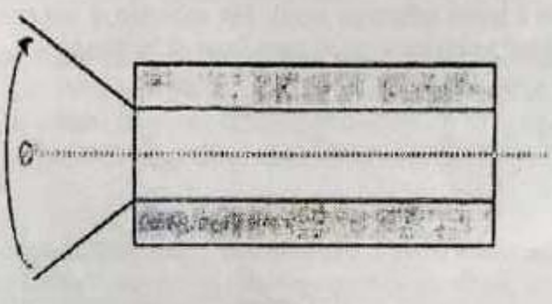


Passage of light along a fiber by total internal reflection

The reflections are made possible by having a high reflective index for the core material and a lower refractive index for the cladding material. To create TIR the core must have a higher refractive index than the cladding, and as we shall see later, the light must not strike the core/cladding interface at too steep an angle.

Acceptance angle and numerical aperture

In order for total internal reflection to take place inside an optic fiber, light rays entering the end of the fiber must fall inside an imaginary 'cone' of angle Φ°, as shown below



Although light rays outside this cone may still enter the fiber, they will hit the core-cladding interface at too steep an angle for TIR to take place, and their energy will be lost into the cladding.

At the far end of the fiber, light will emerge in a similar cone, also of angle Φ. The angle Φ is an important parameter of any fiber-optic cable, and is called the **acceptance angle** of the fiber.

To avoid conversion over units (degrees, radians, etc.), the term numerical aperture is often used in data sheets for optic fibers. The numerical aperture (NA) of a fiber is defined as the sine of half the acceptance angle, i.e. NA=sin (Φ/2)

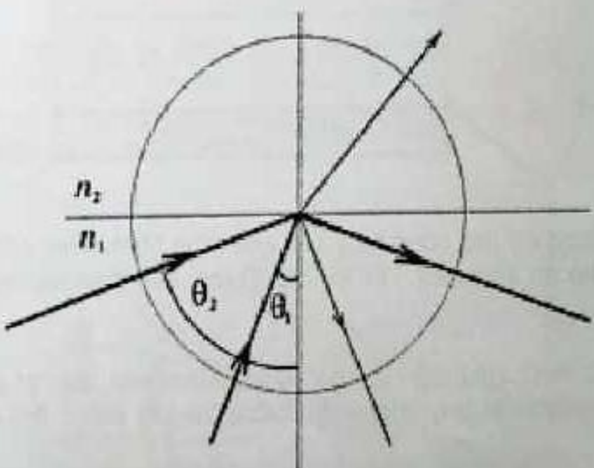
How Optical Fiber Works?

The principle of operation of optical fiber lies in the behavior of light. Light travels in straight line through most optical materials, but that's not necessarily the case at the junction (interface) of two materials of different refractive indices. Think of a fiber cable in terms of a very long cardboard roll (from the inside roll of paper towel) that is coated with a mirror. If you shine a flashlight in one you can see light at the far end - even if you bend the roll around a corner.

Light pulses move easily down the fiber-optic line because of a principle known as the total internal reflection. "This principle of the total internal reflection states that when the angle of incidence exceeds a critical value, light cannot get out of the glass; instead, the light bounces back in as shown in figure. When this principle is applied to the construction of the fiber-optic strand, it is possible to transmit information through fiber lines in the form of light pulses.

Total internal reflection is an optical phenomenon that occurs when light strikes a medium boundary at a steep angle. If the refractive index is lesser on the other side of the boundary, no light can pass through, so all of the light gets reflected effectively. The critical angle is the angle of incidence above which the total internal reflection occurs.

When light crosses a boundary between materials with different refractive indices, the light beam will be partially be refracted at the boundary surface and partially it will get reflected. However, if the angle of incidence is shallower (closer to the boundary) than the critical angle (the angle of incidence where light is refracted so that it travels along the boundary), then the light will stop crossing the boundary altogether, instead it will reflect back totally internally. This can only occur where light travels from a medium with a higher refractive index to the one with a lower refractive index. For example, it will occur when light passes from glass to air, but not when light would pass from air to glass.

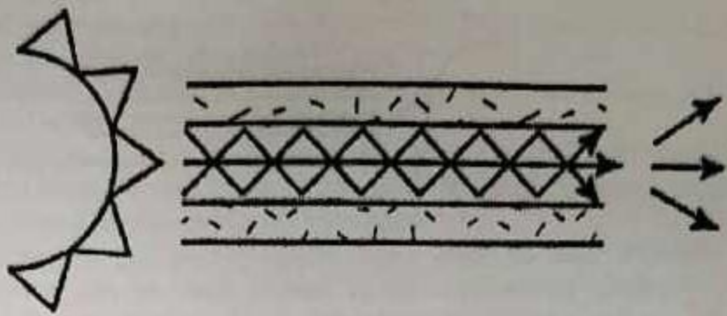


Total internal reflection

Types of Optical Fibers

The three types of fiber optic cables commonly used are as follows:

- Single Mode
- Multimode
- Plastic Optical Fiber (POF)



Fiber optic cable functions as a 'light guide', guiding the light introduced at one end of the cable to the other end. The light source can either be a light-emitting diode (LED) or a laser.

The light source is pulsed on and off, and a light-sensitive receiver on the other end of the cable converts the pulses back into the digital ones and zeros, of the original signal.

Even laser light shining through a fiber optic cable is subject to loss of strength, primarily through dispersion and scattering of the light, within the cable itself. The faster the laser fluctuates, the greater the risk of dispersion. Light strengtheners, called repeaters, may be necessary to refresh the signal in certain applications.

While fiber optic cable itself has become cheaper over time - an equivalent length of copper cable costs lesser per foot, but not in capacity. Fiber optic cable connectors and the equipment required to install them are more expensive than their copper counterparts.

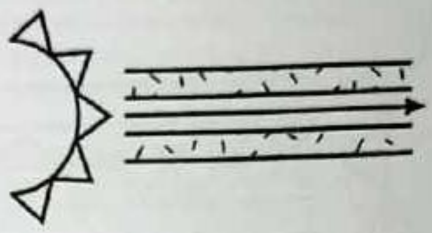
Single Mode Cable

It is a single strand of glass fiber with a diameter of 8.3 to 10 microns that has one mode of transmission. Single Mode Fiber with a relatively narrow diameter, through which only one mode will propagate typically 1310nm or 1550nm, carries higher bandwidth than multimode fiber, but requires a light source with a narrow spectral width.

Single-mode fiber gives you a higher transmission rate and up to 50 times more distance than multimode, but it also costs more. Single-mode fiber has a much smaller core than multimode. The small core and single light-wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type.

Single-mode optical fiber is an optical fiber in which only the lowest order bound mode can propagate at the wavelength of interest, typically 1300nm to 1320nm.

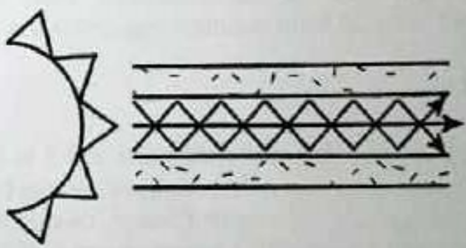
"Single mode fiber"
single path through the fiber



Multimode Cable

It is made of glass fibers, with common diameters in the 50-to-100 micron range for the light carry component (the most common size is 62.5µm). Multimode fiber gives you high bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths, or modes, as they travel through the cable's core, typically 850nm or 1300nm. Typical multimode fiber core diameters are 50, 62.5, and 100 micrometers. However, in long cable runs (greater than 3000 feet [914.4 meters]), multiple paths of light can cause signal distortion at the receiving end, resulting in an unclear and incomplete data transmission.

"Multimode fiber"
multiple paths through the fiber



Plastic Optical Fiber (POF)

It is a newer plastic-based cable which promises performance, similar to glass cable on very short runs, but at a lower cost.

Advantages of Fiber Optics over Conventional Copper Cables

- **Less expensive** - Several miles of optical cable can be made at cheaper rates compared to equivalent lengths of copper wires. This saves your service providers (cable TV, Internet) and your money too.
- **Thinner** - Optical fibers can be drawn to smaller diameters than copper wire.
- **Higher carrying capacity** - Optical fibers are thinner than copper wires, therefore, more fibers can be bundled within a given diameter cable than the copper wires. This allows more phone lines to go over the same cable or more channels to pass through the cable into your cable TV box.
- **Less signal degradation** - The loss of signal in optical fiber is lesser than that observed in copper wires.
- **Light signals** - Unlike electrical signals in copper wires, light signal from one fiber does not interfere with those of the other fibers in the same cable. This means clearer phone conversations or TV reception.
- **Low power** - Signals in optical fibers degrade less; therefore, lower-power transmitters can be used instead of the high-voltage electrical transmitters, as required for copper wires. Again, this saves your provider and your money.
- **Digital signals** - Optical fibers are ideally suited for carrying digital information, which is especially useful in computer networks.
- **Non-flammable** - No electricity is passed through optical fibers; therefore, there is no fire hazard.
- **Lightweight** - An optical cable weighs lesser than a comparable copper wire cable. Also, Fiber-optic cables take very little space in the ground.
- **Flexible** - Fiber optics is very flexible and can transmit and receive light effectively; therefore, they are used in many flexible digital cameras for the various purposes. Some of the examples are mentioned below:
    - **Medical imaging** – Used in bronchoscopes, endoscopes and laparoscopes.
    - **Mechanical imaging** – To inspect mechanical welds along pipes and engines (airplanes, rockets, space shuttles, cars).
    - **Plumbing** - To inspect sewer lines.

With all the above properties of optical fiber, it is becoming very important in sensing fields too. Most of the properties of optical fiber are useful in sensors. Further, optical fiber sensors offer extreme sensitivity & can be used to sense almost any physical parameters like temperature, velocity, current, voltage etc.

INTRODUCTION OF EDFA

Similar to electrical signaling over a wire, optical signals attenuate as they travel through an optical fiber. To compensate for this attenuation, erbium-doped fiber amplifiers (EDFAs) are commonly used to amplify the optical signal in the 1550 nm range. Inside an EDFA is a length of optical fiber with erbium ions (Er^{3+}) inserted within its core during fabrication. This type of fiber is called erbium-doped fiber, and is the key component in amplifying an optical signal in an EDFA

Energy Diagram

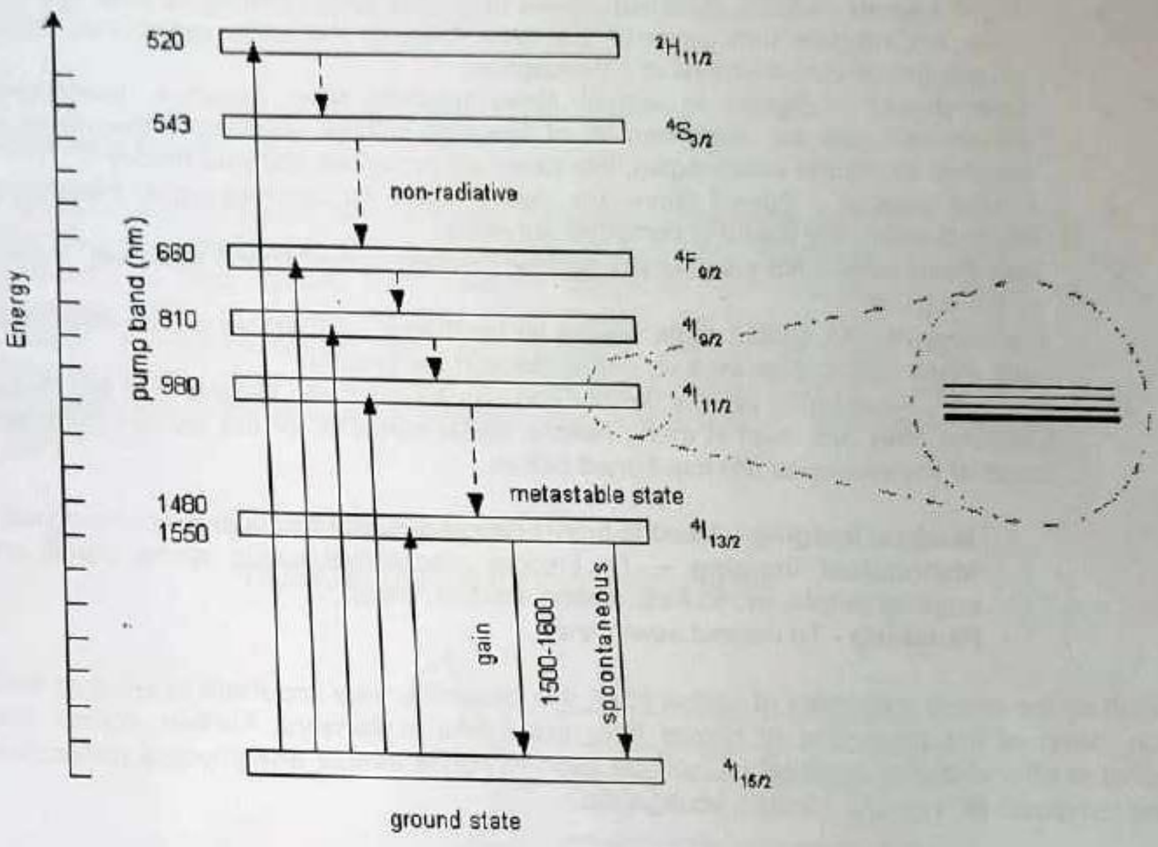


Figure 1. Energy level diagram of the erbium ion (Er^{3+}). Inset shows that the energy levels are bands of smaller energy levels.

Optical Pumping

Commonly, 980 nm or 1480 nm lasers are used to optically pump Er^{3+} to higher energy bands. The purpose of optical pumping is to achieve a **population inversion**, where there are more ions in a higher energy band than there are in the ground energy band. It is necessary for optical gain; otherwise the rate of optical signal photons absorbed by the erbium-doped fiber will be greater than the rate generated by stimulated emission. A **metastable** energy level at $^4I_{13/2}$, with a long decay time (~10 ms), is essential for collecting ions for a population inversion. Increasing the pump power will also increase the rate of ions excited to higher energy bands for population inversion.

The 980 nm pump wavelength is considered a three-level system where a 980 nm photon excites an erbium ion with enough energy to jump from the ground energy band $^4I_{15/2}$ to the $^4I_{11/2}$ energy band. Once there, the ion quickly decays (~2 µs) to the $^4I_{13/2}$ metastable energy level by emitting heat, and then awaits stimulated or spontaneous emission to take the ion back down to the ground energy band. This pump wavelength gives the best EDFA noise performance but requires a higher degree of wavelength accuracy because of its narrow absorption band.

The 1480 nm pump wavelength is considered a two-level system where a 1480 nm photon excites an erbium ion in the ground energy band $^4I_{15/2}$ to the metastable energy level $^4I_{13/2}$. Once there, the ion awaits stimulated or spontaneous emission to take the ion back down to the ground energy band. This pump wavelength has the advantages of having high pump power laser diodes available, good power efficiency due to the small energy difference between 1480 nm and 1550 nm, a broad absorption spectrum that is less demanding on the wavelength accuracy of the pump laser, and lower attenuation in optical fibers for the remote pumping of EDFAs.

Optical Gain and Spontaneous Emission

Once population inversion is achieved, optical gain or amplification is possible. The rate of photons emitted by stimulated emission will now be greater than the rate of those absorbed. Amplification occurs when an optical signal photon arrives at an excited erbium ion along the optical fiber and stimulates its decay from the metastable level $^4I_{13/2}$ to the ground energy band $^4I_{15/2}$. As shown in Figure 2(a), an additional photon with the same optical phase and direction of the original photon is emitted in the decay. The photons can then continue down the fiber to stimulate the emission of more photons with the same optical phase and direction. Therefore the optical signal will be amplified many times larger. A metric of the amplification is the optical gain, which is the ratio of output signal power to input signal power.

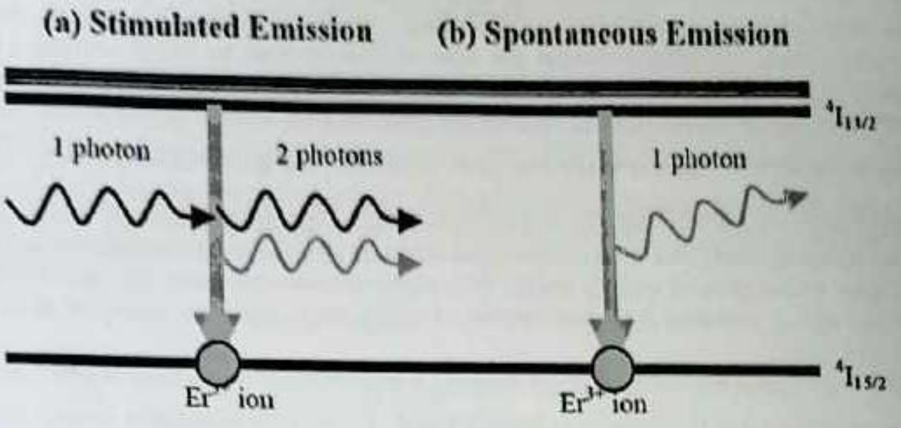


Figure 2. Photons emitted by excited erbium ions through (a) stimulated emission by another photon, and (b) spontaneous decay.

Excited erbium ions that don't interact with incoming photons can decay to the ground energy band spontaneously after 10 ms, and will emit photons random in phase and direction, such as the photon in Figure 2(b). These random photons become a source of optical noise and are amplified to become **amplified spontaneous emission (ASE)**. This ASE degrades the signal-to-noise ratio (SNR) of the optical signal passing through the EDFA.

It should be noted that the decay of the Er^{3+} from the metastable level to the ground energy band emits photons over a span of 1530 to 1565 nm, not only at 1550 nm. This means that any optical signal in this spectrum will be amplified by the erbium-doped fiber. In addition, the ASE noise will also be distributed over this spectrum.

Once the erbium ions reach the ground energy band they are ready to absorb another pump photon to repeat the process again.

Assembling the EDFA

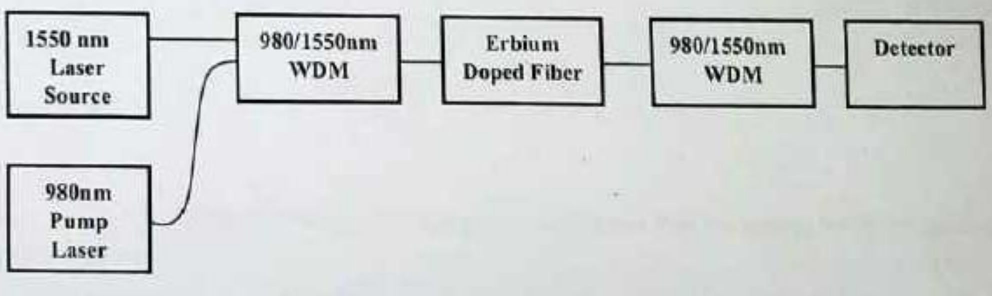


Figure 3. Block diagram of a one stage EDFA.

1. User Safety

Please read the following warnings before proceeding to handle or operate the components.

1. High intensity and invisible light is emitted from the optical output receptacle of the 980 nm Pump Laser and DFB Laser units. Direct irradiation to skin and eyes should be avoided.
2. The equipment cases are fully certified for EMS protection and the user should never attempt to open it, which may result in electric shock and/or EMS attack to vicinity equipments. Note that equipment warranty is valid only with equipment case intact.
3. The user should avoid using any solvent or vaporizing chemicals to clean the equipment panel and case as it may damage the surface and possibly internal circuitries.

2. Components

- The 980 nm Pump Laser

The 980 nm pump laser serves to optically pump the erbium-doped fiber. By controlling the power to the pump laser, the rate of 980 nm photons supplied to the erbium-doped fiber can be tuned

- The 980/1550 nm Wavelength-Division Multiplexer (WDM)

The 980/1550 nm WDM combines the input signal light and pump light into the erbium-doped fiber. It has three ports, Port 1 for 980 nm, Port 2 for 1550 nm, and a Port 3 that can carry light at both 980 and 1550 nm. Inversely, if 980 and 1550 nm light enters Port 3, they will be separated to exit at their respective ports

- The Erbium-Doped Fiber

Erbium-doped fiber looks very much like any ordinary optical fiber. The important difference is that the core of the fiber is implanted with erbium ions. These erbium ions get excited to a higher energy level by the 980 nm photons from the pump laser, then release their energy when 1550 nm input signal photons bump into them, emitting more 1550 nm signal photons. The erbium-doped fiber module has two ports that are direction independent, either port can be used to input light and the other will act as the output port.

- The Optical Filter

The optical filter allows light to pass at a specified wavelength in either direction. The optical filter is used to filter the background ASE source, reducing undesirable noise

- The DFB Laser and Photo-detector

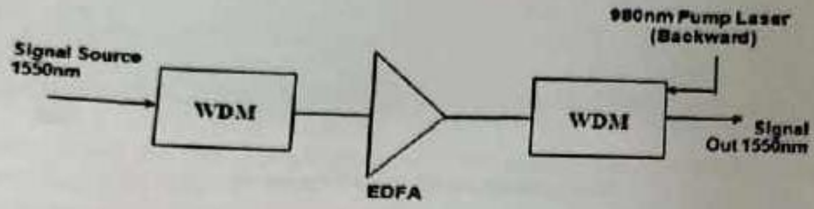
The DFB laser and photo-detector are combined in one case. Both are not normally considered part of the EDFA.

The DFB laser is used as an input signal source for the experiments. Its 1550 nm wavelength is within the amplification bandwidth of the EDFA. Increasing the power to the DFB laser will raise the rate of 1550 nm input signal photons entering the erbium-doped fiber.

The photo-detector is used to detect the amount of optical power in various parts of the experiments.

Experiment No-5

Title: - Implementation of Backward Pumping.



Forward and Backward Pumping

Backward pumping means that the pump wave travels in the opposite direction

Measuring Forward and Backward Pumping

1. Turn on power supply.
2. Switch ON the system from the back panel. Connect Shielded USB cable from system to the PC. Check if the USB connection is detected at PC end
3. Run FOL-EDFA Software installed in PC
4. When asked for the COM-Port, select the appropriate COM-Port assigned by the driver and click 'OK'
5. Go to the Continuous Wave Mode and Turn the power supply ON.
6. Turn on the 1550nm signal source and 980nm Pump source. Press Run.
7. You will find that the two sliders in the right panel for 1550 nm and 980 nm are enabled.
8. Now you can vary the slider and change the signal source current as well as pump source current.

13. ASE power at 13mW of Pump power is practically calculated using spectrum analyzer over a wavelength range of 1551nm to 1552 nm, which is 2.911μW.
14. To calculate the amplified output power of 1550nm use 2[nd] WDM where connect the EDFA output to common port of WDM 2 and read the output power at 1550nm port of WDM2.
15. Use the input, output, ASE powers from above measurements to calculate the gain.

11

DEPARMENT

OF

ELECTRONICS AND COMMUNICATION ENGINEERING

FIBER OPTICS COMMUNICATION LABORATORY

LAB INSTRUCTIONS FOR CARRYING OUT PRACTICAL

ON

MANCHESTER CODING & DECODING IN OPTICAL FIBER LINK (SIMULATION)

BIRLA INSTITUTE OF TECHNOLOGE

MESRA, RANCHI

EXPERIMENT NO. 10

AIM

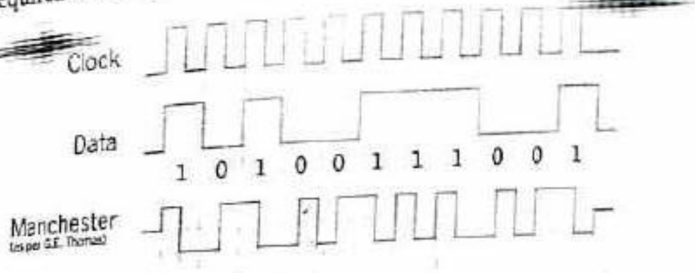
Manchester Coding & Decoding in Optical Fiber Link (Simulation)

OBJECTIVE

The objective of this experiment is to study the techniques of Manchester Coding & Decoding in ... communication.

THEORY

In telecommunication and data storage, Manchester coding (also known as phase encoding, or PE) ... line code in which the encoding of each data bit is either low then high, or high then low, of ... equal time. It therefore has no DC bias, and is self-clocking, which means that it may be inductively or capacitively coupled, and that a clock signal can be recovered from the encoded data. Manchester code always has a transition at the middle of each bit period and may (depending on the information to be transmitted) have a transition at the start of the period also. The direction of the mid-bit transition indicates the data. Transitions at the period boundaries do not carry information. They exist only to place the signal in the correct state to allow the mid-bit transition. The existence of guaranteed transitions allows the signal to be self-clocking, and also allows the receiver to align correctly; the receiver can identify if it is misaligned by half a bit period, as there will no longer always be a transition during each bit period. The price of these benefits is a doubling of the bandwidth requirement compared to simpler NRZ coding schemes.



MANCHESTER CODING

If the data bit is '1' the waveform will be ~~positive~~ high for the first half of the bit cell. For a '0', data bit, the first half of the bit cell will be ~~zero~~ low. The data to be coded and the clock are EX-ORed and the output of the EX-OR gate is the Manchester coded data.

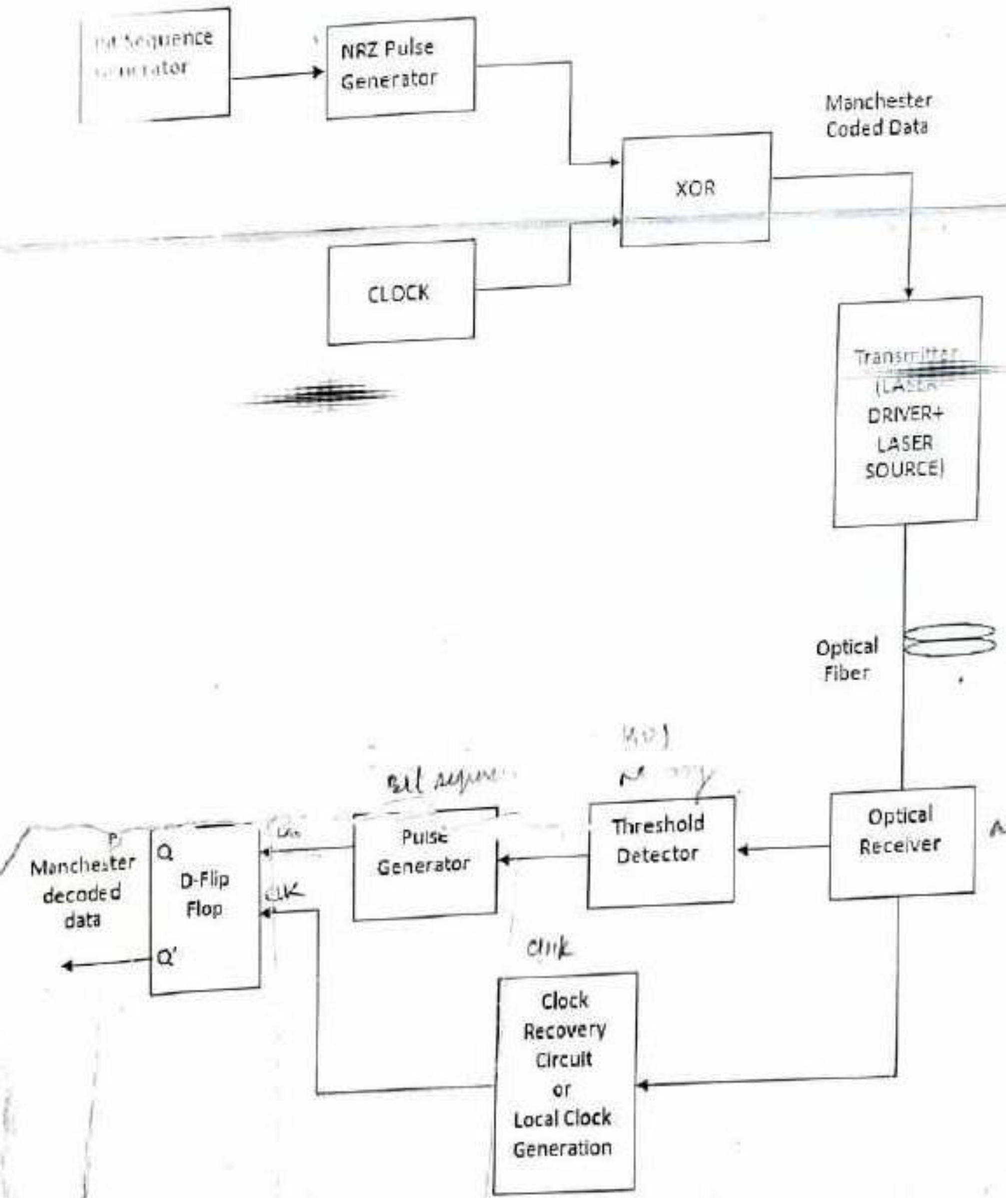
MANCHESTER DECODING

The Manchester coded received data is applied to the input of a D-FF. The clock can be recovered from the coded data itself using a clock recovery circuit. The recovered clock is connected to the clock input of the D-FF. The inverted output of the D-FF would give the Manchester decoded data or the original bit sequence sent. A simple and useful technique for clock recovery is to use a circuit consisting of an Integrator and a MonostableMultivibrator. The received data is integrated using an RC integrator. The output of this integrator is EX-ORed with the received data. The output of this

... gives a low going narrow pulse for each transition of the received data. This signal is ... to a MonostableMultivibrator which is configured to give a high pulse for each high to low ... at its input. The on period of this output waveform is adjusted such that the multivibrator ... the period of the clock pulse used at the transmitter. However, the clock can locally ... and applied to the D-FF if clock recovery circuit is not available.

...: Optisystem(Optiwave) Software

... DESCRIPTION



… the global parametersettings of the design layout as follows: (Double click on the layout)

… 1 bit/s;

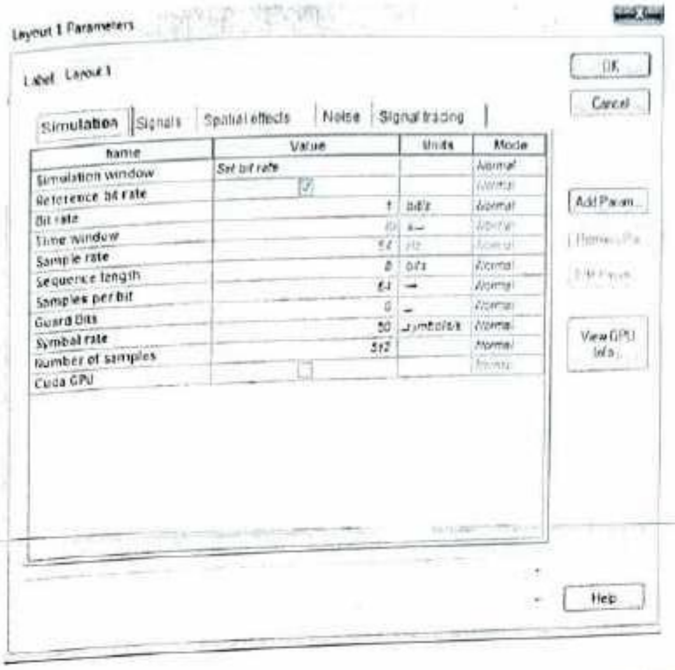
… window: 8 s;

… rate: 64 Hz;

… length: 8 bits;

… per bit: 64;

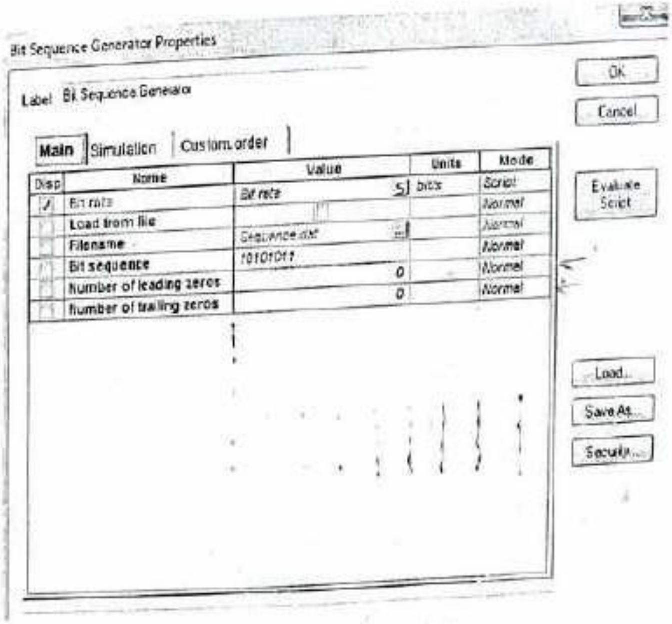
… rate 50 symbols/s;



… generate a sequence of bits as: 10101011 by bit sequence generator. This is the data which will be Manchester-coded and transmitted through optical fiber link.

User defined bit sequence generator

Bit sequence to be entered: 10101011



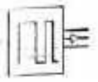
Send the bit sequence to the NRZ Pulse Generator. The binary pulses will be generated according to the bit given sequence. Apply the settings as given below. Observe the waveform usingan oscilloscope visualizer (OSC2) at the output of NRZ Pulse Generator.

Maximum	1
Minimum	0
Peak amplitude	1
DC bias	0
Position	0
Rise time	0
Fall time	0

Label: NRZ Pulse Generator_1

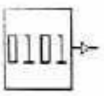
Main | Simulation | Custom order

Disp	Name	Value	Units	Mode
	Rectangle shape	Linear		Normal
	Format for pulse range	Min/Max		Normal
	Maximum	1	a.u	Normal
	Minimum	0	a.u	Normal
	Peak amplitude	1	a.u	Normal
	DC bias	0	a.u	Normal
	Position	0	bit	Normal
	Rise time	0	bit	Normal
	Fall time	0	bit	Normal



NRZ Pulse generator

Generate a clock signal using a bit sequence generator as it was done earlier in Step-2. However, for clock generation the bit sequence to be given as '10' only. The bit rate is twice of the bit rate of input data sequence. Use the following parameters. Observe the waveform using an oscilloscope visualizer (OSC1) at the output of NRZ Pulse Generator.



User defined bit sequence generator

clock Properties

Label: clock [redacted]

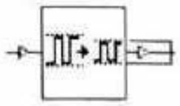
Main | Simulation | Custom order

Disp	Name	Value	Units	Mode
☑	Bit rate	2	bit/s	Normal
☐	Load from file	☐		Normal
☐	Filename	Sequence.dat		Normal
☐	Bit sequence	~~01~~ 10		Normal
☐	Number of leading zeros	0		Normal
☐	Number of trailing zeros	0		Normal

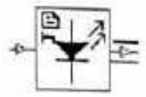
5. The next step is to send the data sequence and the clock signal at the inputs of an EX-OR gate. Place the component 'Electrical XOR' as shown in the design layout.Keep the settings mentioned below. Observe the waveform using an oscilloscope visualizer (OSC3). This is the Manchester coded data.

Threshold	0.5
High level output	1
Low level output	0

... and this data through an optical fiber,design the transmitter section. Use a laser driver and send the Manchester coded data into it. The laser driver should be connected to a laser source. taking (Electrical Rescale)

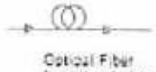


Laser Driver



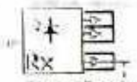
Laser source

... connect the output from laser source to the optical fiber of length 1 km.



Optical Fiber
Length = 1 km

For receiving the Manchester coded data from the optical fiber end, use an optical receiver. Observe the received signal using an oscilloscope visualizer (OSC4). The output of the optical receiver needs to be scaled. Use the component 'Electrical Rescale' and connect it to the output from receiver. Use the setting mentioned.



Optical Receiv

Optical Receiver

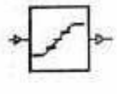
Electrical Rescale

Label: Scale

Main | Simulation | Custom order

Disp	Name	Value	Units	Mode
	Minimum amplitude	0	(a.u.)	Normal
	Maximum amplitude	1	(a.u.)	Normal

9. The output of the receiver is not a binary signal. It is analog in nature. To decide a logic 0 or 1 has been received, the threshold detection is required. Place the element 'M-ary Threshold detector' and connect it after the stage of scaling as given in the design layout.



M-ary Threshold Detector

M-ary Threshold Detector_1 Properties

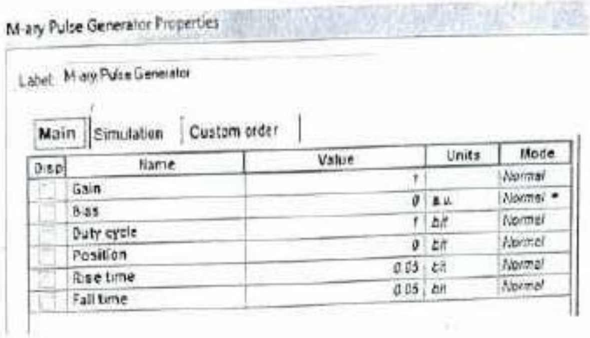
Label: M-ary Threshold Detector_1

Main | Simulation | Random numbers | Custom order

Disp	Name	Value	Units	Mode
	Symbol Rate	Symbol rate 5	symbols/s	Script
	Delay compensation	0	s	Normal
✓	Threshold amplitudes	0.5		Normal
	Decision instant	0.5	Bit	Normal
	Output amplitudes	1 0		Normal

Space

...the threshold detection, it should be converted to the bit sequence. Connect the 'M-ary ...erator at the output of the threshold detector as shown in the diagram. Use the ...settings.Observe the signal using the oscilloscope visualizer (OSC5). This is the ...Manchester... received data.

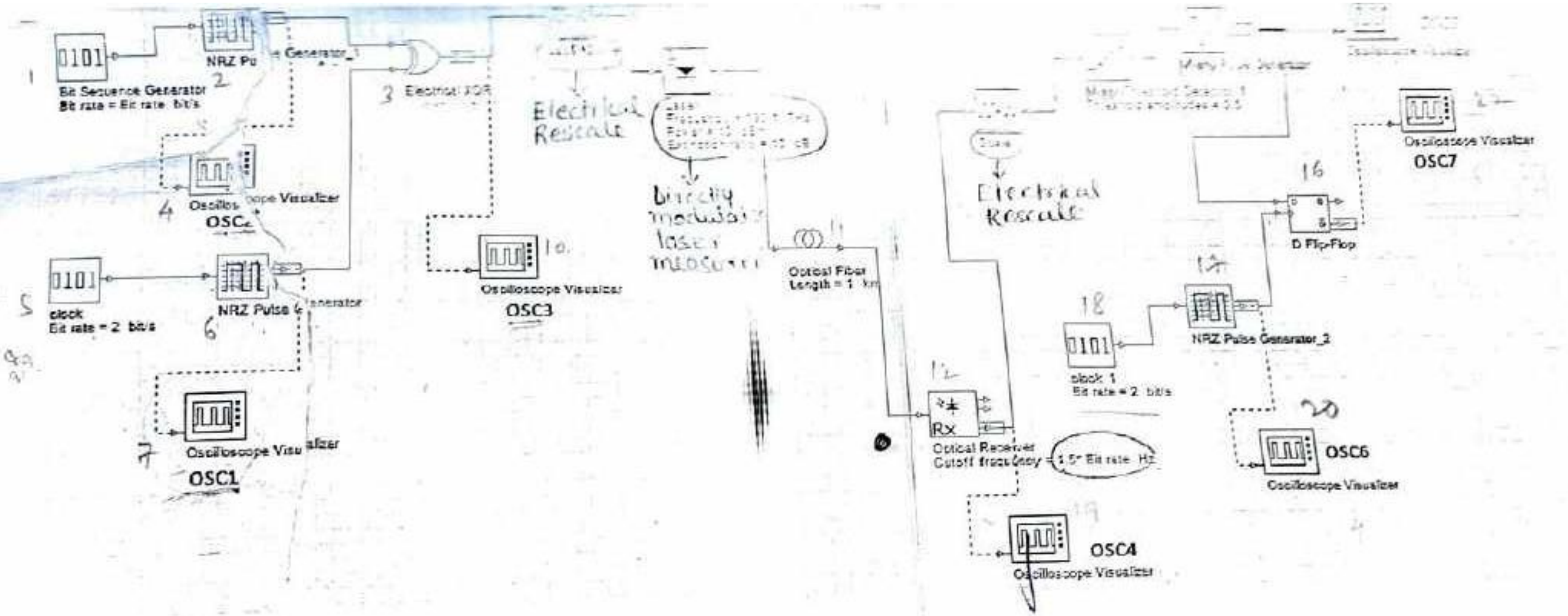

M-ary Pulse Generator Properties

Label: M-ary Pulse Generator

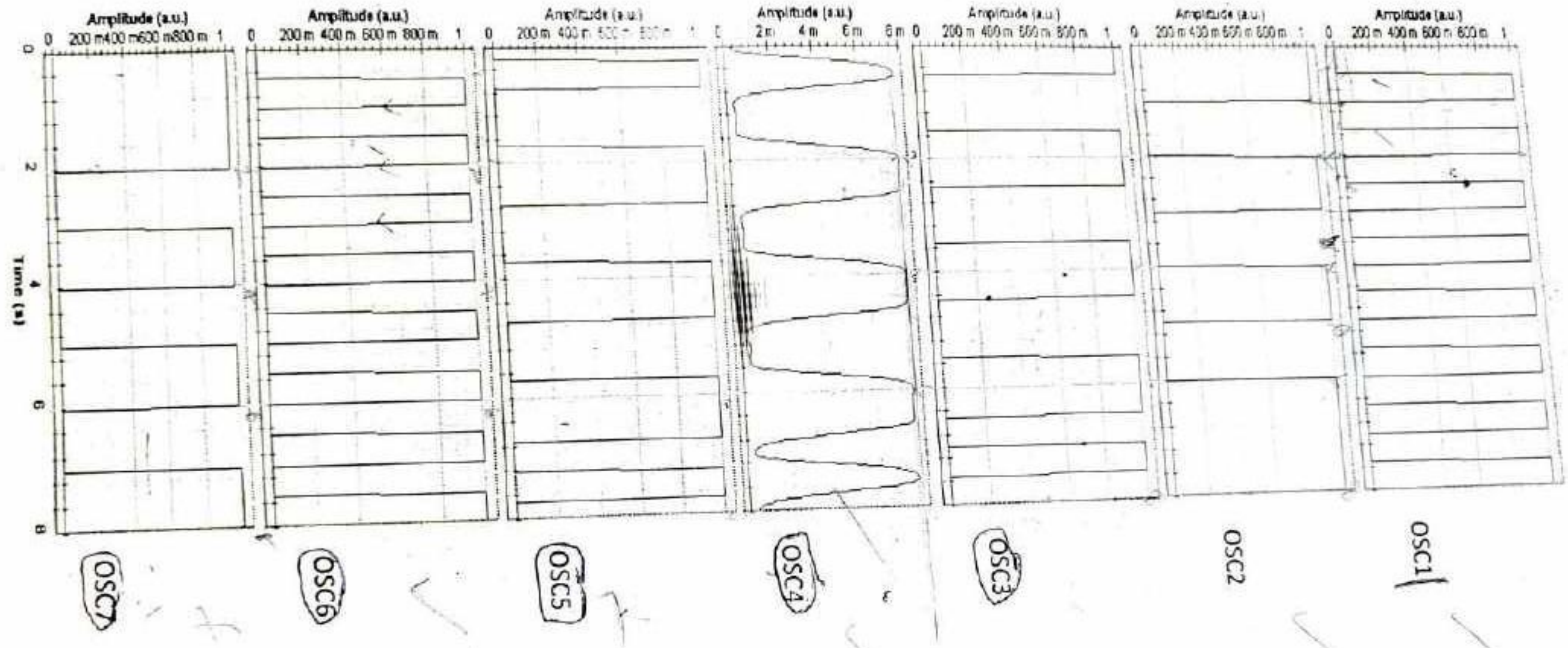
Main | Simulation | Custom order

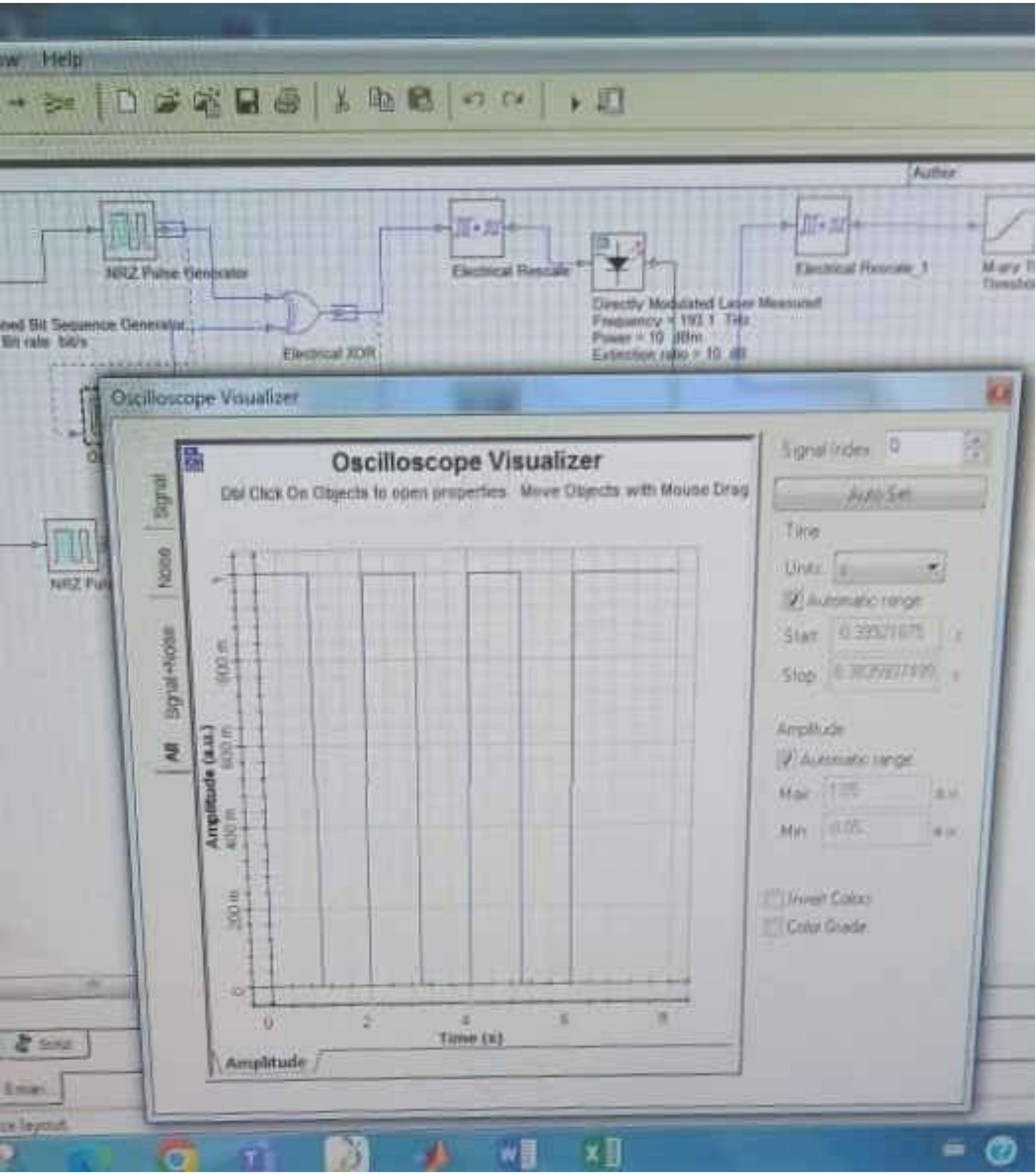
Disp	Name	Value	Units	Mode
	Gain	1		Normal
	Bias	0	a.u.	Normal
	Duty cycle	1	bit	Normal
	Position	0	bit	Normal
	Rise time	0.05	bit	Normal
	Fall time	0.05	bit	Normal

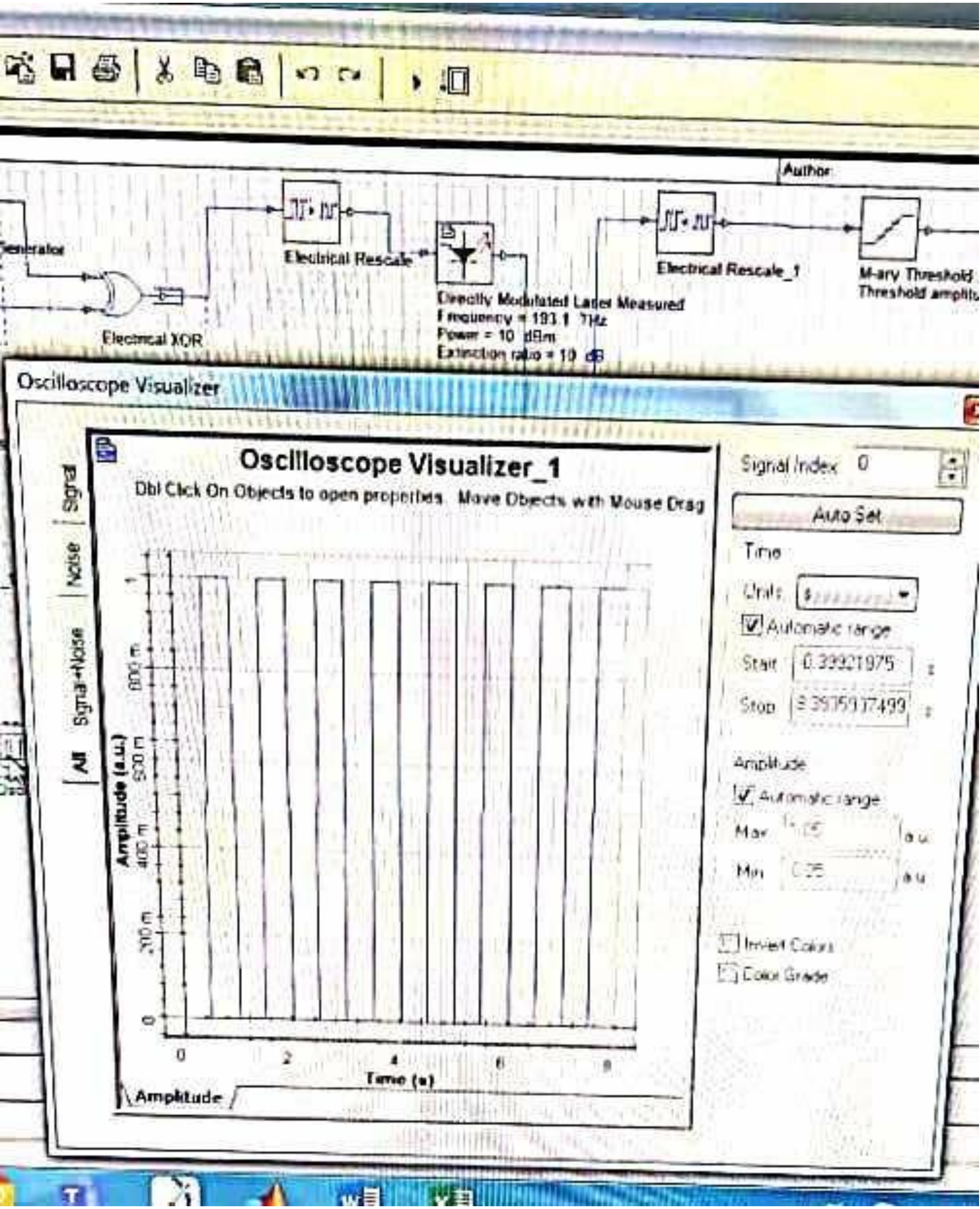
...the Manchester coded received data to the input of a D-FF. Generatea clock locally ...clock recovery circuit is not available] and apply to the D-FF. Generate a clock signal ...using the method given in Step-2 as mentioned in the design layout. Observe the waveform ...at the output (Q') of D-FF using oscilloscope visualizer (OSC7).



DESIGN LAYOUT FOR MANCHESTER CODING AND DECODING USING OPTISYSTEM


Amplitude (a.u.)
0 200 m 400 m 600 m 800 m 1
Time (s)
0 2 4 6 8
OSC7
OSC6
OSC5
OSC4
OSC3
OSC2
OSC1


Help
NRZ Pulse Generator
Electrical Rescale
Electrical Rescale_1
Electrical XOR
Directly Modulated Laser Measured
Frequency = 193.1 THz
Power = 10 dBm
Extinction ratio = 10 dB
Oscilloscope Visualizer
Oscilloscope Visualizer
Dbl Click On Objects to open properties   Move Objects with Mouse Drag
Signal
Noise
Signal+Noise
All
Amplitude (a.u.)
Time (s)
Amplitude
Signal Index
Auto Set
Time
Units
Automatic range
Start
Stop
Amplitude
Automatic range
Max
Min
Invert Colors
Color Grade


Author
Generator
Electrical Rescale
Electrical XOR
Directly Modulated Laser Measured
Frequency = 193.1 THz
Power = 10 dBm
Extinction ratio = 10 dB
Electrical Rescale_1
M-ary Threshold
Oscilloscope Visualizer
Oscilloscope Visualizer_1
Dbl Click On Objects to open properties Move Objects with Mouse Drag
All
Signal+Noise
Noise
Signal
Amplitude (a.u.)
Time (s)
Amplitude
Signal Index
Auto Set
Time
Units
Automatic range
Start
Stop
Amplitude
Automatic range
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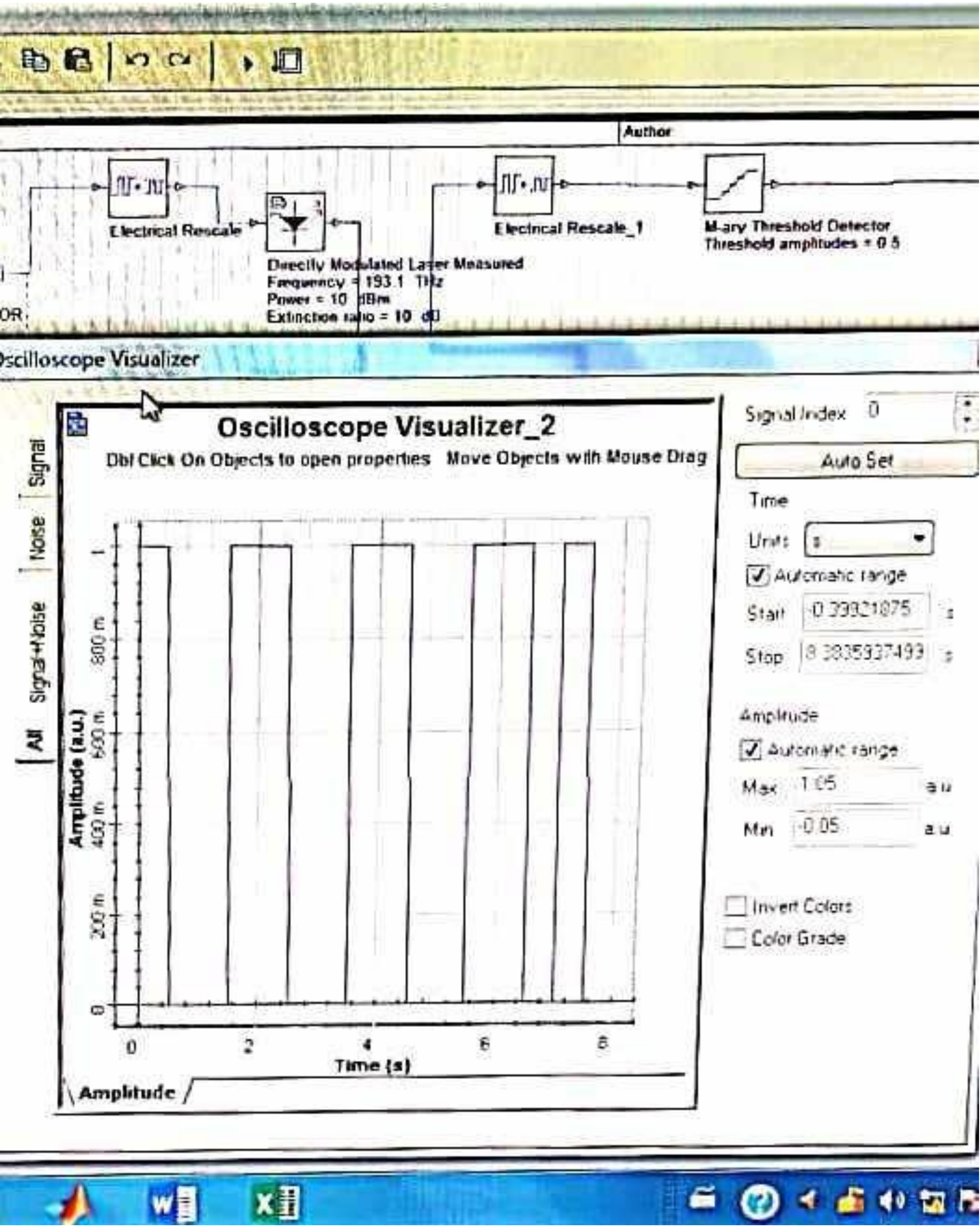
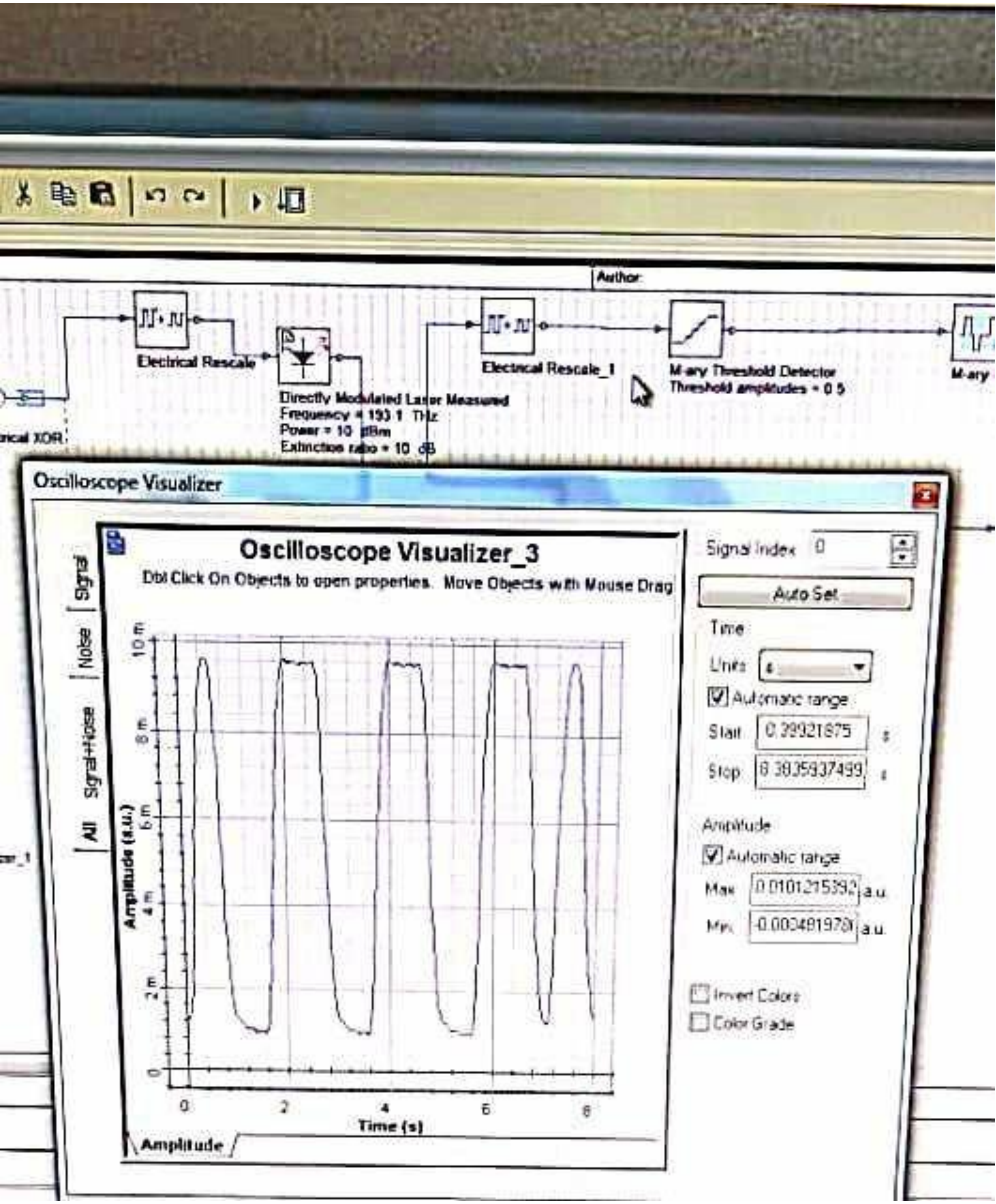
Min
Invert Colors
Color Grade



Author
Electrical Rescale
Directly Modulated Laser Measured
Frequency = 193.1 THz
Power = 10 dBm
Extinction ratio = 10 dB
Electrical Rescale_1
M-ary Threshold Detector
Threshold amplitudes = 0.5
Oscilloscope Visualizer
Oscilloscope Visualizer_2
Dbl Click On Objects to open properties   Move Objects with Mouse Drag
Signal
Noise
Signal+Noise
All
Amplitude (a.u.)
Time (s)
Amplitude
Signal Index 0
Auto Set
Time
Units s
Automatic range
Start -0.39321875 s
Stop 8.3835937493 s
Amplitude
Automatic range
Max 1.05 a.u
Min -0.05 a.u
Invert Colors
Color Grade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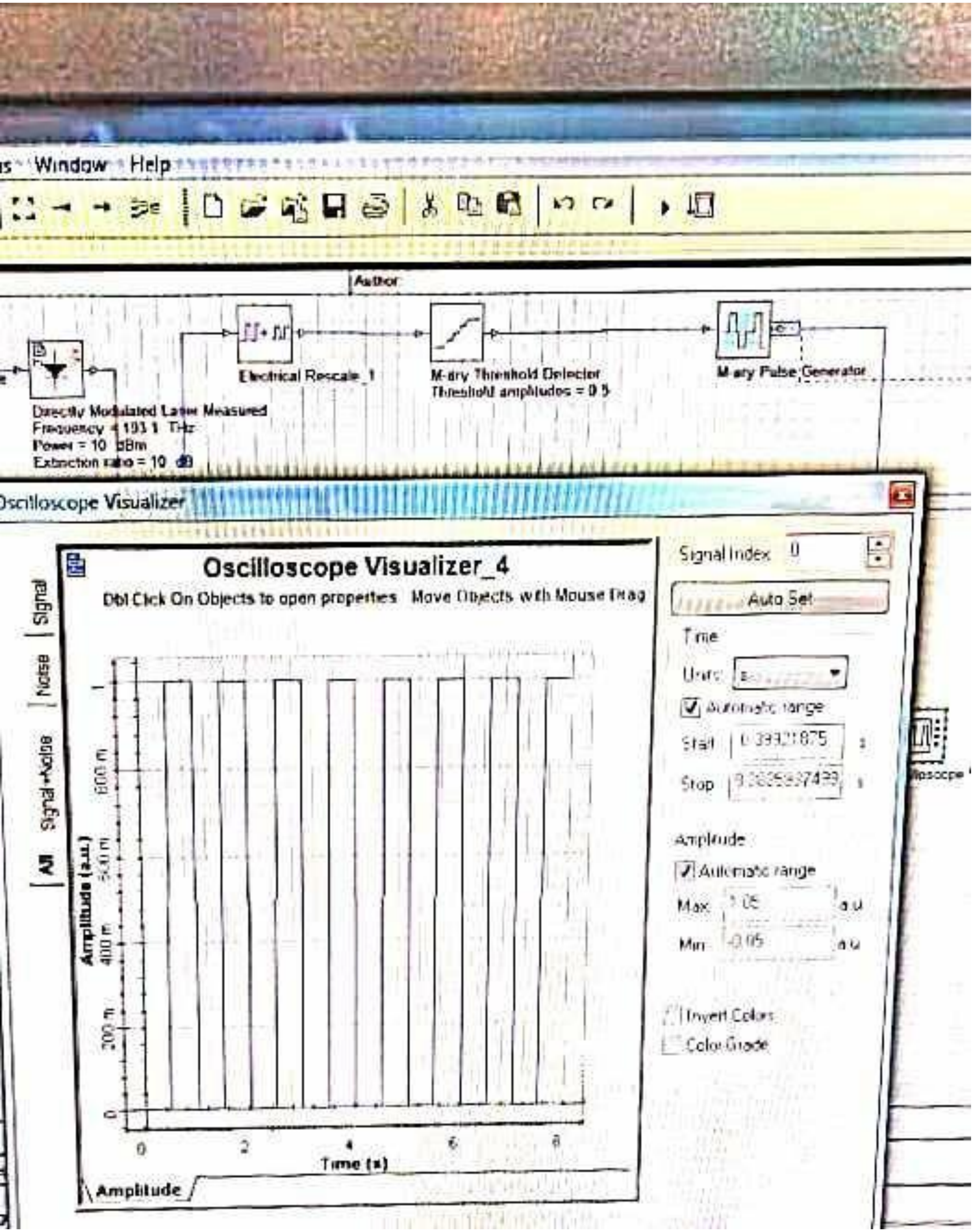
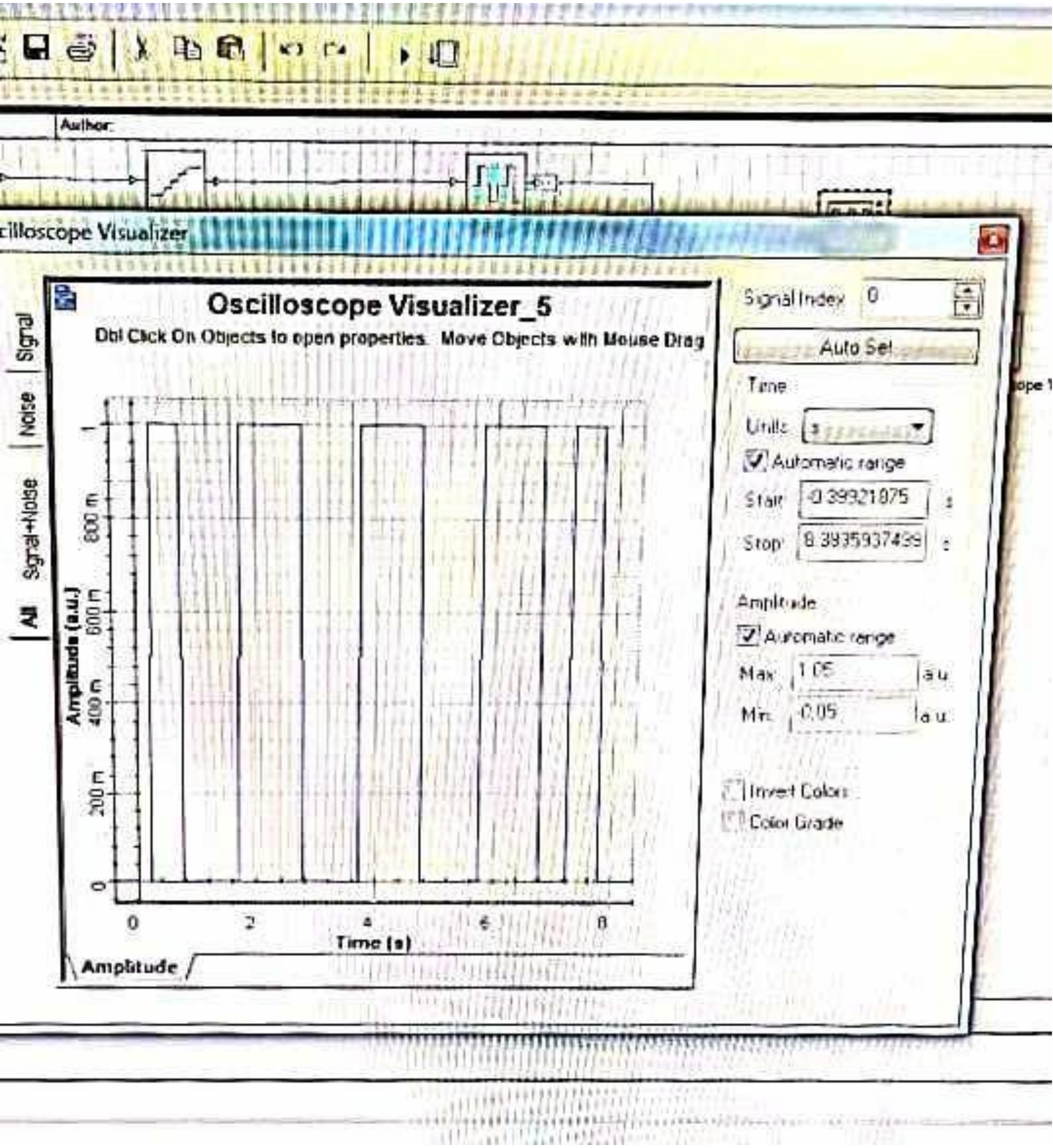
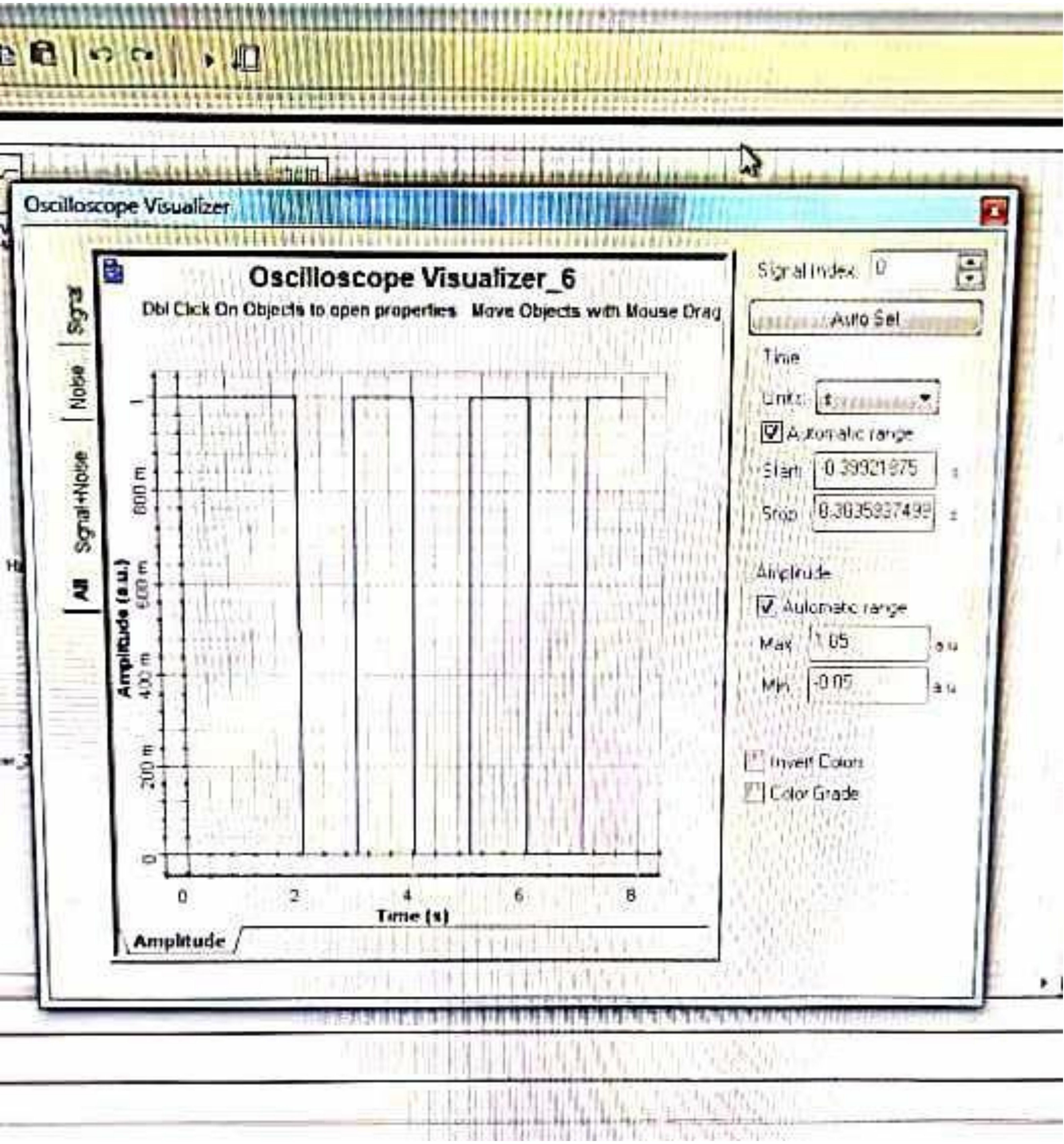
Directly Modulated Laser Measured
Frequency = 193.1 THz
Power = 10 dBm
Extinction ratio = 10 dB
Electrical Rescale_1
M-ary Threshold Detector
Threshold amplitudes = 0.5
Oscilloscope Visualizer
Oscilloscope Visualizer_3
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Amplitude (a.u.)
Time (s)
Amplitude
Signal
Noise
Signal+Noise
All
Signal Index
Auto Set
Time
Units
Automatic range
Start
Stop
Amplitude
Automatic range
Max
Min
Invert Colors
Color Grade



Window Help
Author
Electrical Rescale_1
M-ary Threshold Detector
Threshold amplitudes = 0.5
M-ary Pulse Generator
Directly Modulated Laser Measured
Frequency = 193.1 THz
Power = 10 dBm
Extinction ratio = 10 dB
Oscilloscope Visualizer
Oscilloscope Visualizer_4
Dbl Click On Objects to open properties Move Objects with Mouse Drag
Signal
Noise
Signal+Noise
All
Amplitude (a.u.)
Time (s)
Amplitude
Signal Index
Auto Set
Time
Units
Automatic range
Start
Stop
Amplitude
Automatic range
Max
Min
Invert Colors
Color Grade


Author:
Oscilloscope Visualizer
Oscilloscope Visualizer_5
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Signal
Noise
Signal+Noise
All
Amplitude (a.u.)
Time (s)
Amplitude
Signal Index
Auto Set
Time
Units
Automatic range
Start
Stop
Amplitude
Automatic range
Max
Min
Invert Colors
Color Grade


Oscilloscope Visualizer
Oscilloscope Visualizer_6
Dbl Click On Objects to open properties   Move Objects with Mouse Drag
Signal
Noise
Signal+Noise
All
Amplitude (a.u.)
Time (s)
Amplitude
Signal Index
Auto Set
Time
Units
Automatic range
Start
Stop
Amplitude
Automatic range
Max
Min
Invert Colors
Color Grade

6

DEPARMENT

OF

ELECTRONICS AND COMMUNICATION ENGINEERING

FIBER OPTICS COMMUNICATION LABORATORY

LAB INSTRUCTIONS FOR CARRYING OUT PRACTICAL

ON

MANCHESTER CODING & DECODING IN OPTICAL FIBER LINK

BIRLA INSTITUTE OF TECHNOLOGE

MESRA, RANCHI

EXPERIMENT NO. 8

NAME

Study Of Manchester Coding & Decoding

OBJECTIVE

The objective of this experiment is to study the techniques of Manchester coding & decoding in digital communication.

THEORY

A fiber optic digital communication system usually consists of the following:

- Optical transmitter including electrical to optical converter (E/O)
- Optical receiver including optical to electrical converter (O/E)
- Optical Fiber as data transmission medium
- Connectors, Couplers & Splicers
- Line Coder
- Line Decoder
- Timing recovery unit

In digital communication the recovery of the clock used for transmission is essential. The Technique of timing recovery depends on the no. of "0" to "1" & "1" to "0" transitions. At times, one cannot ensure that the data to be transmitted has such transitions. To introduce the transitions in such a case, line coding is used. For low bit rate fiber optic transmission, the commonly used line coding technique is known as Manchester Coding, whereas for higher bit rates various coding schemes like mBnB coding schemes are used. Thus line coding is implemented in digital communication for the following reasons.

- For ease of timing recovery at the receiver
- To shape the spectrum of the signal as required by various elements in the communication system

The recovery of synchronous clock, synchronous both in terms of phase & frequency, at the receiver is a must for any synchronous digital link. A long string of zeros & ones, i.e. lack of transitions in data, could make the receiver clock lose synchronization. Line coding introduces sufficient transitions in the data for ease of clock recovery. Also a certain pattern of data, like a long string zeros or one, would result in a strong DC component in the transmitted signal. Such a DC component is often not desirable; line coding shifts the spectrum & avoids the DC component. Several methods of coding digital transmission for unique effects are possible each type of coding has inherent advantages. We will consider the simplest line coding technique as Manchester Coding. The data waveform is composed of a binary bit stream with each bit forming a cell, one clock period in length.

The Manchester coded waveform is generated in the following manner. If the Data bit is '1', the waveform will be positive for the first half of the bit cell. For a '0' data bit, the first half of the bit cell will be a zero. A transition always occurs in the center of the bit cell, regardless of whether the bit is '1' or '0'.

EQUIPMENTS

FO-A-P Kit with power supply
Patch chords
20 MHz Dual Trace Oscilloscope
1 Meter fiber cable

NOTE: Keep All Switch Faults In Off Position.

PROCEDURE

- Make connections as shown in diagram.
- Keep jumper & switch settings as shown in fig.
- Observe the Test points of DATA IN & MCDTX OUT. The **MCDTX OUT** shows that when Data is "1" the first half bit of data is high whereas the second half is zero. While for Data as "0" the first half is a "0" level & second half is "1" as shown in the waveforms.
- Select the fiber optic transmitter TX1 SFH756 using jumper & switch settings as shown in fig.9.2.
- Slightly unscrew the cap of SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the one-meter fiber into the cap. Now tighten the cap by screwing it back.
- Slightly unscrew the cap of RX1 Photo Transistor with TTL logic output SFH551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.
- Observe the test points of **INT OUT, ET OUT**. The decoded output is obtained at **RX DATA** test point & the decoding clock at **DATA CLK** test point.FIG.8.2 shows Manchester coded & decoded signals for 32 KHz data input.
  (After inserting the fiber on both sides, align the fiber properly inside both SFH devices if required to get proper indication of o/p LEDs.)
- Observe the waveforms for other data by shifting **JP1** to **64 KHz & MX CLK.**
- Also observe the effect of changing Manchester clock by keeping **JP2** position at **256 KHz.** Now the Manchester coded output will be exact but the Manchester decoded output & clock may not match the data as the decoded clock circuit is tuned to 1.024MHz clock & not 256Khz.So for this observe only the Manchester coded data.

SWITCH FAULTS

NOTE: Keep the connections as per the procedure. Now switch **ON** corresponding fault switch button to **ON** position & observe the different effects on the output. The faults are normally used one at a time.

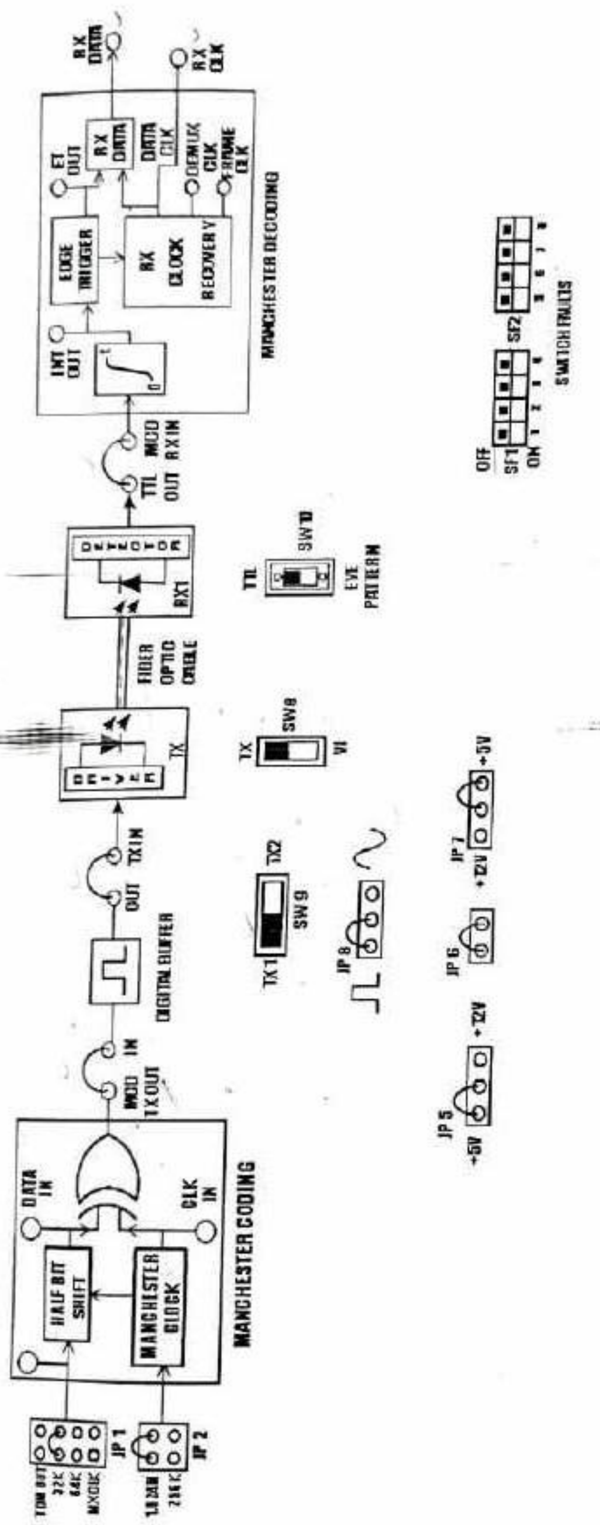


FIG. 8.1 STUDY OF MANCHESTER CODING AND DECODING.

- Put switch **5 (SF2)** in Switch Fault section to **ON** position. This will open pin 2 MCDCLK of U19 (74HC86). This will affect the Manchester coding and the Manchester coded o/p will be in a wrong format.
- Put switch **6 (SF2)** in Switch Fault section to **ON** position. This will disturb the Manchester decoding o/p and data will be disturbed. R71 comes in parallel to PR1 & hence the RC time constant changes & RX CLK gets disturbed.

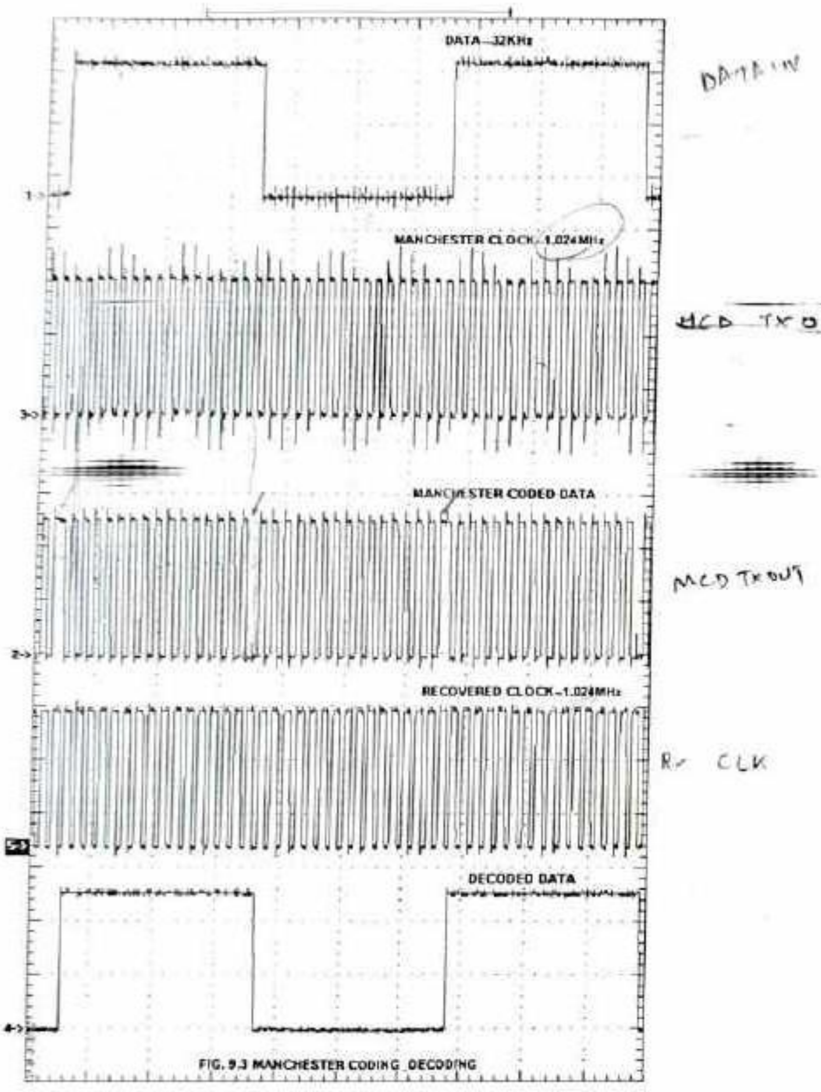


FIG. 9.3 MANCHESTER CODING DECODING

EXP-10 : Implementation of Mach-Zehnder electro-optic modulator

Sl. no.	Voltage	Normalized Power
1.	1	0.01948
2.	1.5	0.4675
3.	2	0.92208
4.	2.5	0.48701
5.	3	0.0129
6.	3.5	0.45455
7.	4	0.94805
8.	4.5	0.53896
9.	5	0.01948
10.	5.5	0.41558

20/3/23

EXPERIMENT NO.

NAME

Measurement Of Bit Error Rate

OBJECTIVE

To measure Bit error rate

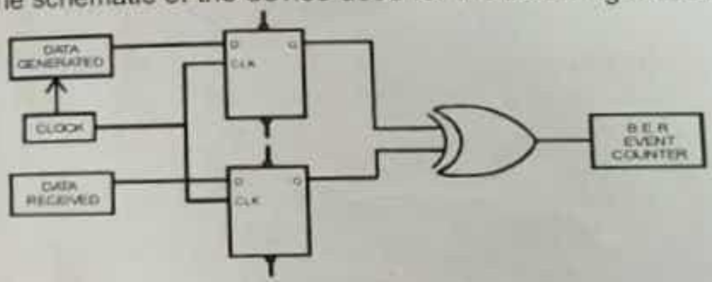
THEORY

Bit Error Rate
In telecommunication transmission, the bit error rate (BER) is a Ratio of bits that have errors relative to the total number of bits received in a transmission. The BER is an indication of how often a packet or other data unit has to be retransmitted because of an error. Too high BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent.

Measuring Bit Error Rate
A BERT (bit error rate tester) is a procedure or device that measures the BER for a given transmission. The BER or quality of the digital link is calculated from the number of bits received in error divided by the number of bits transmitted.

BER= (Bits in Error) / (Total bits transmitted)

Using a bench test setup, this is easily measured by means of a comparator in which the transmitted bits are matched in an XOR gate with the received bits. Fig shows the schematic of the device used for the following measurements.



BIT ERROR RATE TESTER (B.E.R.T.)

If the bits are alike at the XOR gate input, when clocked in from the D flip flop, the output is low. If they are different, the XOR output goes high, causing an event count. The event counter can be set for various time periods. In general, the longer the time period, the more accurate is the count.

A random character generator and white noise source should be used for these measurements.

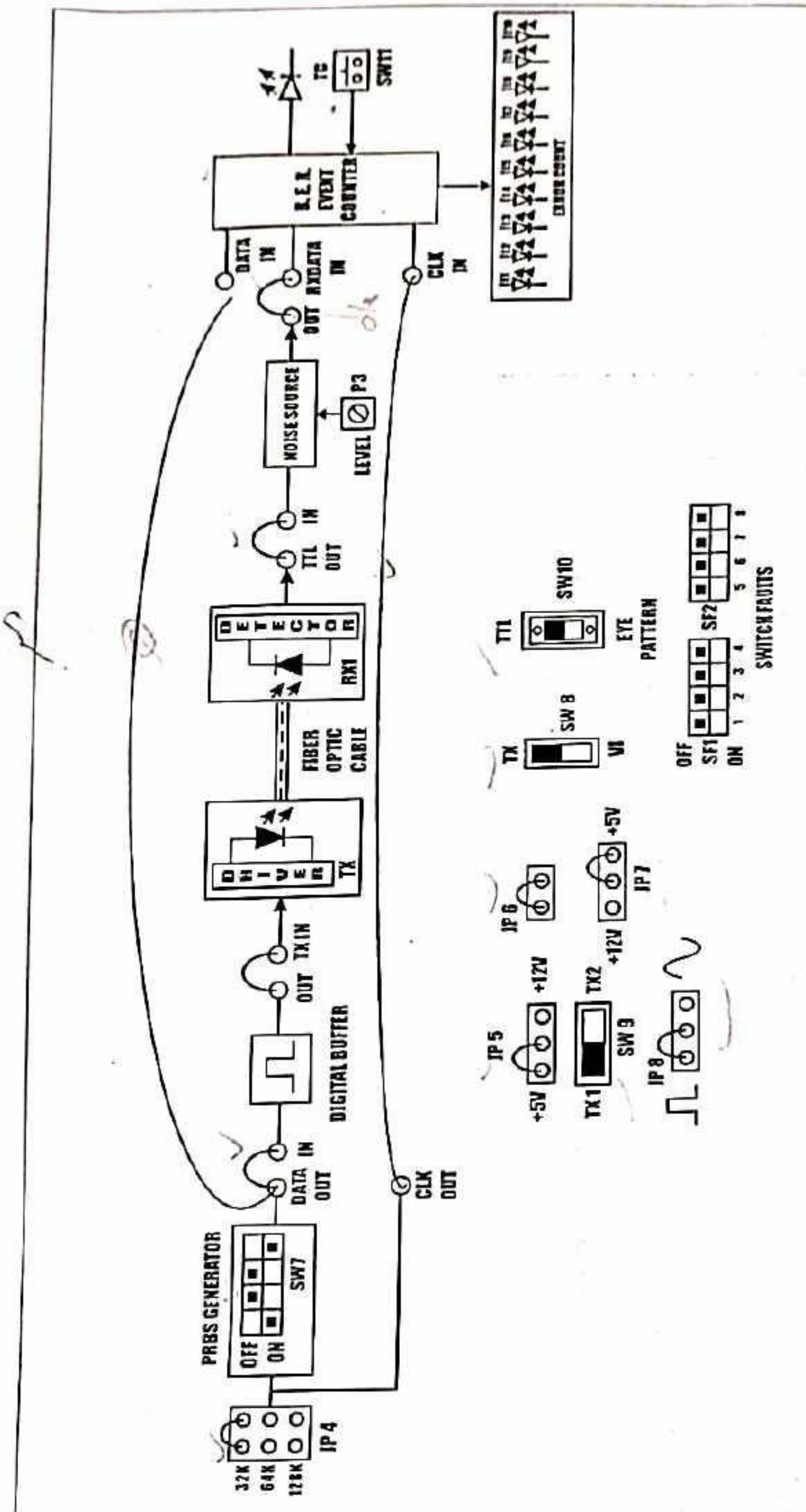


FIG.11.1 BLOCK DIAGRAM FOR BIT ERROR RATE MEASUREMENT

The number of bit errors is dependent upon the amount of noise entering the system. White noise or background noise has an average or RMS value that is exceeded periodically by peaks that may get raised many times that level. These peaks exist only for a very short period of time. When the peak equals or exceeds the signal level, that is noise energy = bit energy, there is a 50/50 chance of error. The peak time periods can be calculated statistically from the error function.
In Link-B, PRBS sequence is generated by using a 4-bit right shift register whose feedback is completed by the EX-OR gate.
Let Initially 1001 be the 4-bit switch setting on the SW7.

Clock States	D1	D2	D3 A	D4 B	C
1	1	0	0	1	1
2	1	1	0	0	0
3	0	1	1	0	1
4	1	0	1	1	0
5	0	1	0	1	1
6	1	0	1	0	1
7	1	1	0	1	1
8	1	1	1	0	1
9	1	1	1	1	0
10	0	1	1	1	0
11	0	0	1	1	0
12	0	0	0	1	1
13	1	0	0	0	0
14	0	1	0	0	0
15	0	0	1	0	1
16	1	0	0	1	1

Thus the sequence repeats constantly with a period corresponding to 16 clock states.
Length of sequence = $2^4 = 16$
Now the Pseudo Random Sequence pattern is C = 1010111100010011

EQUIPMENTS

FO-A-P Kit with power supply
Patch chords
1 Meter Fiber cable
Patch chords
20 MHz Dual Channel Oscilloscope

NOTE: Keep All Switch Faults In Off Position.

PROCEDURE

- Make connections as shown in fig.11.1. Connect the power supply cables with proper polarity to FO-A-P Kit. While connecting this, ensure that the power supply is OFF.

- Keep PRBS switch **SW7** as shown in fig.11.1 to generate PRBS signal.
- Keep switch **SW8** towards **TX** position.
- Keep switch **SW9** towards **TX1** position.
- Keep the switch **SW10** at fiber optic receiver output to **TTL** position.
- Select PRBS generator clock at 32 KHz by keeping jumper **JP4** at **32K** position.
- Keep Jumper **JP5** towards **+5V** position.
- Keep Jumpers **JP6** shorted.
- Keep Jumper **JP8** towards **pulse** position.
- Switch ON the power supply.
- Connect the post **DATA OUT** of PRBS Generator to the **IN** post of Digital Buffer and also to the **DATA IN** post of Bit Error Rate event counter.
- Connect the **OUT** post of Digital Buffer to **TX IN** post Transmitter.
- Slightly unscrew the cap of LED SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the one-meter fiber into the cap. Now tighten the cap by screwing it back.
- Slightly unscrew the cap of RX1 Photo Transistor with TTL logic output SFH551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.
- Connect detected signal **TTL OUT** to post **IN** of Noise Source.
- Connect post **OUT** of Noise Source to post **RXDATA IN** of Bit Error Rate event counter.
- Connect post **CLK OUT** of PRBS Generator to post **CLK IN** of Bit Error Rate event counter.
- Press Switch **SW11** to start counter.
- Vary pot **P3** for **Noise Level** to observe effect of noise level on the error count.
- Observe the Error Count LEDs for the error count in received signal in time 10 seconds as shown in **FIG. 11.2**.

BER Measurement

As per the definition the BER is a ratio of Error bits (Eb) to Total bits Transmitted (Tb) in a period of time t seconds.

i.e. BER = Eb / Tb

For eg. in this experiment if PRBS data is transmitted at 32Kbits per second (i.e. jumper selection at 32KHz) for a period of 10 seconds.

So total bits transmitted in 10 seconds (Tb) = 320Kbits.

The TTL OUT data & data with noise is fed to BER counter which compares the two data inputs at each clock input.

The counter displays the Error count (Eb) on LED in 10-bit binary form (e.g. 0000001010), which has to be converted in decimal form (it becomes 10) so the BER ratio then becomes

BER = 10 / (320 x 10 E 3)

= 0.00003125

i.e. the channel Bit Error Rate ratio is 3.1x10E-5 (3 / 100000) or in other words we can say that out of 100000 bits transmitted through the channel the channel gives 3 bits in error.

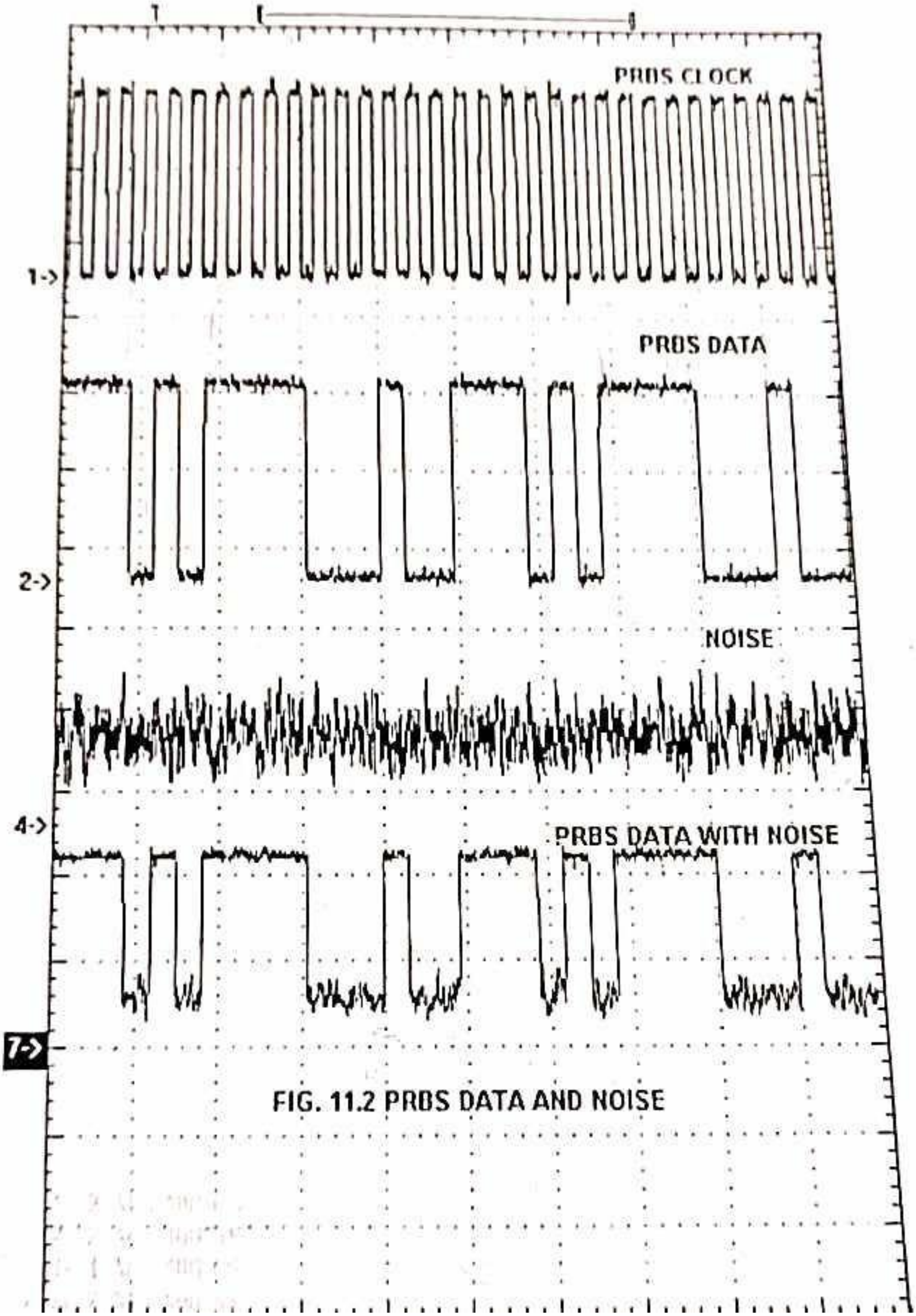


FIG. 11.2 PRBS DATA AND NOISE

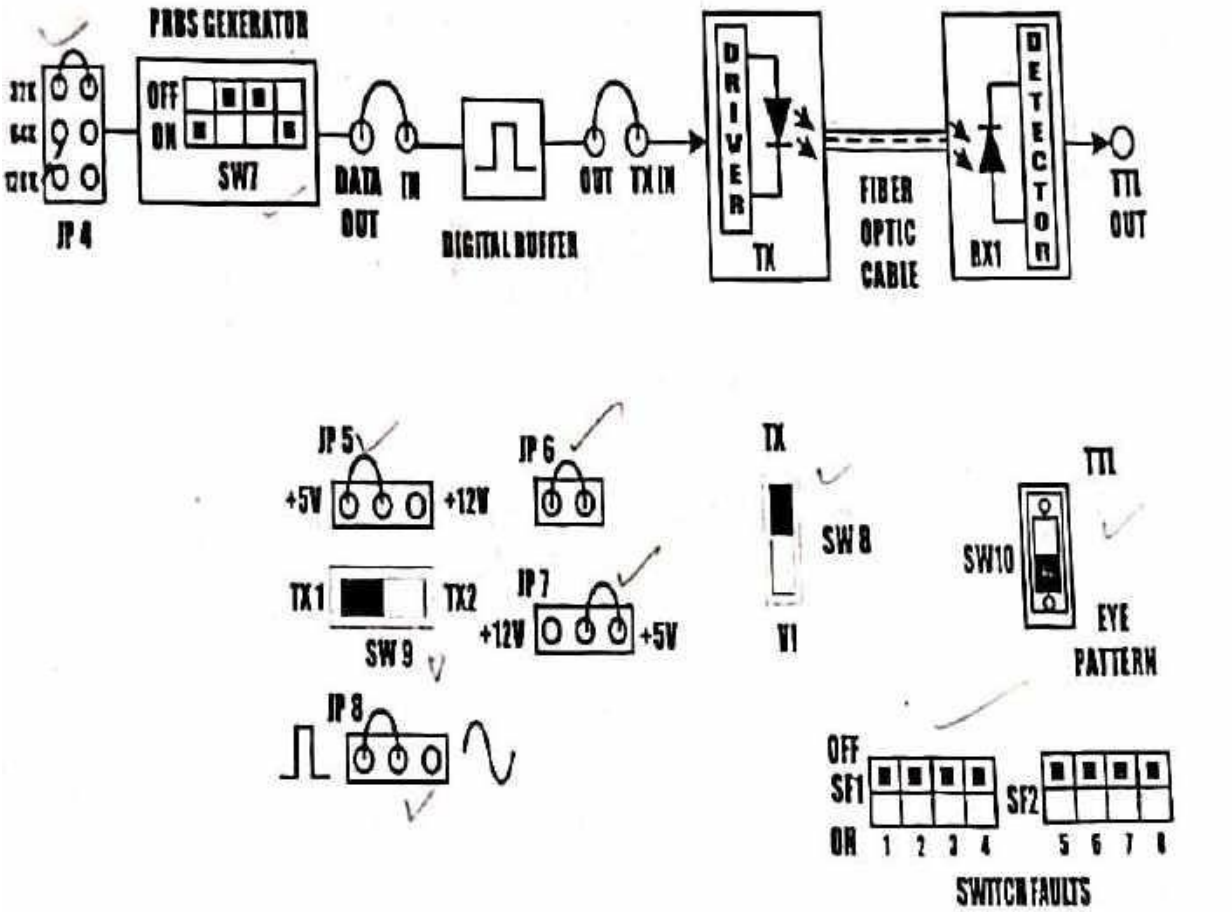


FIG. 12.1 BLOCK DIAGRAM FOR STUDY OF EYE PATTERN

EXPERIMENT NO.

NAME

Study Of Eye Pattern

OBJECTIVE

The objective of this experiment is to study eye pattern using fiber optic link.

THEORY

The eye-pattern technique is a simple but powerful measurement method for assessing the data-handling ability of a digital transmission system. This method has been used extensively for evaluating the performance of wire systems and can also be applied to optical fiber data links. The eye-pattern measurements are made in the time domain and allow the effects of waveform distortion to be shown immediately on an oscilloscope.

An eye-pattern can be observed with the basic equipment shown in Fig. 12.1. The output from a pseudorandom data pattern generator is applied to the vertical input of an oscilloscope and the data rate is used to trigger the horizontal sweep. This results in the type of pattern shown in Fig. 12.2, which is called the **eye pattern** because the display shape resembles a human eye. To see how the display pattern is formed, consider the eight possible 4-bit-long NRZ combinations. When these sixteen combinations are superimposed simultaneously, an eye pattern as shown in Fig. 12.2 is formed.

To measure system performance with the eye-pattern method, a variety of word patterns should be provided. A convenient approach is to generate a random data signal, because this is the characteristic of data streams found in practice. This type of signal generates ones and zeros at a uniform rate but in a random manner. A variety of pseudorandom pattern generators are available for this purpose. The word pseudorandom means that the generated combination or sequence of ones and zeros will eventually repeat but that it is sufficiently random for test purposes. A pseudorandom bit sequence comprises four different 2-bit-long combinations, eight different 3-bit-long combinations, sixteen different 4-bit-long combinations and so on (that is, sequences of different N-bit-long combinations) up to a limit set by the instrument. After this limit has been generated, the data sequence will repeat.

A great deal of system performance information can be deduced from the eye-pattern display. To interpret the eye pattern, follow the procedure ahead.

EQUIPMENTS

FO-A-P Kit with power supply
Patch chords
1 Meter Fiber cable
Patch chords
20 MHz Dual Channel Oscilloscope

NOTE: Keep All Switch Faults In Off Position.

PROCEDURE

- Make connections as shown in fig.12.1. Connect the power supply cables with proper polarity to FO-A-P Kit. While connecting this, ensure that the power supply is OFF.
- Keep switch **SW7** as shown in fig.12.1. to generate PRBS signal.
- Keep switch **SW8** towards **TX** position.
- Keep switch **SW9** towards **TX1** position.
- Keep the switch **SW10** to **EYE PATTERN** position.
- Select PRBS generator clock at 32 KHz by keeping jumper **JP4** at **32K** position.
- Keep Jumper **JP5** towards **+5V** position.
- Keep Jumpers **JP6** shorted.
- Keep Jumper **JP8** towards **TTL** position.
- Switch ON the power supply.
- Connect the post **DATA OUT** of PRBS Generator to the **IN** post of digital buffer.
- Connect **OUT** post of digital buffer to **TX IN** post.
- Slightly unscrew the cap of LED SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the one-meter fiber into the cap. Now tighten the cap by screwing it back.
- Slightly unscrew the cap of RX1 Photo Transistor with TTL logic output SFH551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.
- Connect **CLK OUT** of PRBS Generator to **EXT. TRIG.** of oscilloscope.
- Connect detected signal **TTL OUT** to vertical channel **Y** input of oscilloscope. Then observe EYE PATTERN by selecting EXT. TRIG KNOB on oscilloscope as shown in **FIG 12.2**. Observe the Eye pattern for different clock frequencies. As clock frequency increases the EYE opening becomes smaller.

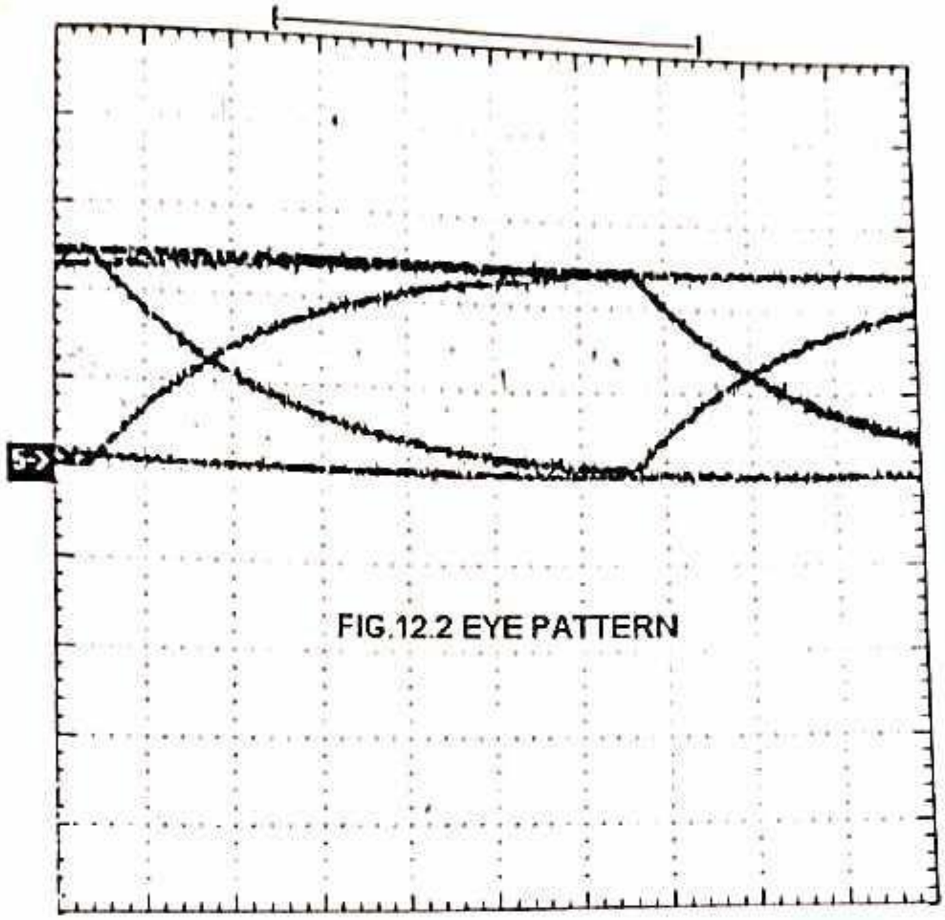


FIG.12.2 EYE PATTERN

Date: 16|1|23
Page: 1

Experiment → 1

Aim :- To measure the bit error rate.

Equipment Required :-

i) FO-A-P kit
ii) Patch chords
iii) 1 meter fibre cable
iv) 20Hz Dual channel oscilloscope

Theory :-

→ BIT ERROR RATE

In telecommunication transmission the bit error rate (BER) is a Ratio of bits that have Error relative to the total number of bit recieved in a transmission. The BER is an indication of how often a packet or other data unit has to be retransmitted because of the error.

→ MEASURING BIT ERROR

A BERT (Bit Error Tester) is a producer or device that measures the BER for a Given transmission.

BER = (Bit in error) / total bit transmitted.

The number of bit error is dependent upon the amount of noise entering the system white noise or Background noise has an avg of or RMS value of that is exceeded periodically by peaks that may get raised many times that level. these signal peak exist only for a very short of time. when peak equals or exceed the signal level the noise energy bit energy, there is a 50/50 chance or error.

clock start	D_1	D_2	D_3	D_4	
			A	B	C
1	1	0	0	1	1
2	1	1	0	0	0
3	0	1	1	0	1
4	1	0	1	1	0
5	0	1	0	1	1
6	1	0	1	0	1
7	1	1	0	1	1
8	1	1	1	0	1
9	1	1	1	1	0
10	0	0	1	1	0
11	0	0	0	1	1
12	1	0	0	0	0
13	0	1	0	0	0
14	0	0	1	0	1
15	1	0	0	1	1
16					

length of sequence $= 2^4 = 16$

Now, the Pseudo Random sequence pattern is

$C = 1010111100010011$

Page 3

BER MESUREMENT

$$BER = Eb/Tb \quad \begin{cases} Eb = \text{Error bit} \\ Tb = \text{Total bit} \end{cases}$$

RESULT:-

we calculated the BER ratio and drawn the graph of PRBS clock, PRBS DATA & PRBS DATA with noise.

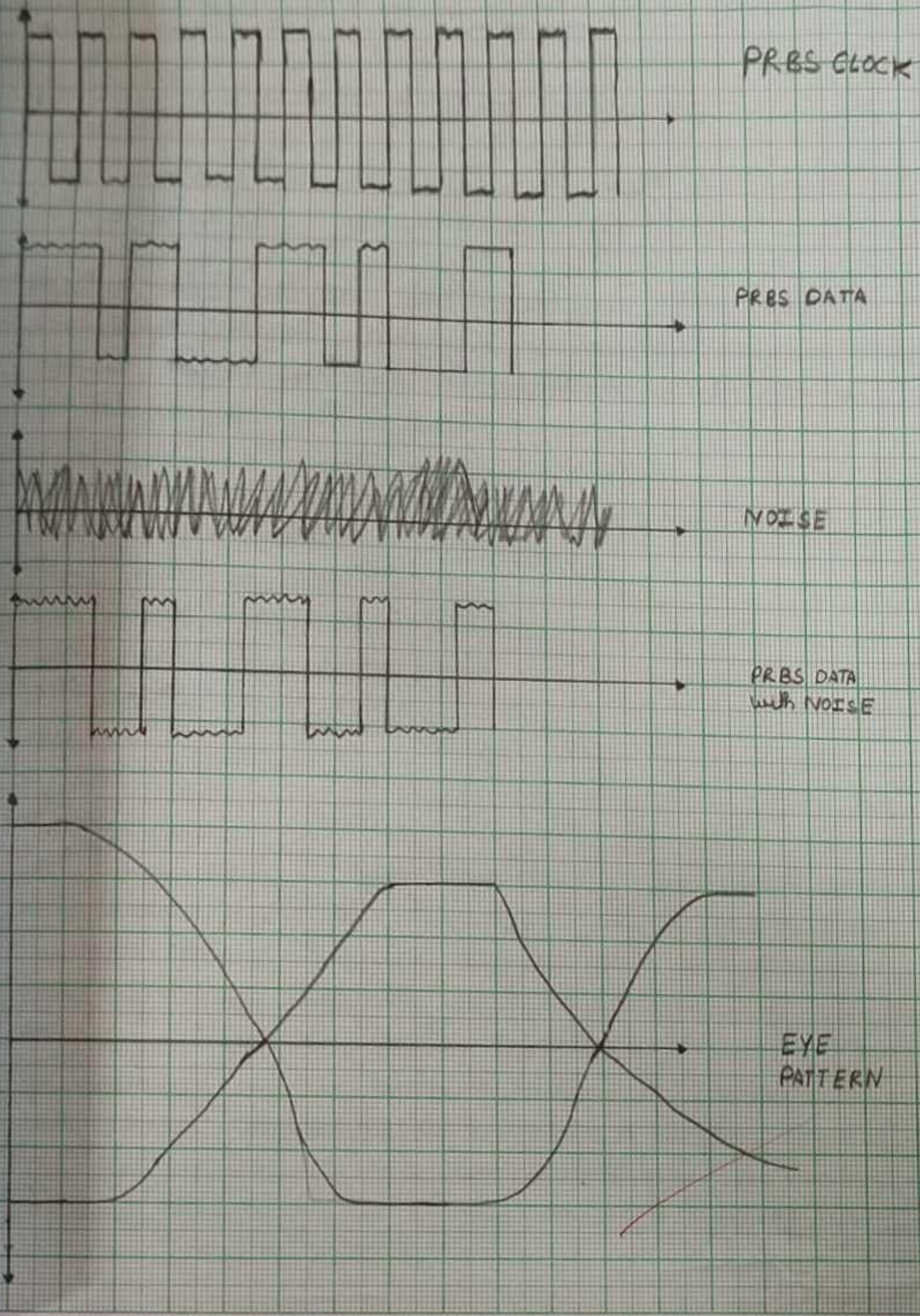
Calculation:- (320 Kbit transmitted in 10 sec)

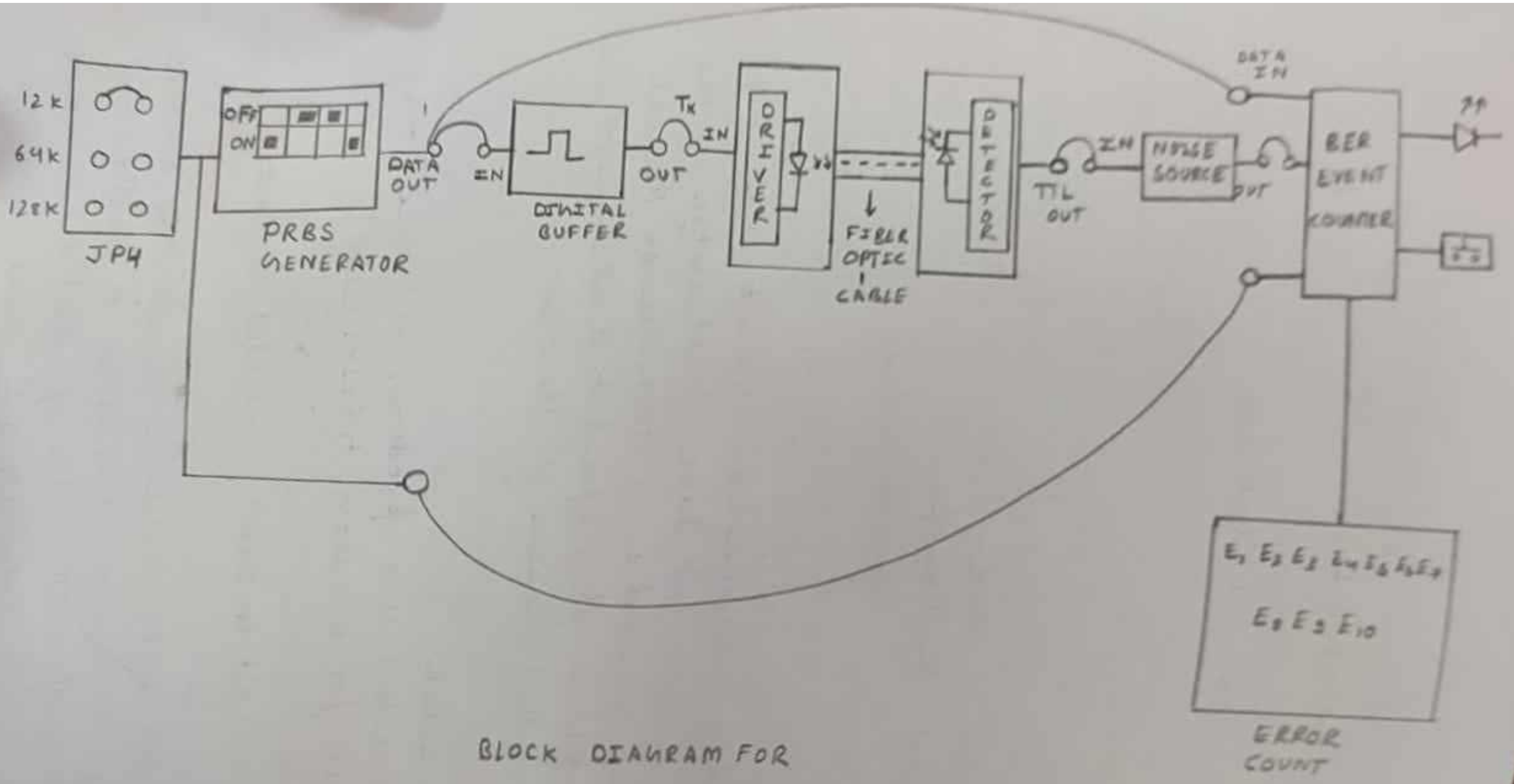
3.1×10^{-4}

6.2×10^{-5}

error count	BER
10	$10/(320\times10^3)$ = 0.00031 25
20	$20/(320\times10^3)$ = 0.00006250
12	$12/(320\times10^3)$ = 0.0000375
17	$17/(320\times10^3)$ = 0.000053125

Exp → 1





BLOCK DIAGRAM FOR
BIT ERROR MEASUREMENT

Experiment - 3(1)

Aim: To Study the ckt action of pulse width modulation and demodulation over fiber optic Digital link.

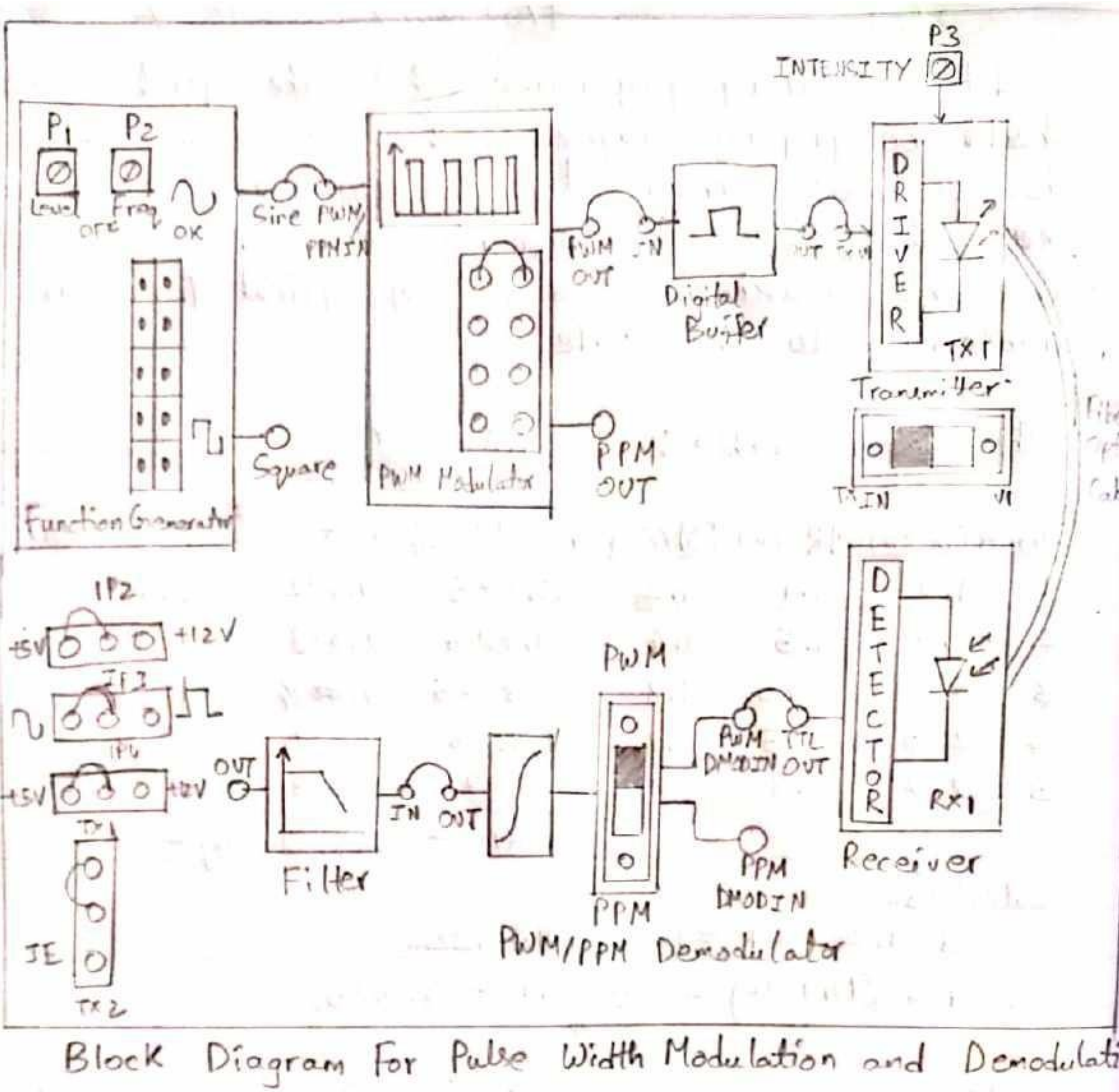
Equipments:
1) FOL-B-P kit
2) Dual Channel oscilloscope
3) 1 Meter fiber Cable
4) Power Supply

Theory:

Pulse Width Modulation: This technique of modulation controls the variation of duty cycle of the Square wave according to the input modulating signal. the amplitude variation of the modulating signal is reflected into ON Period variation of Square wave. Hence, it is also called as technique of V to T Conversion.

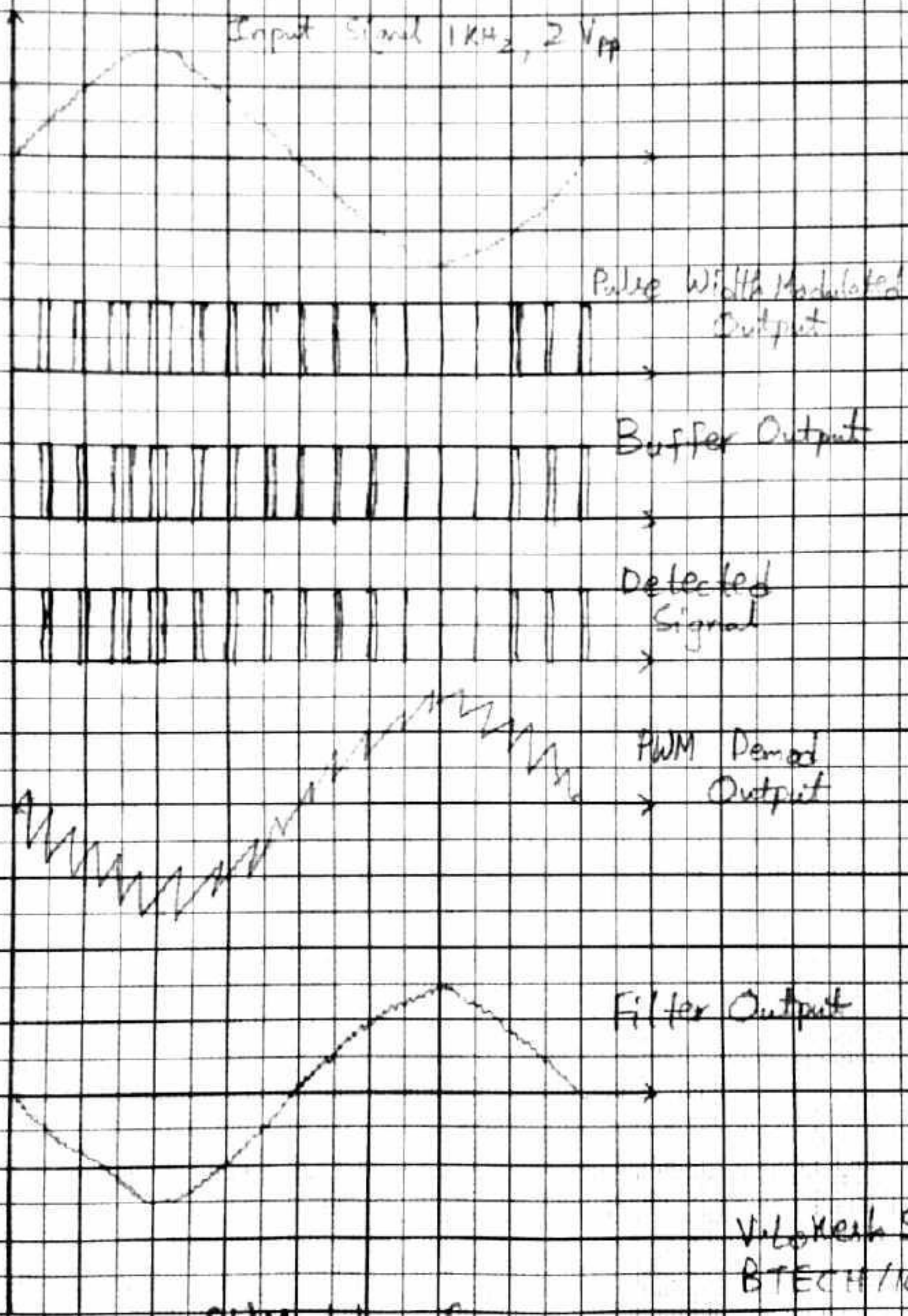
Pulse Width demodulation: The input signal is PWM, the ON time of the signal is changing according to modulating signal In this PWM is applied to an integrator, whose o/p is then filtered to obtain original signal.

Conclusion: We observed the circuit action of PWM, demodulation over fiber optic digital link



Block Diagram For Pulse Width Modulation and Demodulation

V.Lokesh Sriram
BTECH/10690/19



V.Lokesh Sriram
BTECH/10590/19

PWM Wave forms

Experiment-3(2)

Aim: To Study the ckt action of pulse Position modulation & demodulation over fiber optic digital link.

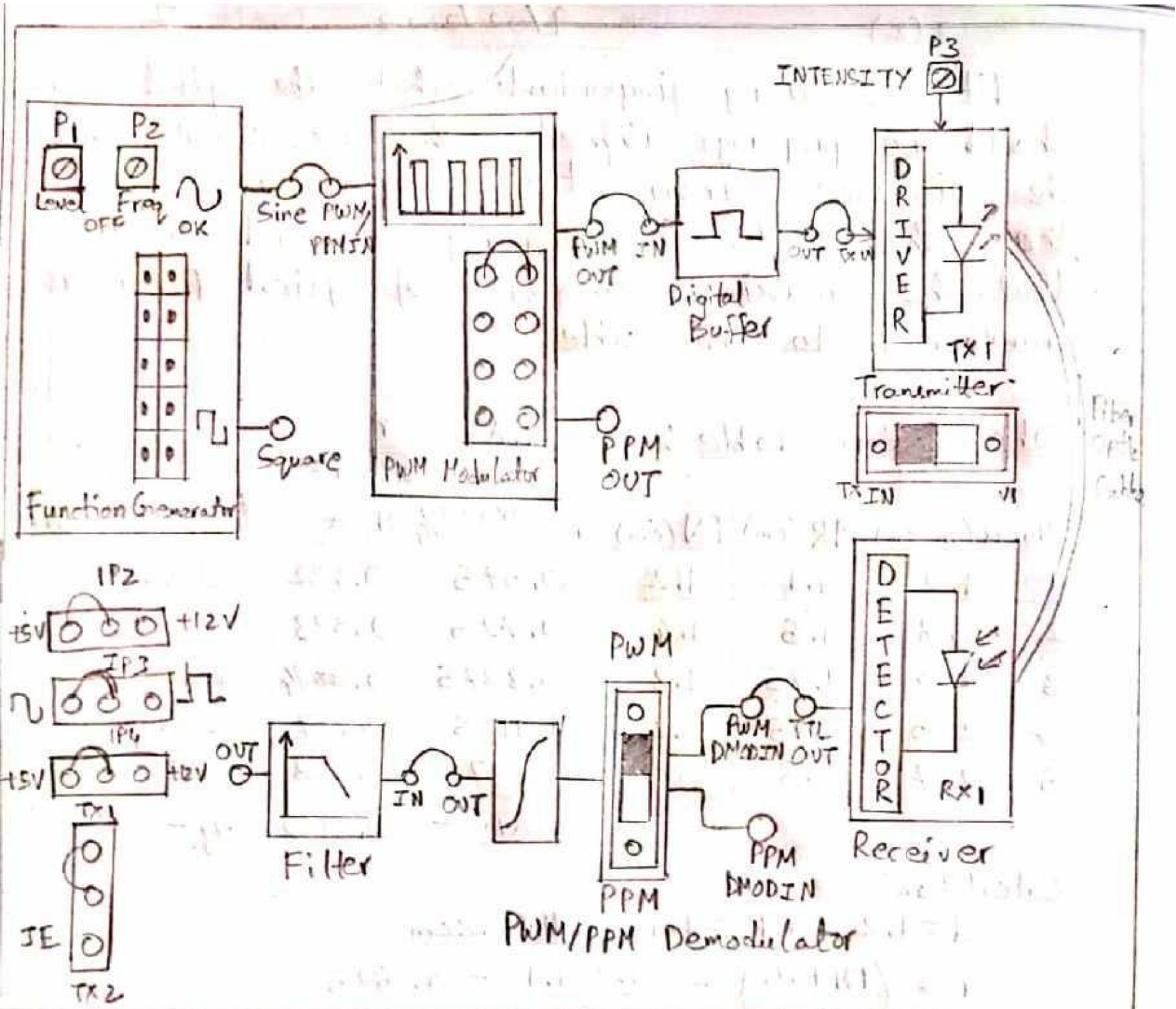
Equipments:
1) FOL-BP-Kit
2) Dual channel Oscilloscope
3) 1-Meter fiber Cable
4) Power Supply

Theory:

Modulation: The position of the TTL Pulse is changed on time scale according to the variation of I/P modulating signal amplitude. Pulse positions are proportional to instantaneous values of modulating signal

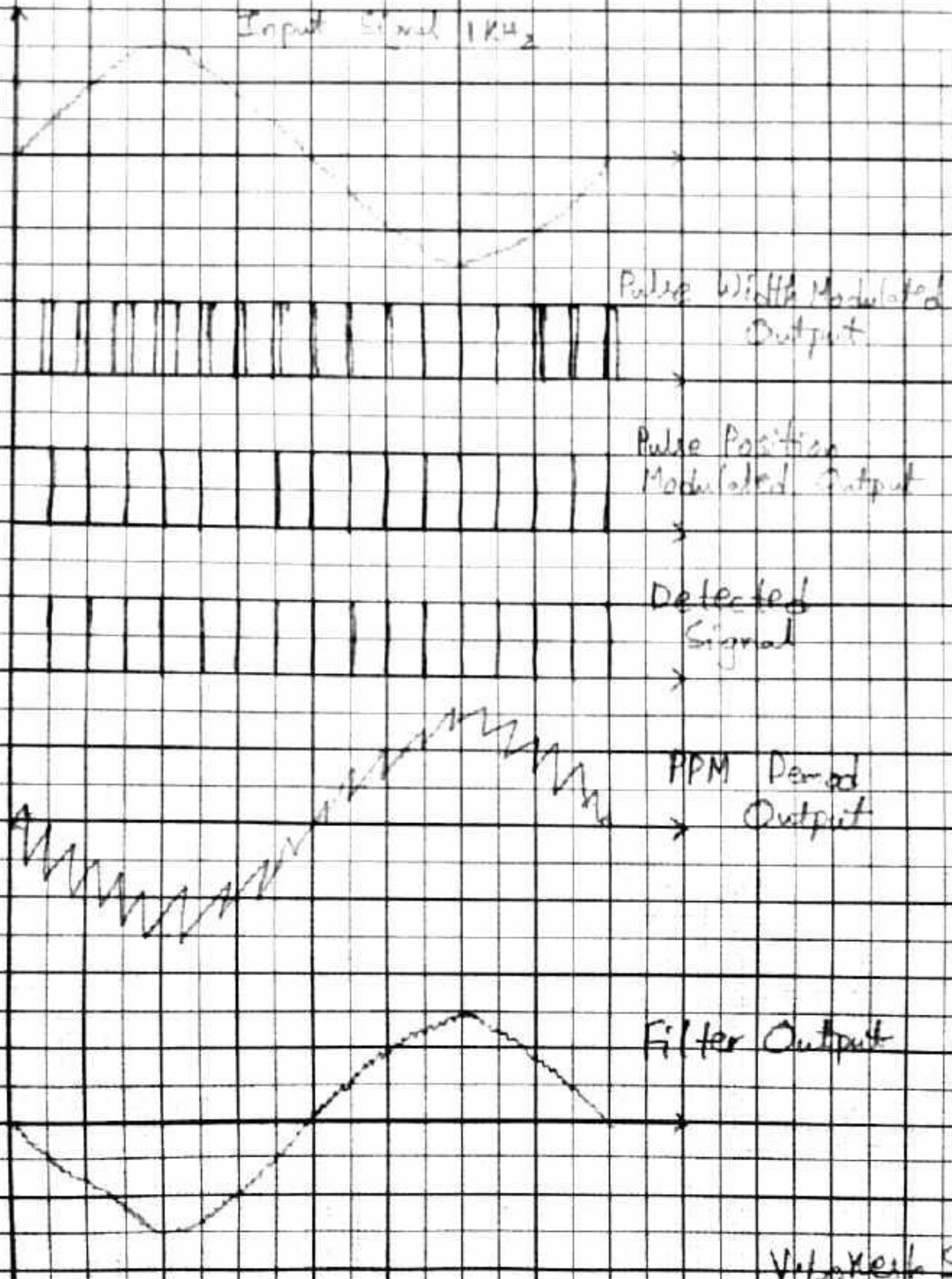
demodulation: The PPM signal is 'OR'ed with pulse generated by the rising edge of PPM signal. The signal is demodulated using same technique of PWM demodulation.

Conclusion: We observed the circuit action of PPM & demodulation over fiber optic digital link.



Block Diagram For Pulse Position Modulation and Demodulation

V.Lokesh Sriram
BTECH/10690/19



V. Lokesh Sriram
BTECH/10590/19

PPM Wave forms

3

DEPARTMENT
OF
ELECTRONICS AND COMMUNICATION ENGINEERING

FIBER OPTICS COMMUNICATION LABORATORY

LAB INSTRUCTIONS FOR CARRYING OUT PRACTICAL

ON

REALIZATION OF PULSE WIDTH MODULATION (PWM) AND PULSE POSITION MODULATION (PPM) IN FIBER OPTIC LINK

BIRLA INSTITUTE OF TECHNOLOGY
MESRA, RANCHI

EXPERIMENT NO. 7

NAME:

Study of Pulse Width Modulation And Demodulation

OBJECTIVE:

The objective of this experiment is to study the circuit action of Pulse Width Modulation and Demodulation over Fiber Optic Digital Link.

THEORY:

Pulse Width Modulation

This technique of modulation controls the variation of duty cycle of the square wave (With some fundamental frequency) according to the input modulating signal. Here the amplitude variation of the modulating signal is reflected into ON period variation of square wave. Hence, it is also called as technique of V to T conversion.

Pulse Width Demodulation

The input signal is pulse width modulated, so the ON time of the signal is changing according to the modulating signal. In this demodulation technique, the PWM signal is applied to an Integrator, whose output is then Filtered to obtain original signal.

EQUIPMENTS:

- FOL-B-P kit
- Dual Channel oscilloscope
- 1 Meter Fiber cable
- Power Supply

PROCEDURE:

- Slightly unscrew the cap of SFH756V (660 nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tight the cap by screwing it back.
- Make the connections and jumper settings as shown in **FIG. 7.1** Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF. Now switch on the power supply.
- Connect **SINE** post (**FIG. 7.2a**) of the Function Generator section to **PWM IN** post of PWM/ PPM Modulator Section.
- Select the frequency **100Hz-1kHz** with amplitude of 1V p-p (Max) for proper observation of phenomena.
- Observe PWM signal at **PWM OUT** Post (**FIG. 7.2b**). Variation in width of square wave is seen clear. Then keep frequency range upto 1KHz, 1Vp-p, if the frequency is high then due to persistence of vision, only blurt band in the waveform will be observed. If the Function generator is OFF, only square wave of fundamental frequency and fixed ON time will be observed and no width variations are present.
- Connect **PWM OUT** post of PWM/PPM Modulator Section to **IN** post of Digital Buffer Section.
- Connect **OUT** post of the Digital Buffer Section to **TX IN** post of TRANSMITTER.
- Connect the other end of fiber to detector SFH551V (Digital Detector) very carefully as per the instructions in step 1.
- Observe the received signal over fiber at **TTL OUT** post it should be exactly similar to the signal available at **PWM OUT** post.
- Slide the switch SW 8 to [redacted] position.
- Connect this **TTL OUT** post to **PWM DEMOD IN** Post in PWM / PPM Demodulator Section.
- Vary input freq. POT **P23** and observe demodulated signal at **DEMOD OUT** post (FIG. **7.2c**) of PWM / PPM Demodulator Section. Connect **PWM / PPM DEMODOUT** post to **IN** post of Filter Section and observe output at its **OUT** post (FIG. **7.2d**), which is same as Input signal.
- For Different Sampling frequencies change the jumper cap of **JP1** from 8 KHz to the desired value of frequency. You can observe the PWM output clearly at lower sampling frequency demodulated **PWM OUT** is more distorted at lower sampling frequency.
- Observe the waveforms at different test points as shown in **FIG. 7.2**
- Repeat the above all procedures for SFH450V.

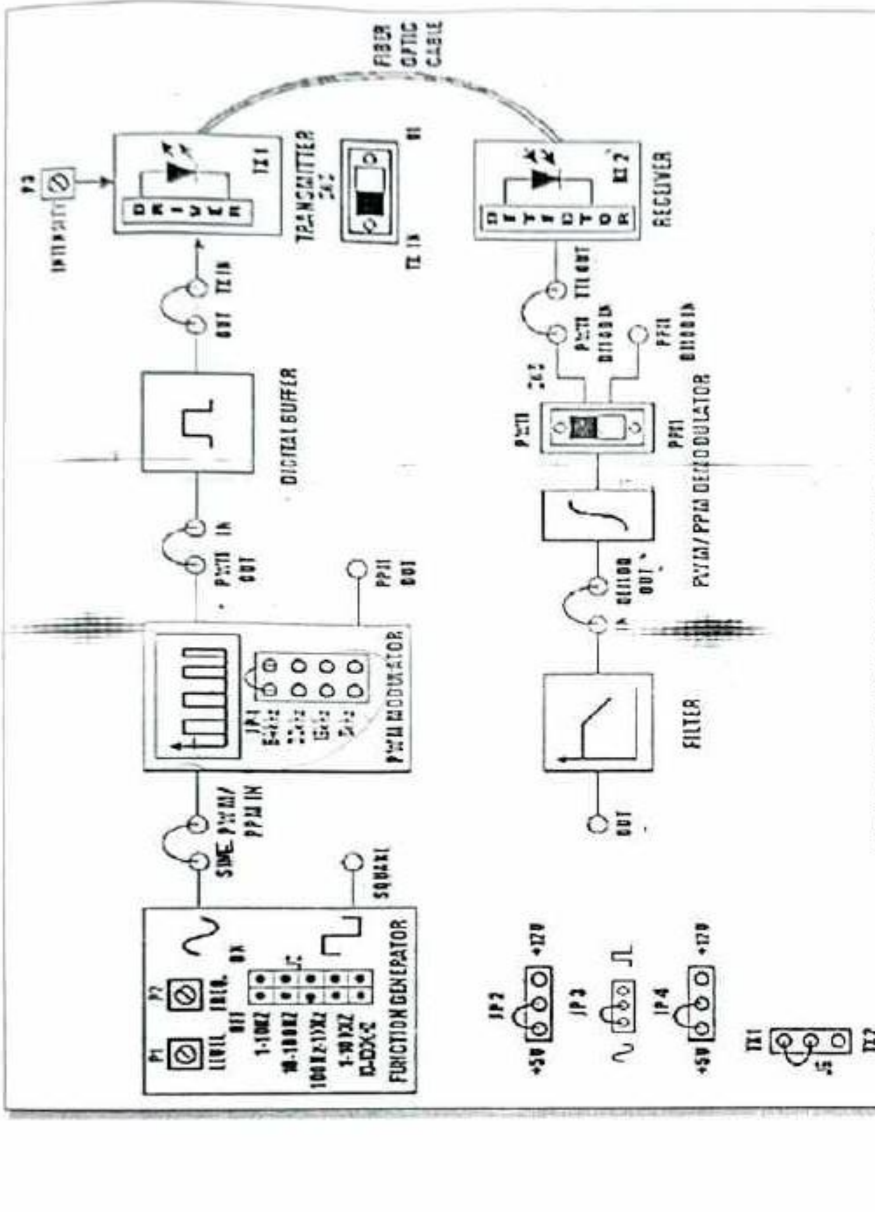


FIG.7.1 BLOCK DIAGRAM FOR PULSE WIDTH MODULATION AND DEMODULATION

Adjust offset ~~in~~ input of DEMOD

Don't use Analog buffer, output is coming clipped

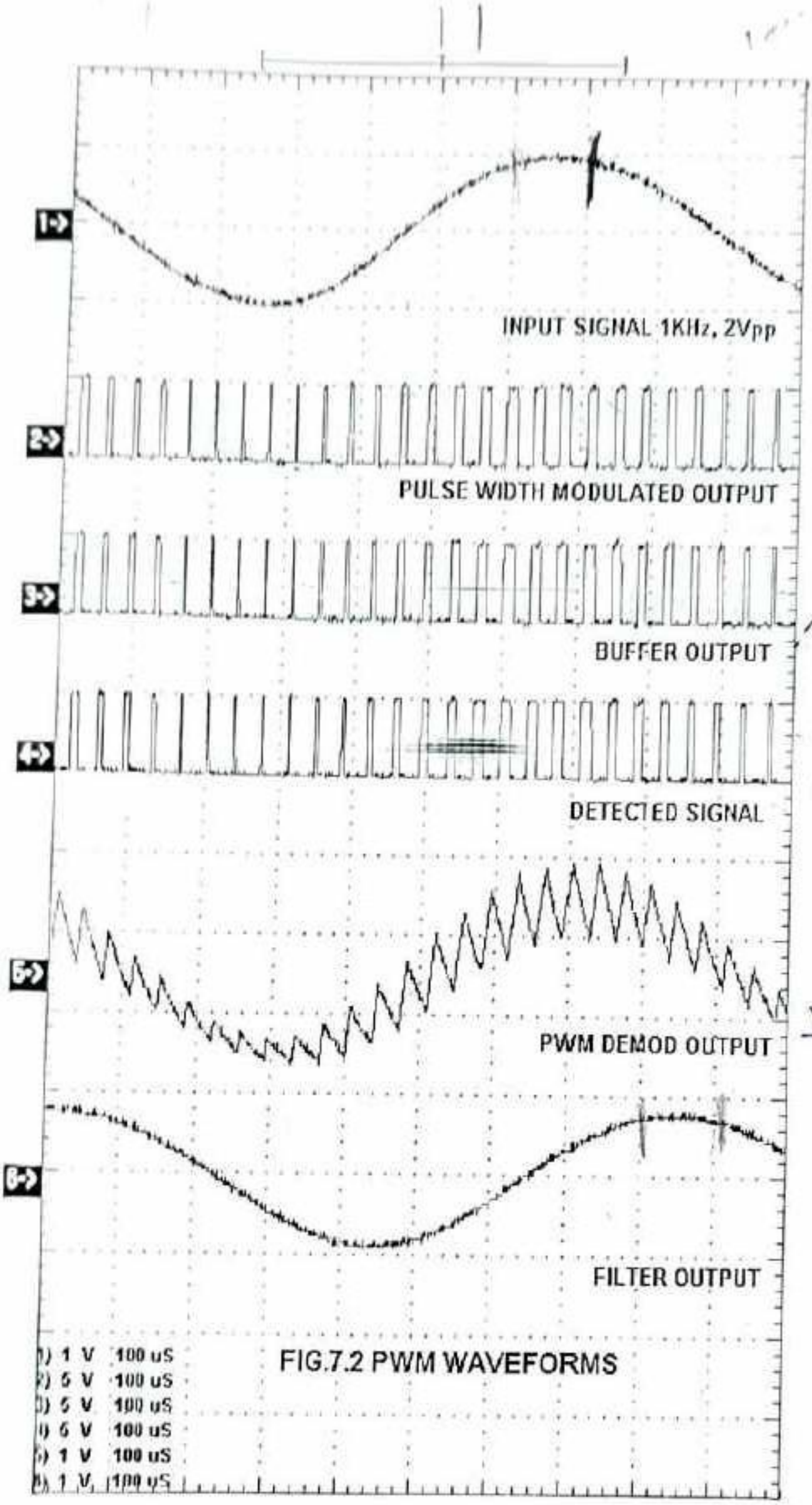


FIG.7.2 PWM WAVEFORMS

EXPERIMENT NO. 8

NAME:

Study of Pulse Position Modulation & Demodulation

OBJECTIVE:

The objective of this experiment is to study the circuit action of Pulse Position Modulation & Demodulation over Fiber Optic Digital Link.

THEORY:

Modulation

The position of the TTL pulse is changed on time scale according to the variation of input modulating signal amplitude.
Now pulse width modulated signal is fed as input to this circuit. Please note that input modulating signal must be converted into pulse width modulated form before applying to pulse modulator. As the signal is PWM, naturally, according to the input signal, the pulse duration is changing and this change in pulse duration causes for the delay in triggering. The input is given to trailing edge trigger input of monoshot. So finally we get the pulses at the output, which are shifted on the time slot. This is nothing but pulse position modulation.
The Pulse Positions are directly proportional to the instantaneous values of modulating signal.

Demodulation

The pulse position modulated signal is ORed with pulse generated by the rising edge of pulse width modulated signal. The o/p of the OR gate is fed to clk I/p of flip-flop. Thus flip-flop acts as a bistable multivibrator giving out high o/p for the duration between rising edge of PWM signal & PPM signal. Since PPM corresponds to the end of PWM pulse, o/p of flip-flop is exactly same as that of PWM signal. This signal is then demodulated using the same technique of PWM demodulation as described in previous experiment.

EQUIPMENTS:

- FOL-B-P kit
- Dual Channel Oscilloscope
- 1-Meter Fiber Cable
- Power Supply

PROCEDURE:

- Slightly unscrew the cap of SFH 756V (660 nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tight the cap by screwing it back.
- Make the connections and jumper settings as shown in **FIG. 8.1** Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF.
- Connect **SINE** post of the Function Generator section to **PPM IN** post of PWM/PPM Modulator Section.
- Keep the Function Generator in sine wave mode & select the frequency 1-10Hz with amplitude of 2V p-p (Max) for proper observation of phenomena.
- Connect **PPM OUT** post of PWM/PPM Modulator section to **IN** post of Digital Buffer Section.
- Switch on the power supply.
- Observe PPM signal at **PPM OUT** post by connecting I ST Channel of CRO at **PPM OUT** post. Refer **FIG. 8.2c**. Variation in width of square wave is seen clear by connecting II ND Channel of CRO at **PWM OUT** post. If the frequency is high i.e. frequency is 1 KHz having Level 2Vp-p then due to persistence of vision, only blurt band in the waveform will be observed. If the Function generator is **OFF**, only square wave of fundamental frequency and fixed ON time will be observed and no width position variations are present.
- Connect **OUT** post of the Digital Buffer Section to **TX IN** post of TRANSMITTER.
- Connect the other end of the fiber to detector SFH551V (Digital Detector) very carefully as per the instructions in step 1.
- Observe ~~the received~~ signal over fiber at **TTL OUT** Post. It should be exactly similar to the signal available at **PPM OUT** post.
- Connect this **TTL OUT** post to **PPM DEMOD IN** Post in PWM / PPM Demodulator Section.
- Vary input freq. (not more than 3 KHz) & observe demodulated signal at **DEMOD OUT** post (**FIG. 8.2d**).
- Connect **DEMOD OUT** post to **FILTER IN** post & observe output at **FILTER OUT** post (**FIG. 8.2e**), which is same as Input signal (**FIG. 8.2a**).
- For Different Sampling frequencies change the jumper cap of **JP1** from 8 KHz to the desired value of frequency.
- Observe the waveforms at different test points as shown in **FIG. 8.2**
- Repeat the above all procedures for SFH450V.

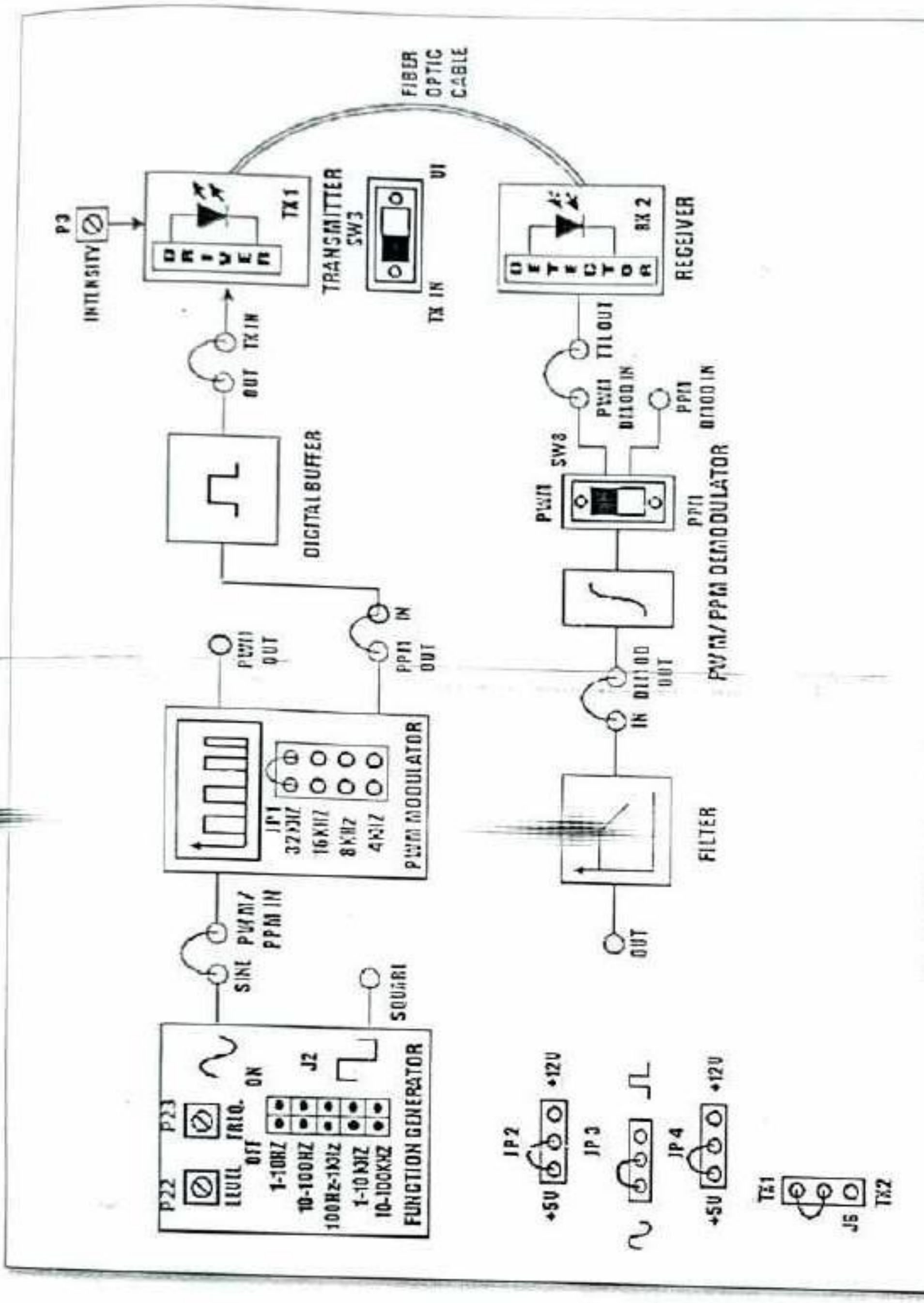


FIG. 8.1 BLOCK DIAGRAM FOR PULSE POSITION MODULATION AND DEMODULATION

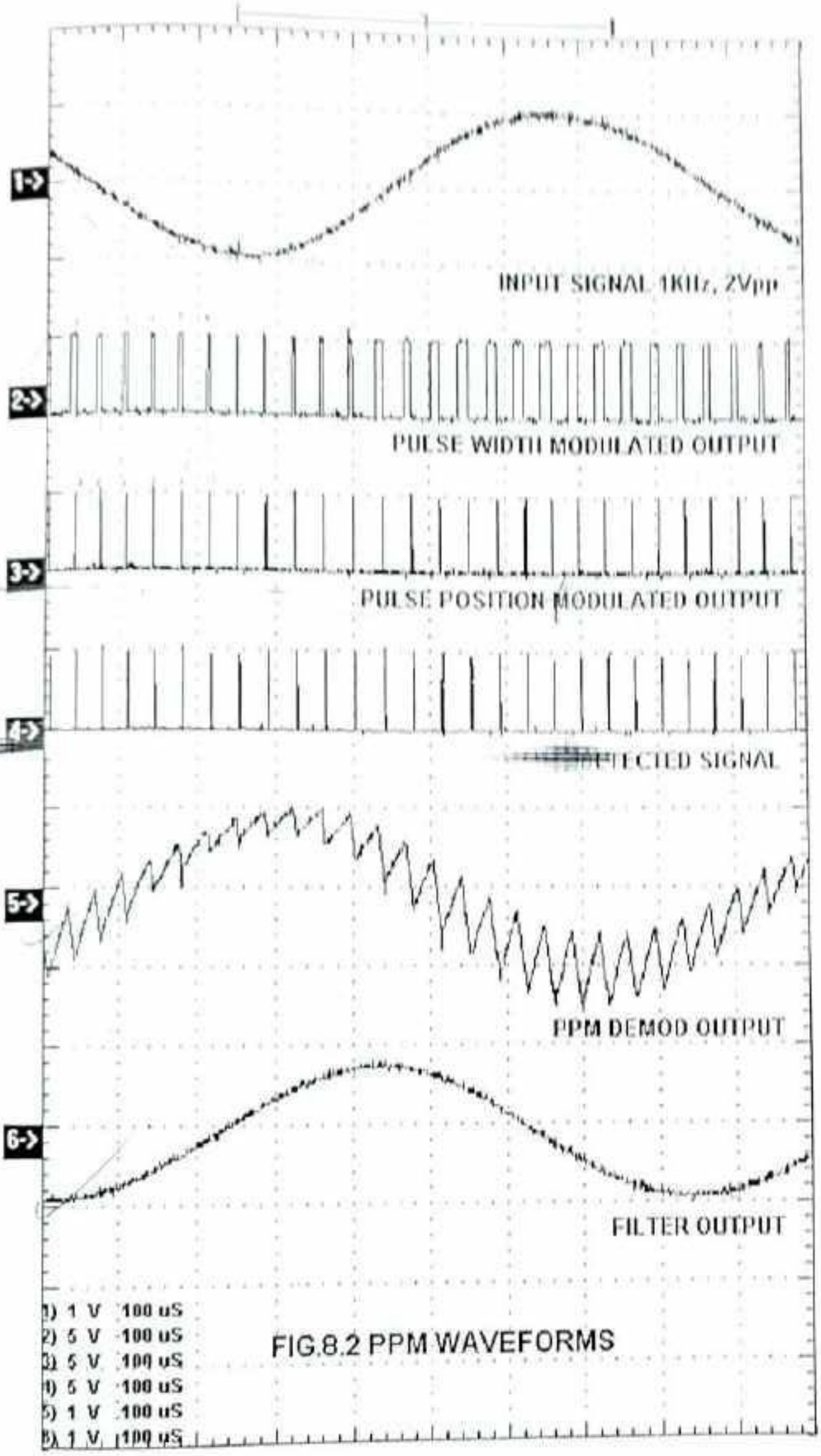
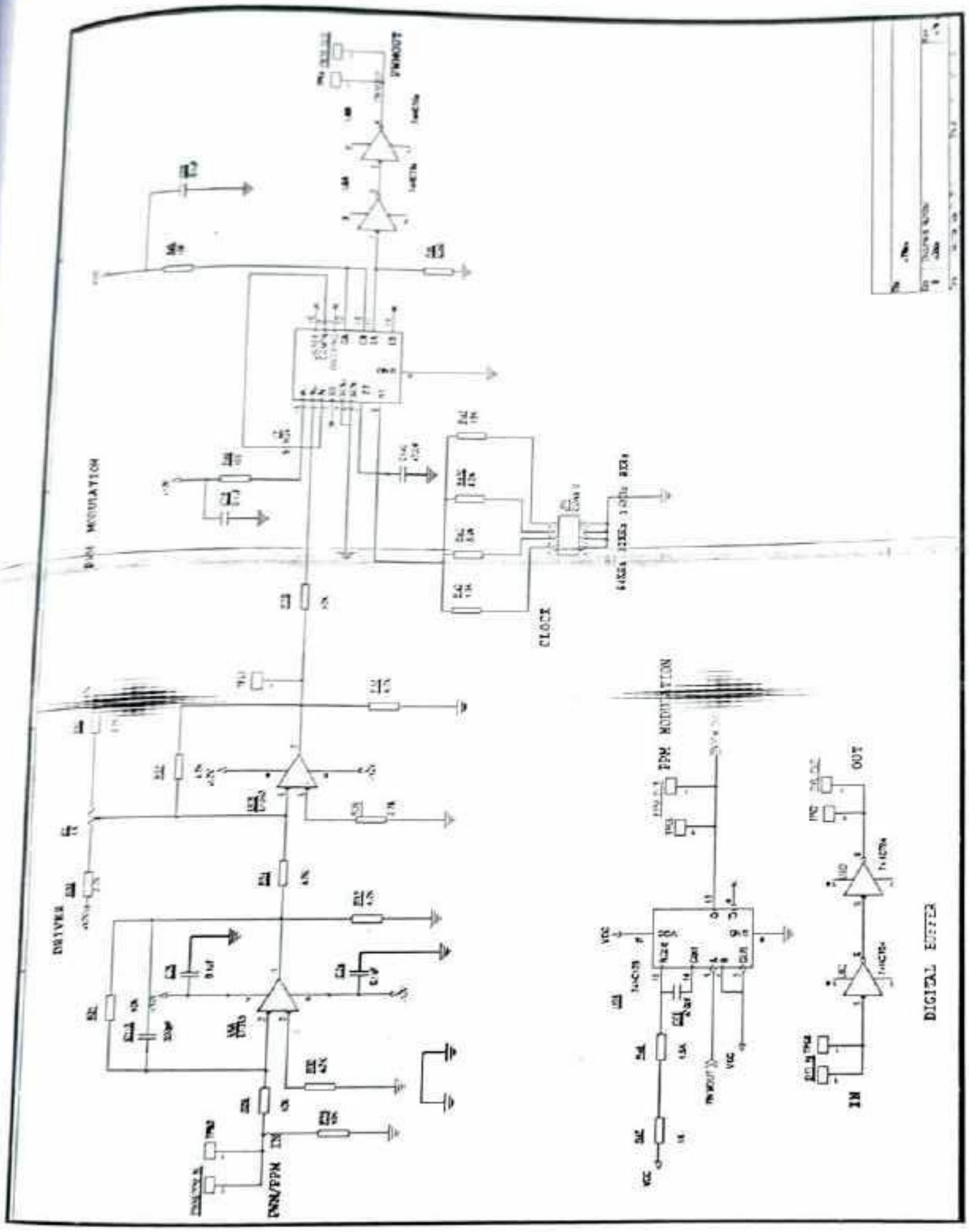
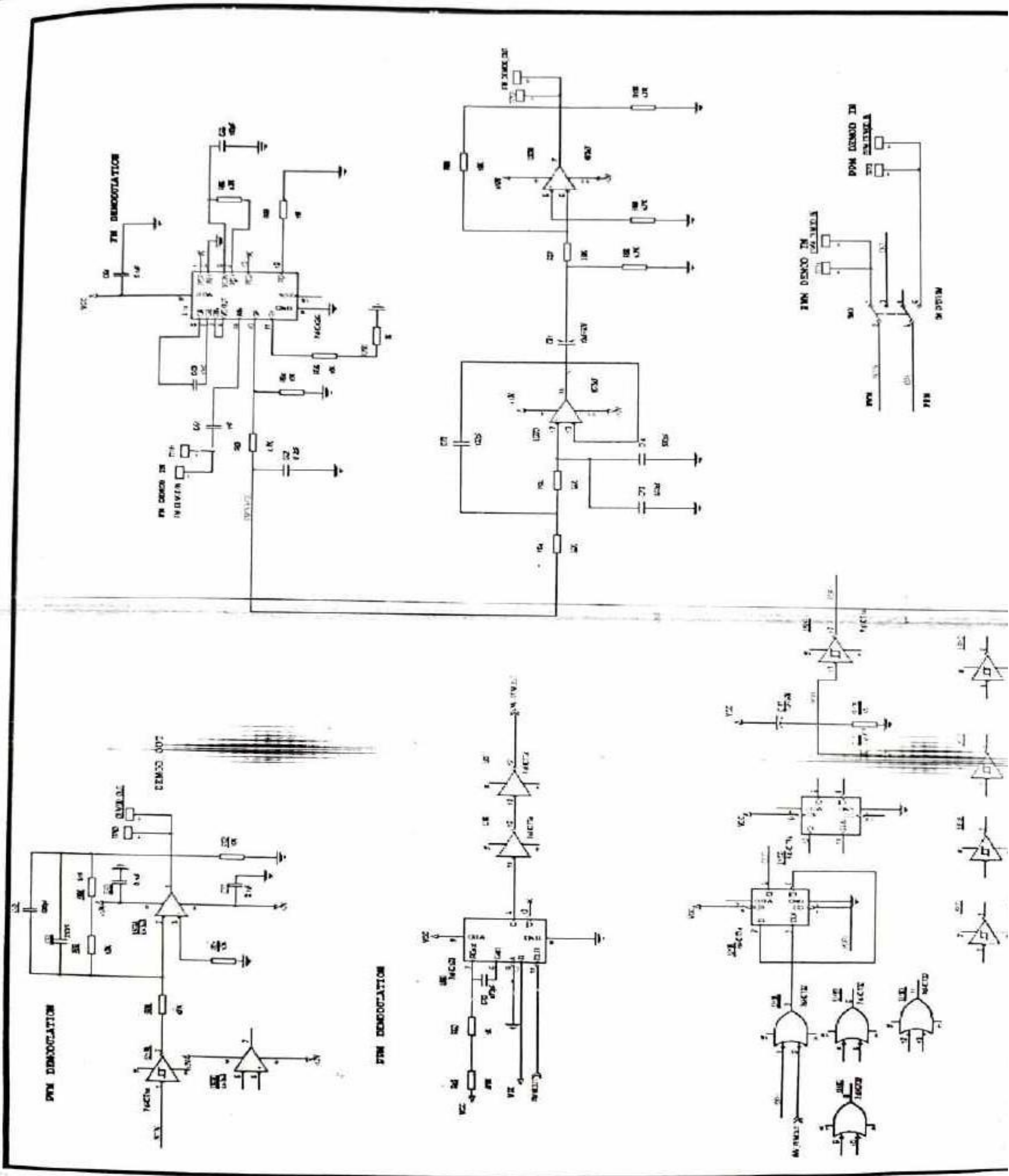


FIG.8.2 PPM WAVEFORMS


PWM MODULATION
DRIVER
CLOCK
PPM MODULATION
DIGITAL BUFFER
PWM/PPM
PWMOUT
IN
OUT


FM DEMODULATION

(5)

EXPERIMENT NO. 2 5

NAME

Study Of Digital Time Division Multiplexing

OBJECTIVE

The objective of this experiment is to study simultaneous transmission of several signals using synchronous time division multiplexing.

THEORY

In case of communication systems, signals, which are transmitted usually, carry voice or video information with them & are interpreted by human eye or ears, which have slow response. Persistence of vision as well as of hearing has given rise to the concept of time division multiplexing. In time division multiplexing various signals are sampled & transmitted for a fixed duration of time one after the other. At the receiving end, these signals are extracted in the same order & form of transmission.

To implement this scheme, we have used 8 channel digital multiplexer at transmission end with clock generator for timing of signals. One channel is reserved for marker transmission; two channels for voice data transmission, five channels take their inputs from five data switches. Each channel has a data rate of 64 Kbits / Sec.

This multiplexed data is then Manchester coded & fed as digital data to the transmitter. The received digital data is first Manchester decoded & passed through a clock recovery circuit & then demultiplexed giving each signal separate in its original form & shape.

EQUIPMENTS

FCL-04
1 Meter Fiber cable
Patch chords
Telephone Handsets
Power Supply (Use only one provided)
20 MHz Dual Channel Oscilloscope

NOTE: Keep All Switch Faults In Off Position.

PROCEDURE

- Make connections as shown in fig.2.1. Connect the power supply cables with proper polarity to FCL-04 Kit. While connecting this, ensure that the power supply is OFF.
- Keep the switch **SW5** to **VOICE IN** position, **SW7** to **TTL** position on FCL-04 as shown in fig.2.1.
- Keep the jumpers **JP2** & **JP3** on FCL-04 as shown in fig.2.1.
- Switch ON the power supply.
- Connect the post **MCDTX** to the **TX IN** post on FCL-04.
- Slightly unscrew the cap of LED SFH450V (950nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tighten the cap by screwing it back.
- Slightly unscrew the cap of Photo Transistor with TTL logic output SFH551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.
- Connect detected signal **TTL OUT** to post **MCDRX**.
- Connect Telephone handsets to posts **HS1** & **HS2**.
- Set **MARKER TX1** & **MARKER TX2** each for bit pattern shown in fig.2.1using **SW1** & **SW2** respectively.
- Set **MARKER RX1** & **MARKER RX2** each for bit pattern shown in fig.2.1using **SW3** & **SW4** respectively.
- Observe the time division multiplex data at **TDMTX** on Oscilloscope.
- Carefully observe the time duration for which each channel is selected. Observe & measure the frame period.
- Press either of the Channel keys (CH2, CH3, CH5, CH7 & CH8) and observe how data is transmitted in the corresponding time slot. Thus, you can observe the signals at different points of the transmitter section.
- Observe the Manchester coded data at **MCDTX**. This data is transmitted through the fiber. The received data, which is still in Manchester coded form, is available at **MCDRX** & **TDMRX** signals with respect to **TDMTX**.
- Observe the data transmission by pressing keys (CH2, CH3, CH5, CH7 & CH8) & observing the corresponding LEDs lit up.
- The voice input at one mouthpiece can be heard at the earpiece of another handset. Observe this TDM effect.
- Repeat the above procedure for marker1 & 2 as given in the marker settings table below.

Note

The students can form hundreds of other combinations apart from the marker settings table. Few settings may not give proper TDM o/p. Avoid 4 consecutive 1's or 0's in a single marker setting to get proper TDM data.

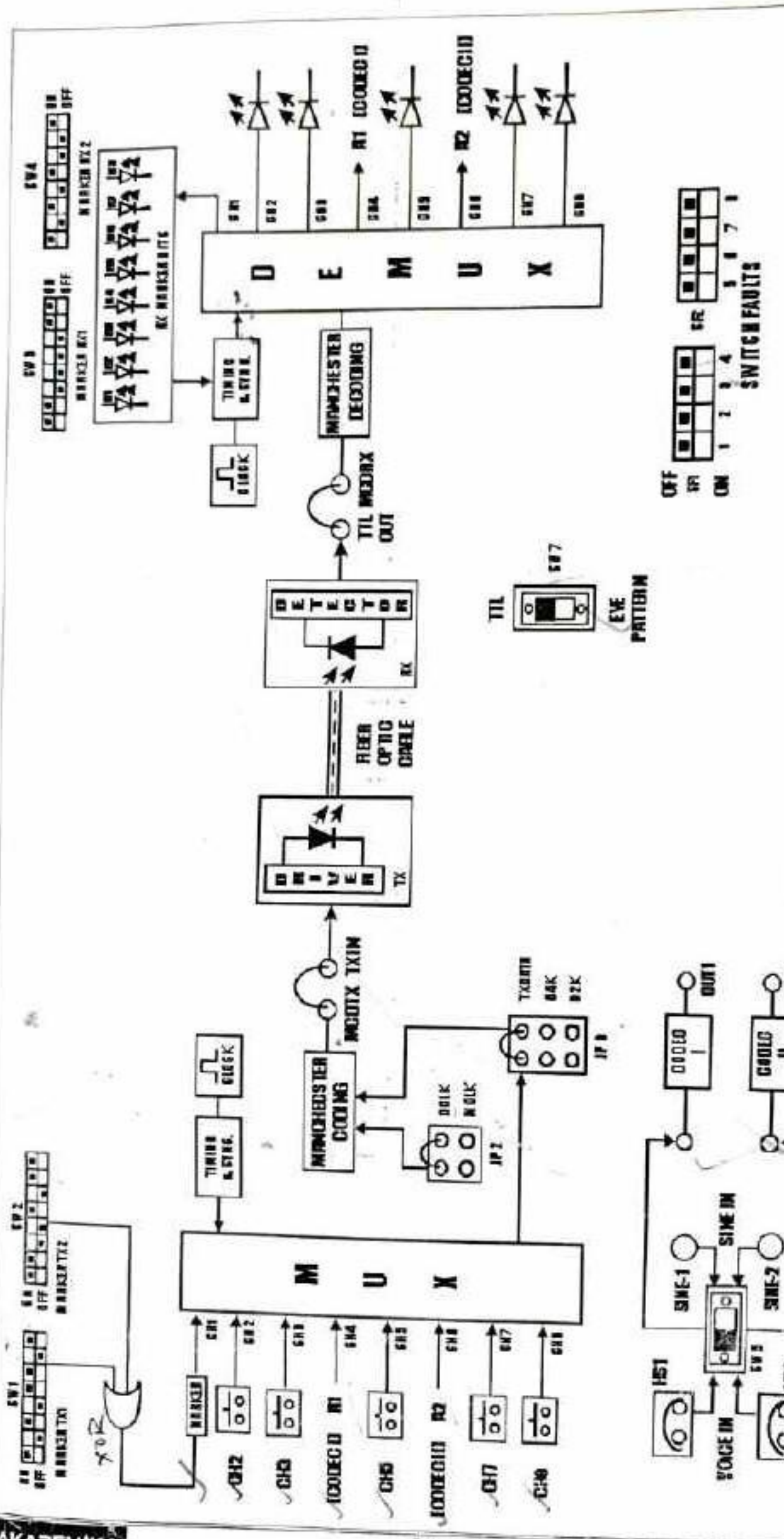


FIG. 2.1 BLOCK DIAGRAM FOR TIME DIVISION MULTIPLEXING

SWITCH FAULTS

NOTE: Keep the connections as per the procedure. Now Switch ON corresponding fault switch button to **ON** position & observe the different effects on the output. The faults are normally used one at a time.

- Put switch **1 (SF1)** in Switch Fault section to **ON** position. Clock 8KHz of U16 (4051) is removed. Output channels loose synchronization. All channels are affected.
- Put switch **2 (SF1)** in Switch Fault section to **ON** position. Transmitter markers are removed at the U16 (4051) mux I/P. Hence data is transmitted without marker & hence no sync pulse at receiver and synchronization is lost at Output.
- Put switch **3 (SF1)** in Switch Fault section to **ON** position. This will open pin 2 of U28a (XOR) in Manchester coding section. MCDTX Output gets disturbed at TP5 and hence Output channels at receiver get disturbed. (No coding takes place & hence MCD clock recovery is disturbed and no demultiplexing takes place.
- Put switch **5 (SF2)** in Switch Fault section to **ON** position. This will open pin 5 of U36 (74154) demux IC. The channel 5 is not enabled at Output. No LED indication for channel 5.
- Put switch **8 (SF2)** in Switch Fault section to **ON** position. This will open pin 21 of U36 (74154) demux IC. The demux clock Q3 is removed which affects the Output channel demultiplexing, channel indication and bit indications are disturbed.

TX MARKER -1	TX MARKER -2
10010001	10110110
11011001	10110110
11011001	10001010
01011101	10001010
10101101	10001010
10101101	11001011
10111001	11001011
10110001	01101010
10011101	01100010
10010101	01011001

MARKER SETTINGS TABLE

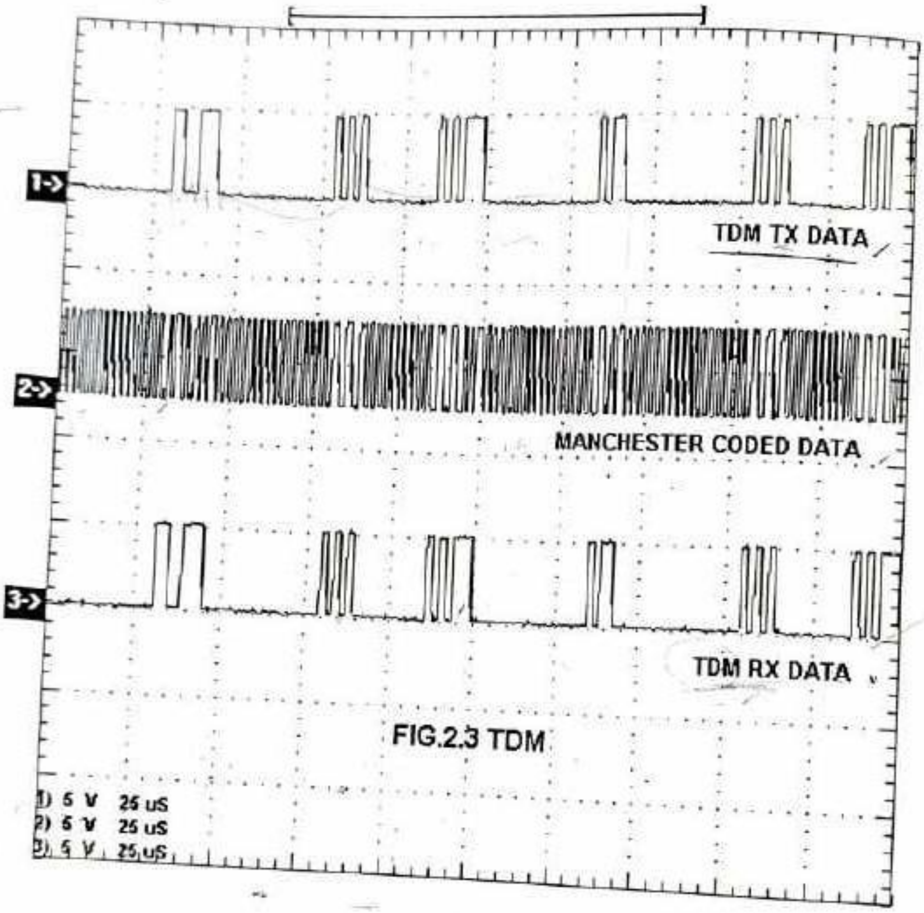

1->
TDM TX DATA
2->
MANCHESTER CODED DATA
3->
TDM RX DATA
1) 5 V 25 uS
2) 5 V 25 uS
3) 5 V 25 uS

FIG.2.3 TDM

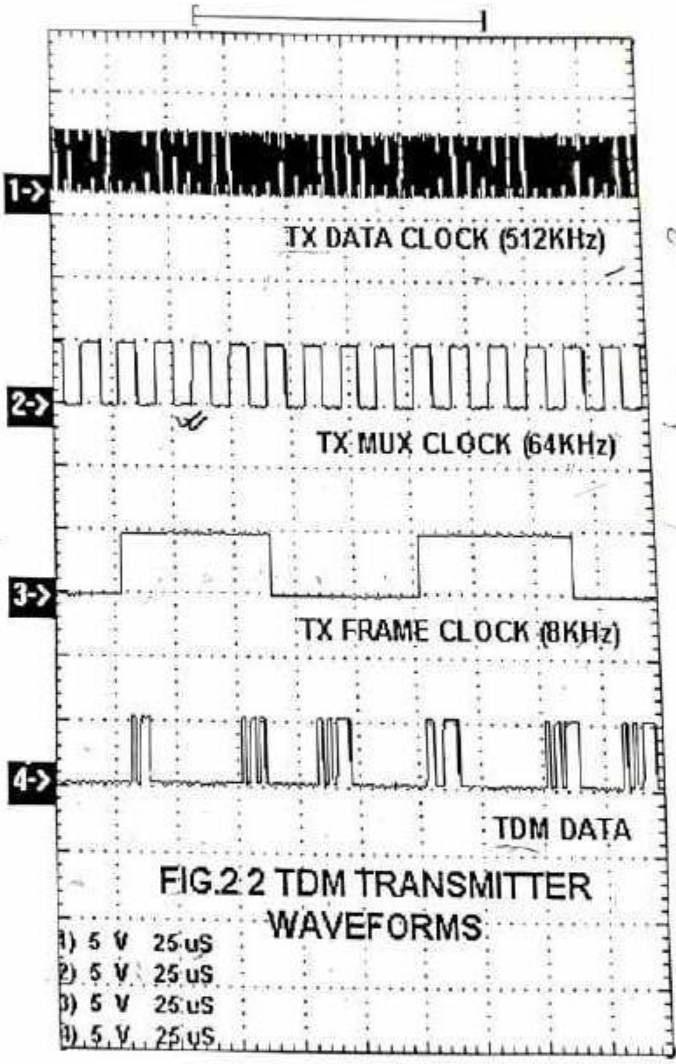


FIG.2.2 TDM TRANSMITTER WAVEFORMS

EXPERIMENT NO.~~3~~ 6

NAME

Study Of Framing In Time Division Multiplexing

OBJECTIVE

The objective of this experiment is to study the technique of FRAMING in time division multiplexing.

THEORY

This is an advanced experiment on Time Division Multiplexing. This experiment examines the method of synchronous multiplexing. A FRAME plays a vital role in synchronous time division multiplexing, which repeats itself after every T seconds. The frame has 'n' bits & frame rate is 1/T frames per sec. The total data rate is n/T bits per sec. A synchronous signal can occupy one or more bits in every frame. A signal occupying one bit per frame will have a data rate of 1/T bits per sec & a signal occupying 'm' bits per frame will have a data rate of m/T bits per sec.
Now the repetition rate of frame depends on channel sampling frequency. Since we are transmitting audio signals on these channels, we should sample channel at least twice the highest frequency component in audio signal, which is 4 KHz. This determines frame frequency of 8KHz. Within this period of 125 microsec, we transmit 8 channels. Hence ON period of each channel comes about 125/8 micro sec. This corresponds to the frequency of 64 KHz. Lastly, since we transmit 8 bits of data per channel, data rate can be derived as 15.625/8=1.953125 &1/1.953125 = 512 KHz.

EQUIPMENTS

FCL-04
1 Meter Fiber cable
Patch chords
Power Supply (Use only one provided)
20 MHz Dual Channel Oscilloscope

NOTE: Keep All Switch Faults In Off Position.

PROCEDURE

- Make connections as shown in fig.3.1. Connect the power supply cables with proper polarity to FCL-04 Kit. While connecting this, ensure that the power supply is OFF.
- Keep the switch **SW5** to **VOICE IN** position, **SW7** to **TTL** position on FCL-04 as shown in fig.3.1.
- Keep the jumpers **JP2** & **JP3** on FCL-04 as shown in fig.3.1.
- Switch ON the power supply.
- Connect the post **MCDTX** to the **TX IN** post on FCL-04.
- Slightly unscrew the cap of LED SFH450V (950nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tighten the cap by screwing it back.
- Slightly unscrew the cap of Photo Transistor with TTL logic output SFH551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.
- Connect detected signal **TTL OUT** to post **MCDRX**.
- Connect Telephone handsets to posts **HS1** & **HS2**.
- Set **MARKER TX1** & **MARKER TX2** each for bit pattern shown in fig.3.1using **SW1** & **SW2** respectively.
- Set **MARKER RX1** & **MARKER RX2** each for bit pattern shown in fig.3.1using **SW3** & **SW4** respectively.
- Observe Frame Frequency at **FRM CLK** and Slot frequency at **MUX CLK** simultaneously on the Oscilloscope. Draw the waveforms. You should get 8 periods of slot frequency within one period of frame frequency. Similarly observe Data Clock at **DATA CLK** and compare it with the slot frequency.
- Observe the multiplexed data at **TDMTX**. This clearly indicates the frame pattern as explained above. Compare it with the frame frequency.
- Observe the transmitted clock at **DATA CLK** and received clock at **RX DATA CLK**. The duty cycles of the two are not the same but the clocks are synchronized except for a slight transmission delay in the received clock.

SWITCH FAULTS

NOTE: Keep the connections as per the procedure. Now Switch ON corresponding fault switch button to **ON** position & observe the different effects on the output. The faults are normally used one at a time.

- Put switch **1 (SF1)** in Switch Fault section to ON position. Clock 8KHz of U16 (4051) is removed. Output channels loose synchronization. All channels are affected.
- Put switch **7 (SF2)** in Switch Fault section to ON position. This will open pin 1 of IC U38 (74LS125). The CODEC2 (U22) channel selection is removed and no CODEC response for analog signal or voice channel.

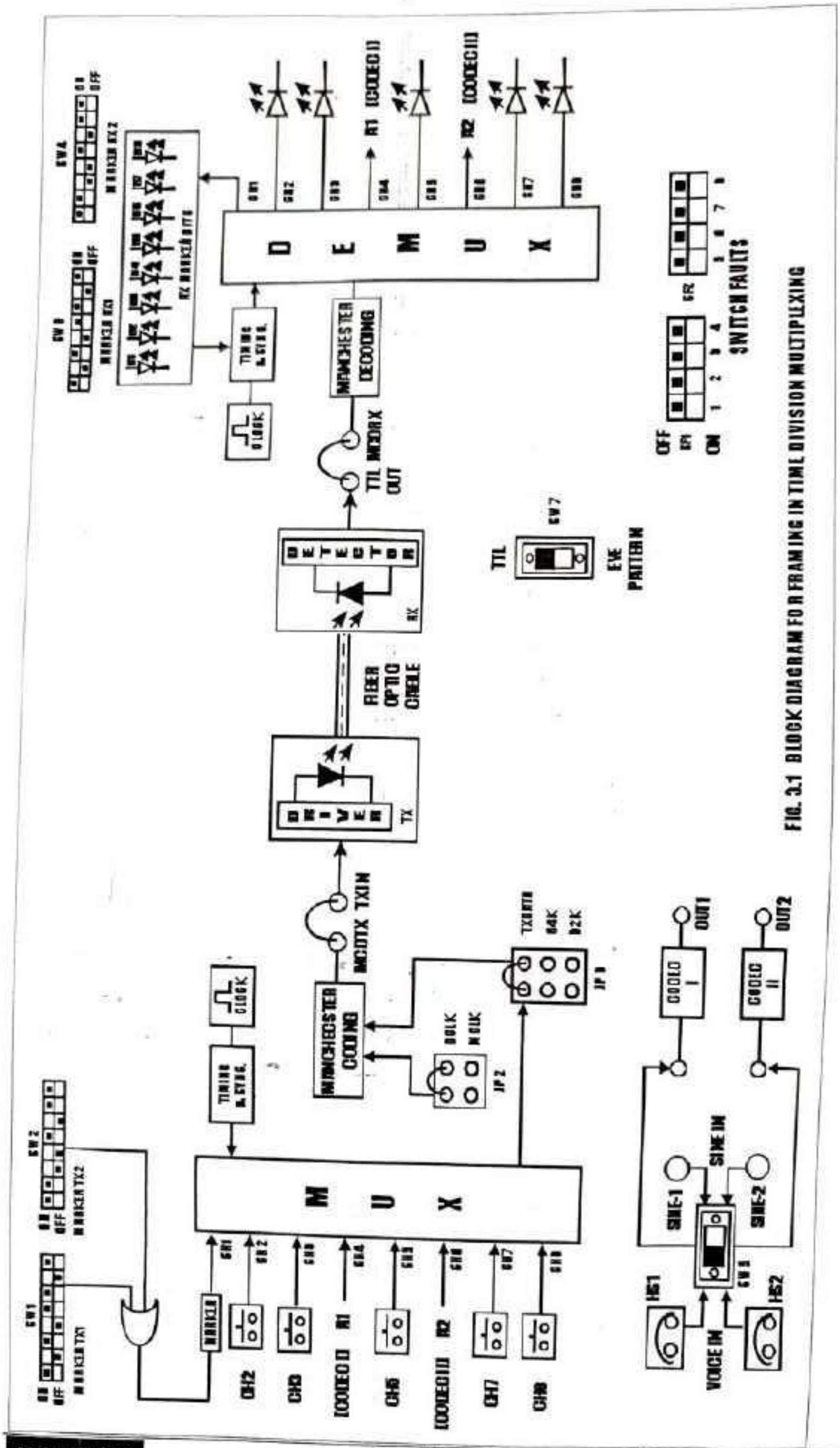


FIG. 3.1 BLOCK DIAGRAM FOR FRAMING IN TIME DIVISION MULTIPLEXING

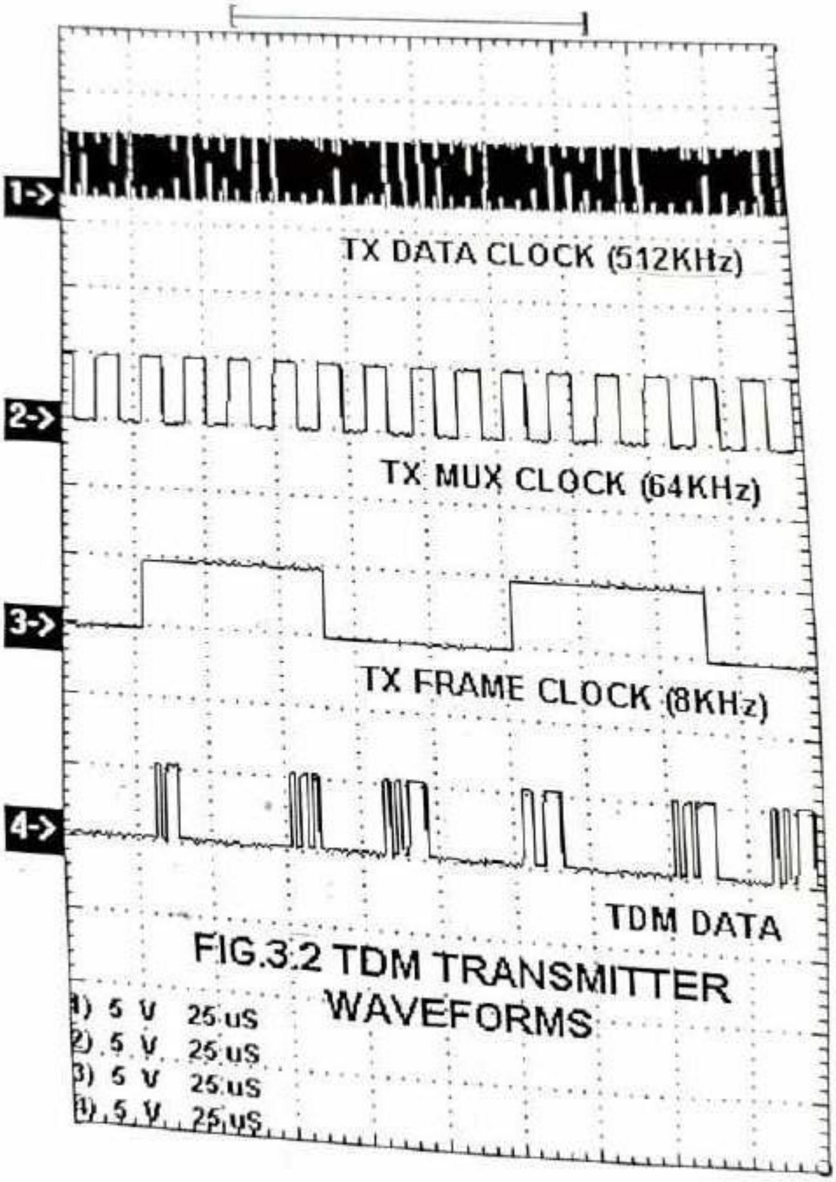


FIG.3.2 TDM TRANSMITTER WAVEFORMS

EXPERIMENT NO. 6

NAME:

Setting Up A Fiber Optic Digital Link

OBJECTIVE:

The objective of this experiment is to study 950 and 660 nm fiber optic digital link. Here you will study how digital signal can be transmitted over fiber cable and reproduce at the receiver end.

THEORY:

In the experiment no. 1, we have seen how analog signal can be transmitted and received using LED, fiber and detector. The same LED, fiber and detector can be configured for the digital applications to transmit binary data over fiber. Thus basic elements of the link remain same even for digital applications.

Transmitter

LED digital, DC coupled transmitters are one of the most popular variety due to their ease of [illegible]. We have used a standard TTL gate [illegible] NPN transistor, which modulates the LED SFH450V OR SFH756V source (Turns it ON and OFF).

Receiver

There are various methods to configure detectors to extract digital data. Usually detectors are of linear nature. We have used a photodetector SFH551V having TTL type output. Usually it consists of PIN photodiode, transimpedance amplifier and level shifter.

EQUIPMENTS:

- FOL-B-P kit
- Dual Trace Oscilloscope
- 1-Meter Fiber Cable
- Power Supply

PROCEDURE:

Slightly unscrew the cap of LED SFH 756V (660 nm). Do not remove the cap from the connector. Once the cap is loosened, insert the fiber into the cap. Now tight the cap by screwing it back.

Make the connections and Jumper settings as shown in **FIG. 6.1**. Connect the power supply cables with proper polarity to kit. While connecting this, ensure that the power supply is OFF. Now switch on the power supply.

Feed the Onboard Square (TTL) signal of about 1 KHz to **IN** post of Digital Buffer Section and observe the signal at its **OUT** post. It should be same as that of the input signal.

Connect OUT post of the Digital Buffer Section to **TX IN** post of TRANSMITTER.

Connect the other end of the fiber to detector SFH 551V **RX2** (Digital Detector) very carefully as per the instructions in step 1.

Observe the received signal on CRO at **TTL OUT** post. The transmitted signal and received signal are same. Vary the frequency of the input signal and observe the output response.

To set up a digital link using SFH 450 (950 nm) change jumper connections as shown in jumper block diagram **FIG. 6.2**& repeat steps 1 to 8 using SFH 450V (950 nm) instead of SFH 756V (660 nm).

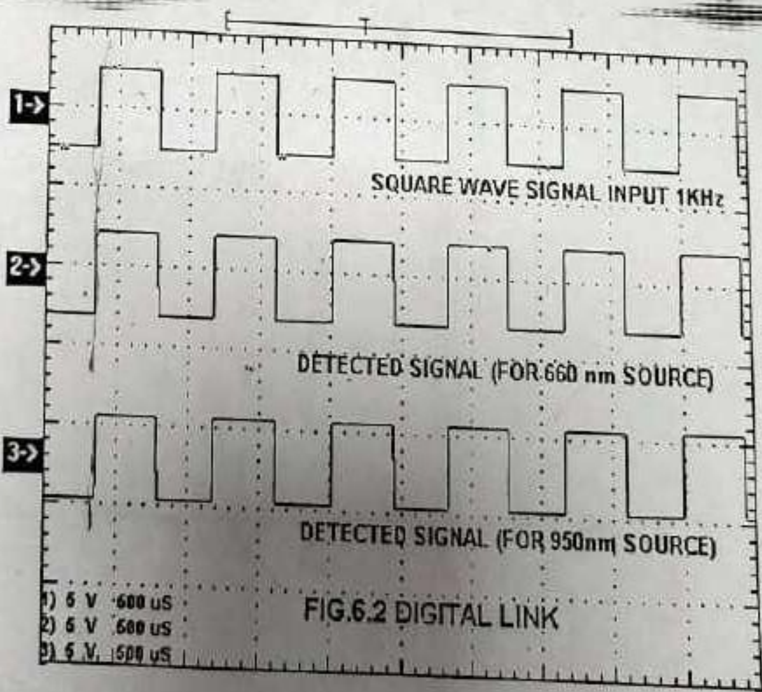


FIG.6.2 DIGITAL LINK

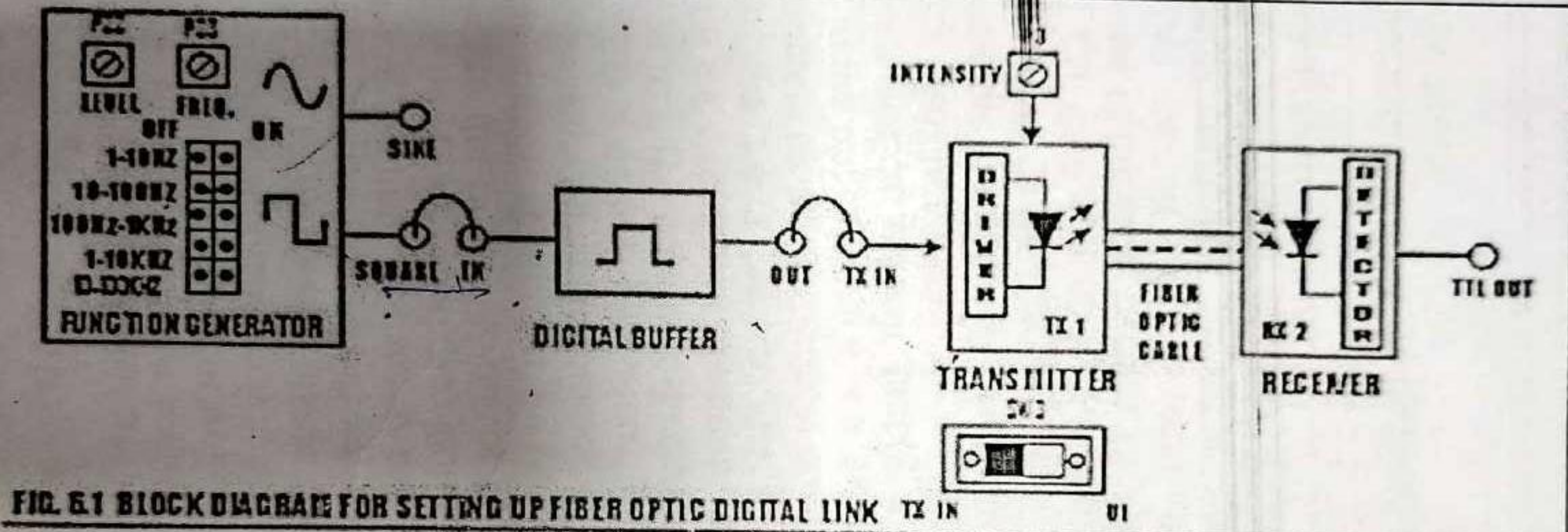
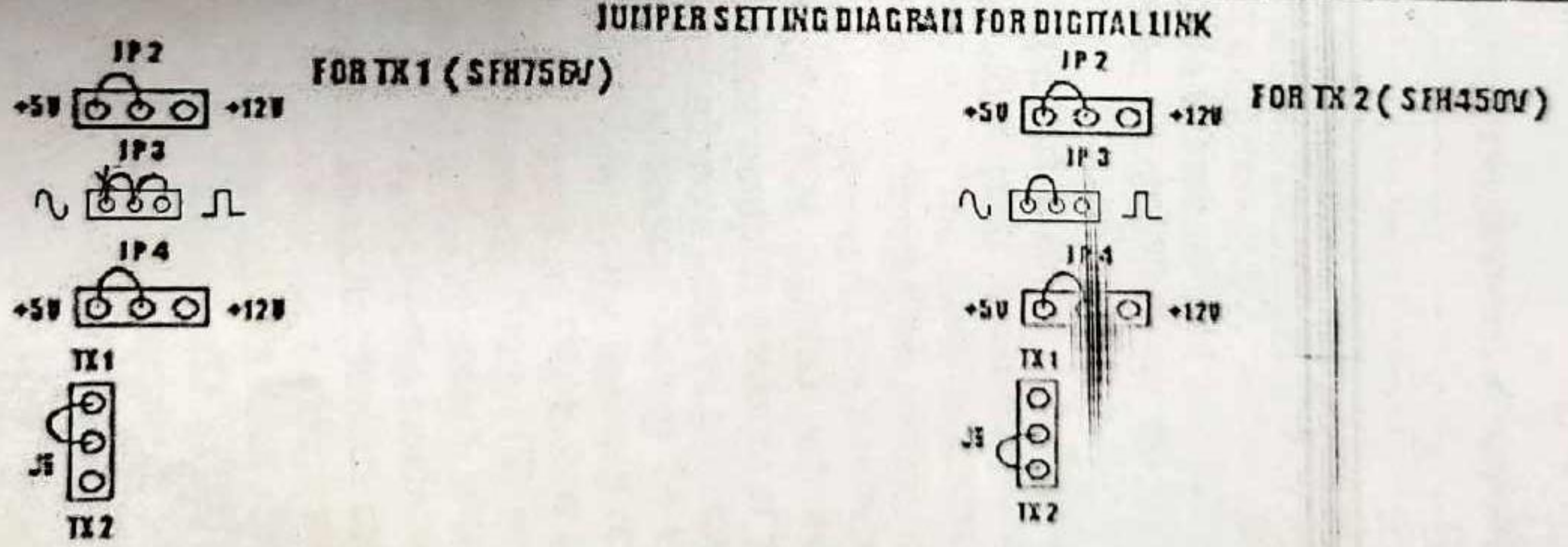


FIG. 6.1 BLOCK DIAGRAM FOR SETTING UP FIBER OPTIC DIGITAL LINK



dual monostable multivibrator. The ON period of the output pulse from the monostable is decided by the external R and C network. Here, the active low reset input pin (3) is tied to VCC. Circuit uses monostable I in the IC. Pin 2 and pin 1 are the rising and trailing edge trigger inputs of IC. Here trailing edge triggering is used. Output is taken from pin no. 13 of monostable I (Q).

Now Pulse Width Modulated signal is fed as input to this circuit. Please note that input modulating signal must be converted into Pulse Width Modulated form before applying to Pulse Position Modulator. As the signal is PWM, naturally, according to the input signal, the pulse duration is changing and this change in pulse duration causes for the delay in triggering. The input is given to trailing edge trigger input of monoshot. So finally, we get the pulses at the output, which are shifted on the time slot. This is nothing but pulse position modulation.

Thus, Pulse Positions are directly proportional to the instantaneous values of modulating signal.

1.6 Audio Pre-Amplifier

Audio Pre-Amplifier is built around Q5 (BC548) transistor in common emitter mode.

1.7 Fiber Optics Transmitter

The transmitter module takes the input signal in electrical form & then transforms it into optical (light) energy containing the same information. The optical fiber is the medium, which carries this energy to the receiver.Transmitter- LED, digital, DC coupled transmitters are one of the most popular variety due to their ease of fabrication. We have used a standard TTL gate to drive a NPN transistor, which modulates the LED SFH450V source (Turns it ON and OFF).

Fiber optic transmitters are typically composed of a buffer, driver & optical source. The buffer electronics provides both an electrical connection & isolation between the transmitter & the electrical system supplying the data. The driver electronics provides electrical power to the optical source in a fashion that duplicates the pattern of data being fed to the transmitter. Finally the optical source (LED) converts the electrical current to light energy with the same pattern. The LED SFH450V supplied with the FOL-B-P-IIoperates outside the visible light spectrum. Its optical output is centered at near infrared wavelength of 950 nm. The emission spectrum is broad, so a faint red glow can usually be seen when the LED is on in a dark room. The LED SFH450V used in the FOL-B-P-II is coupled to the transistor driver in common emitter mode. In the absence of input signal half of the supply voltage appears at the base of the transistor. This biases the transistor near midpoint within the active region for linear applications. Thus LED emits constant intensity of light at this time. When the signal is applied to the amplifier it overrides the DC level at the base of the transistor which causes the Q point of the transistor to oscillate about the midpoint. So the intensity of the LED varies about its previous constant value. This variation in the intensity has linear relation with the input electrical signal. NPN transistor (Q2) Emitter is modulated by changing Potentiometer P3 value. Optical signal is then carried over by the optical fiber.Another source used is LED SFH756V at 660nm wavelength, which is visible red light source. A standard TTL gate drives NPN transistor (Q2), which modulates the LED SFH756V source (Turns it ON and OFF).

Selection between different sources is done through jumpers provided on board.

1.8 Fiber Optics Receiver

At the receiver, light is converted back into electrical form with the same pattern as originally fed to the transmitter. The function of the receiver is to convert the optical energy into electrical form, which is then conditioned to reproduce the transmitted electrical signal in its original form. The detector SFH250V used in the FOL-B-P has a diode type output. The parameters usually considered in the case of detector are it's responsively at peak wavelength & response time. SFH250V has responsively of about 4μA per 10 μW of incident optical energy at 950 nm and it has rise & fall time of 0.01 μ sec. PIN photodiode is normally reverse biased. When optical signal falls on the diode, reverse current start to flow, thus diode acts as closed switch and in the absence of light intensity, it acts as an open switch. Since PIN diode usually has low responsivity, a transimpedance amplifier is used to convert this reverse current into voltage formed around U12 (IC LF356). This voltage is then amplified with the help of another amplifier circuit U13 (IC LF357) & U20 (IC LF357). This voltage is the duplication of the transmitted electrical signal. There are various methods to configure detectors to extract digital data. Usually detectors are of linear nature. We have used a photo detector having TTL type output (SFH 551/V). Usually it consists of integrated photodiode, transimpedance amplifier and level shifter.

1.9 FM Demodulation

FM Demodulation is carried out using Phase Lock Loop Technique (PLL) with the help of IC U14 (IC 74HC4046). FM signal is applied to pin no. 14 & capacitor C63 & preset P16 decides the Locking frequency range of the PLL.

1.10 Pulse Width Demodulation

The PWM signal is applied to IC U15 (IC LF353) which acts as an integrator from which the signal emerges whose amplitude at any time is proportional to the pulse width at that time. This Integrated output is then filtered to get original signal.

1.11 Pulse Position Demodulation

The pulse position modulated signal is ORed with pulse generated by the rising edge of pulse width modulated signal using U18 (IC 74LS32). The o/p of the OR gate is fed to CLK I/p of flip-flop U19 (IC 74HC74). Thus flip-flop acts as a bistablemultivibrator giving out high o/p for the duration between rising edge of PWM signal & PPM signal. Since PPM corresponds to the end of PWM pulse o/p of flip-flop is exactly same as that of PWM signal. This signal is then demodulated using the same technique of PWM demodulation as described in previous expt.

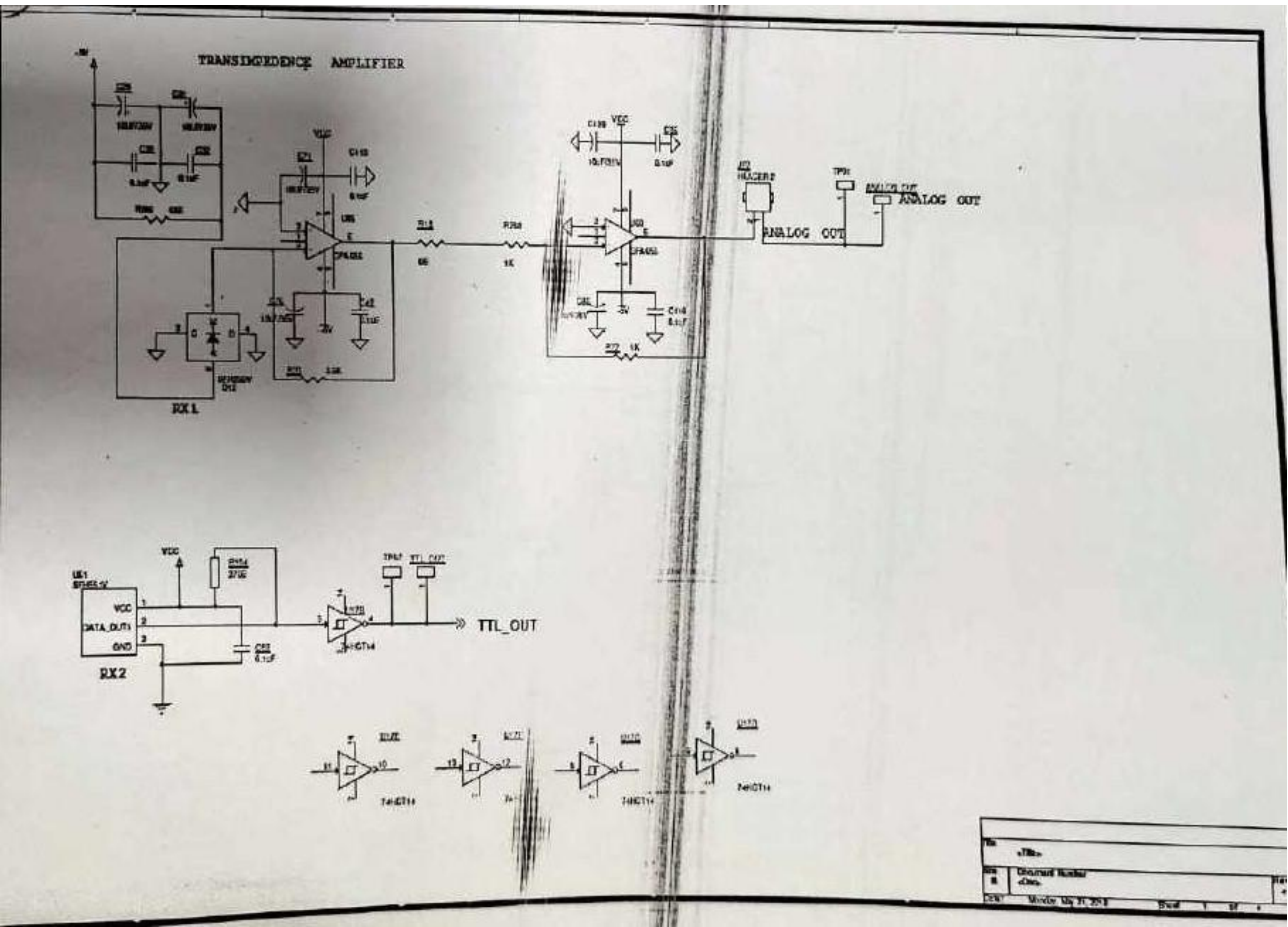
.12 Audio Amplifier

udio signal is fed to the input Pin 3 of U23 (IC LM386), through Capacitor and otentiometer P5 which controls the Volume. The gain is controlled by connecting a esistor or capacitor between Pin No. 1 and 8. The output is obtained from Pin No. 5 /hich is fed to the Speaker.

13 Filter

lter is formed by using R-C network and U22 (IC LM324) which forms a Low –Pass utterworth Filter. The LOW - PASS FILTER block strongly attenuates the high-frequency ple component at the detector's output, and also blocks the dace offset voltage. onsequently, the signal at the output of the LOW - PASS FILTER block should very osely resemble the original audio modulating signal.

te that the demodulated signal has null continuous component. Vary the amplitude and quency of the FM signal and check that the amplitude of the detected signal varies, too.


TRANSIMPEDENCE AMPLIFIER
RX1
VCC
ANALOG OUT
ANALOG OUT
RX2
VCC
DATA_OUT1
GND
TTL_OUT

classmate

Date

Exp - 9: Excitation of LP_{01}, LP_{11}, LP_{13} & LP_{21} Modes and to find their power distribution.

$\lambda = 1.55$

Background index = 1.44

Index difference = 0.01

Width = Height = 3

~~3d Structure~~ = Fibre

$$V = \frac{2\pi a}{\lambda NA}$$

$X_{min} = -60$ $Z_{min} = 0$

$X_{max} = 60$ $Z_{max} = 100$

$$V = \frac{2\pi}{1.55 \times 10^{-6}} \times a \times \frac{1.45}{1-0.01} \times \sqrt{2 \times 0.01}$$

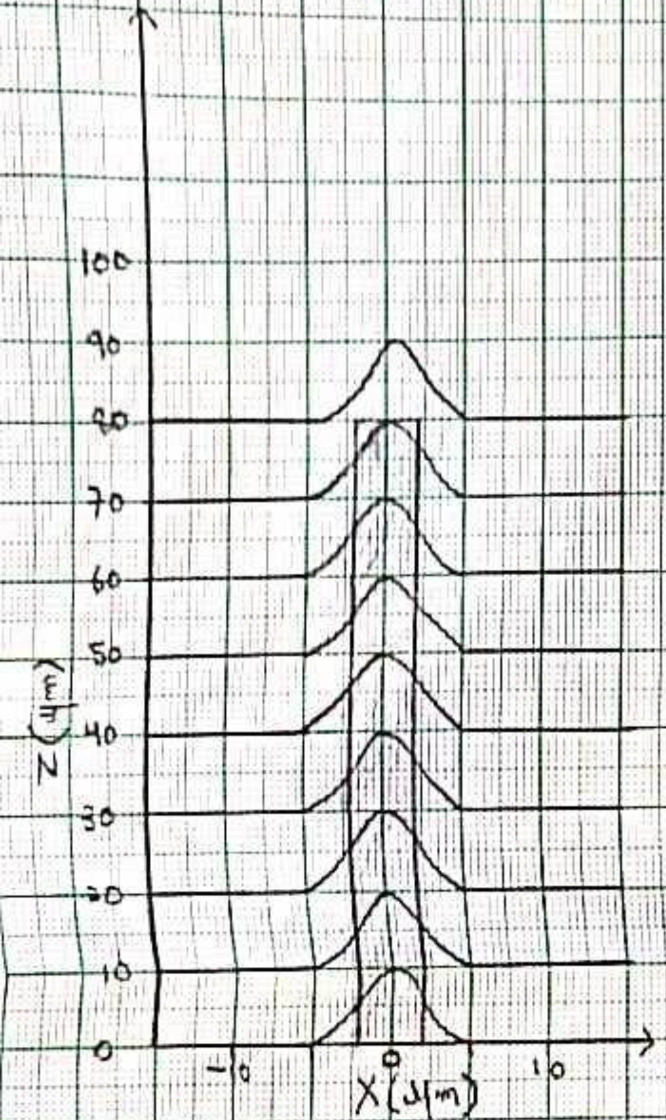
$$= 0.839 \times 10^{6} \times a$$

Sl. no.	Radius	V no.	Normalized Core Power	Normalized Clad power
1.	1.5	1.2585	0.3344	0.6655
2.	1.7	1.4263	0.4895	0.5104
3.	1.9	1.5941	0.6354	0.3695
4.	2.0	1.678	0.6875	0.3128
5.	2.2	1.8458	0.7812	0.2187
6.	2.5	2.0975	0.8802	0.1497
7.	2.6	2.1814	0.8958	0.1041
8.	2.7	2.2653	0.9106	0.0833
9.	2.8	2.3492	0.9375	0.0625
10.	2.86	2.39954	0.9375	0.0625

Should be
<2.405 for
single
mode fiber

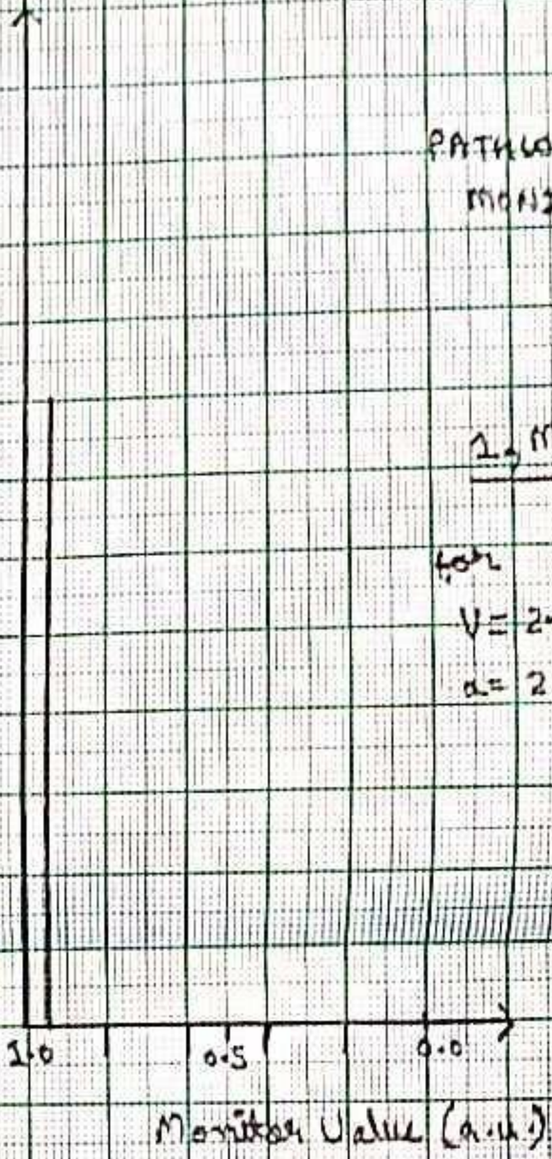
13-03-23

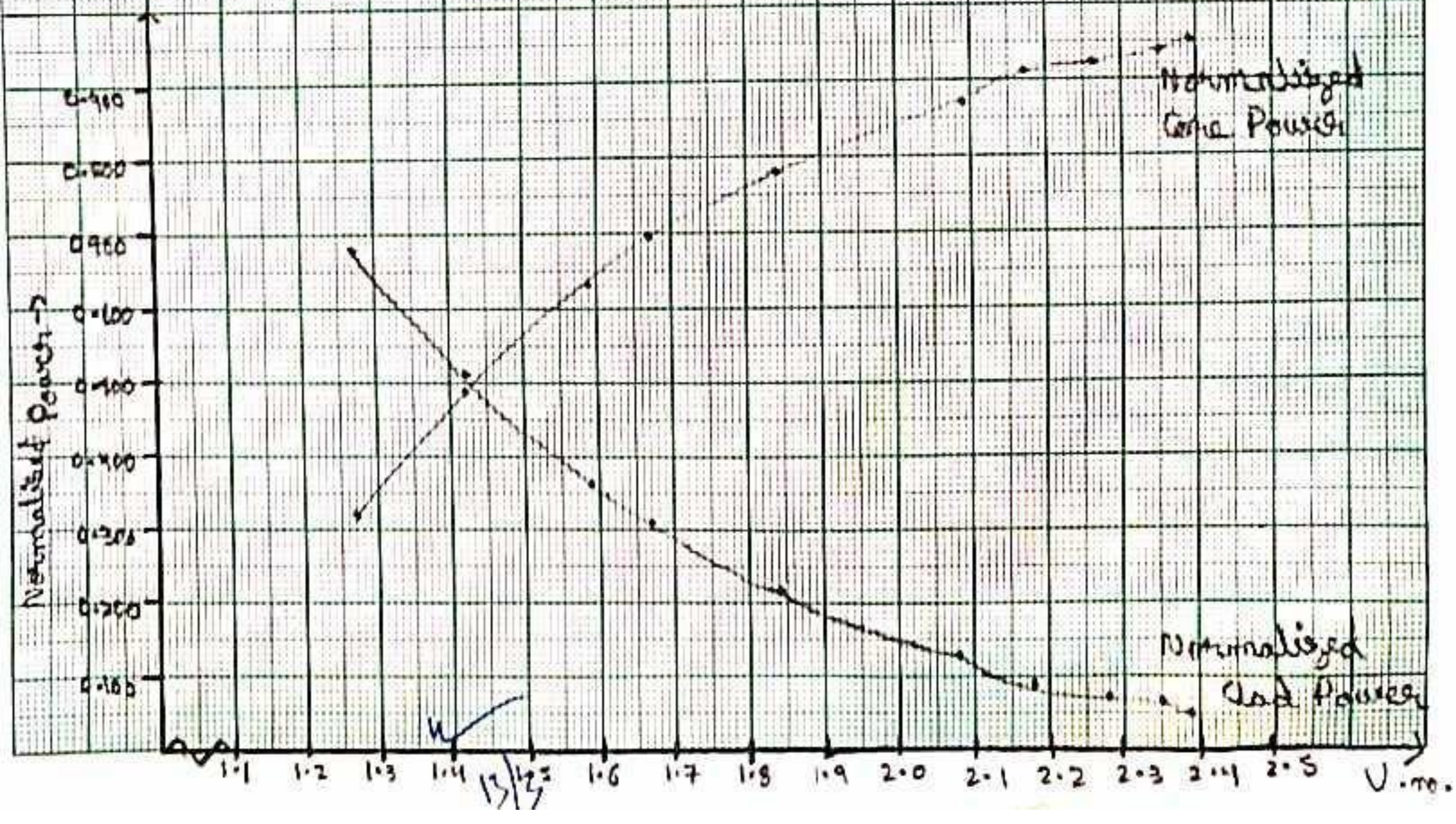
PATHWAY
MONITOR

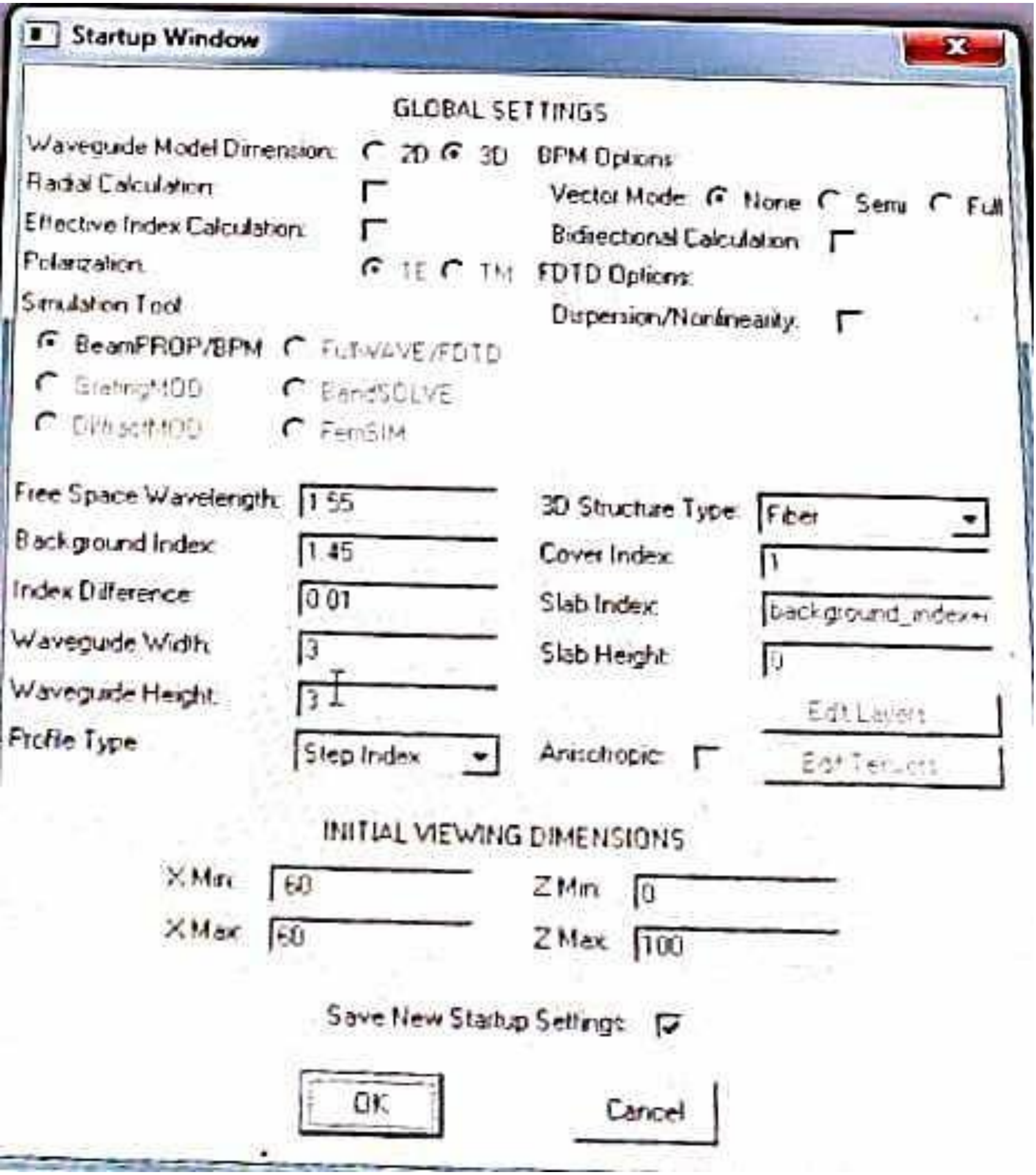


1) Mode 0

for
V = 2.3995
a = 2.86






Startup Window
GLOBAL SETTINGS
Waveguide Model Dimension: 2D 3D
Radial Calculation
Effective Index Calculation:
Polarization TE TM
Simulation Tool
BeamPROP/BPM
FullWAVE/FDTD
BandSOLVE
FemSIM
BPM Options
Vector Mode: None Semi Full
Bidirectional Calculation
FDTD Options:
Dispersion/Nonlinearity:
Free Space Wavelength: 1.55
Background Index: 1.45
Index Difference: 0.01
Waveguide Width: 3
Waveguide Height: 3
Profile Type Step Index
3D Structure Type: Fiber
Cover Index: 1
Slab Index: background_index+
Slab Height: 0
Edit Layers
Anisotropic
INITIAL VIEWING DIMENSIONS
X Min: 60
X Max: 60
Z Min: 0
Z Max: 100
Save New Startup Settings
OK
Cancel

Reference Links: https://mega.nz/folder/WgACjQpY#-mePmcwPYT-OsMsIdpYdTA s: