

ANSWER ALL QUESTIONS

Question ONE: (6 Marks)

- a-What are the conditions of total internal reflection ?
b-Define NA and prove its equation.

Question Two: (8 Marks)

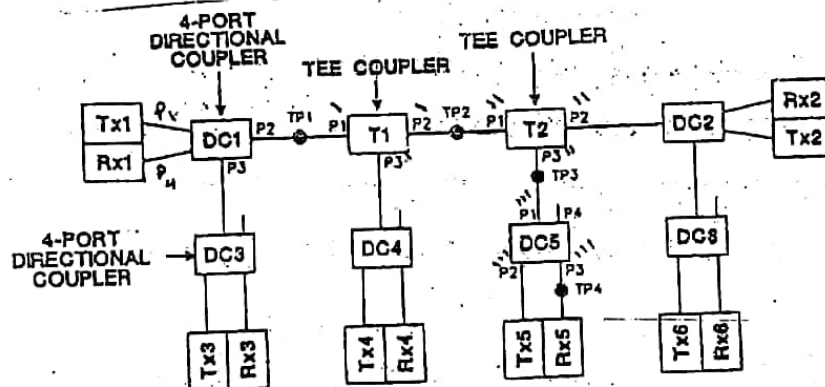
- a-What are the disadvantages of multimode step-index? How to overcome these disadvantages?
b- Why the bending losses occurs only in Optical Fiber? How to minimize its effects?

Question Three: (10 Marks)

- a- What is the type of DC bias for optical sources and optical detectors? Why?
b- Explain the theory of operation of PN photodiode. What are its disadvantages? How to overcome these disadvantages?

Question Four: (12 Marks)

- a-Explain briefly the extrinsic factors of optical connector losses.
b-For the network shown in Fig.1, If Tx1 transmits 2mW of optical power, how much power will be received at Rx4?



DC : Coupling ratio: 10%
Insertion loss: 1 dB

T: Coupling ratio: 15%
Insertion loss: 1.5 dB

Fig.1

Question Five: (14 Marks)

Design a Fiber optic data link that meet the following specifications:

- 1-Digital transmission
- 2- Bit rate ≥ 6 Mbps
- 3-Bit error rate $\leq 10^{-10}$ (=25dB)
- 4- transmission length =5 km

Good luck
Prof. Ahmed samra

DETECTORS CHART

DEVICE STRUCTURE	ACTIVE MATERIAL	RISE TIME (ns)	WAVELENGTH OF PEAK SENSITIVITY (nm)	MIN. ACCEPTABLE POWER LEVEL (dBm)	RESPON- SIVITY (A/W)	PACKAGING	MODEL #
PIN	Si	1.0	850	-80	0.5	SMA	D01
apd	Ge	2.0	850	-51	1.0	SMA	D02
PIN	Si	0.1	850	-47	0.5	SMA	D03
PIN	Ge	1.0	1300	-41	0.5	SMA	D04
apd	InGaAs	1.2	1300	-36	1.5	SMA	D05
apd	Ge	1.1	1300	-58	2.1	pigtail	D06
PIN	Si	0.9	1550	-28	0.5	pigtail	D07
PIN	Ge	1.0	1300	-51	0.5	pigtail	D08
apd	Si	0.8	1550	-36	1.9	pigtail	D09
apd	Ge	1.0	1550	-43	5.0	pigtail	D10

OPTICAL FIBERS CHART

OPERATING WAVELENGTH OF MODEL (nm)	FIBER SIZE μM	NUMERICAL APERTURE	BANDWIDTH DIST. PROD. (MHZ-km)	DISPERSION (ps/km-nm)	ATTENUATION (dB/km)	SPOOL LENGTH (m)	MODEL #
1300, 1550	3.2/125	0.11	---	425	2, 0.3	500	F01
780	4/125	0.10	---	285	3.0	500	F02
850	5/125	0.10	---	120	3.0	500	F03
1550	6.7/125	0.11	---	3.0	2.0	500	F04
1300	8/125	0.10	---	2.0	4.0	500	F05
850, 1300	50/125	0.20	1000	---	8.4, 7.1	500	F06
850, 1300	50/125	0.20	400	---	5.0, 4.0	500	F07
850, 1300	62.5/125	0.27	250	---	3.0, 1.0	500	F08
850, 1300	62.5/125	0.27	200	---	5.0, 3.0	500	F09
850, 1300	100/125	0.30	100	---	4.5, 2.0	500	F10

SOURCES CHART

SOURCE TYPE	OPERATING WAVELENGTH (nm)	OUTPUT POWER μ W	SPECTRAL WIDTH (nm)	RISE TIME (ns)	DRIVE CURRENT (mA)	PACKAGING	MODEL #
LED	1300	300	40	8.0	2	PIGTAIL	S01
LED	850	500	35	10.0	10	PIGTAIL	S02
LED	780	300	25	4.9	15	PIGTAIL	S03
LED	850	30	30	0.25	20	PIGTAIL	S04
LED	1300	1000	40	4.1	20	PIGTAIL	S05
LASER	1300	1000	4	2.1	40	PIGTAIL	S06
LASER	850	4000	4	1.5	60	SMA	S07
LASER	1300	10000	4	3.0	50	SMA	S08
LASER	1550	5000	2	2.0	50	SMA	S09
LASER	1300	1000	4	2.1	80	SMA	S10

CONNECTORS CHART

FIBER TYPE	FIBER SIZE (μ m)	ATTENUATION (dB)	COMPATIBLE WITH	MODEL #
Single Mode	3.2/125	0.25	SMA/pigtail	C01
Single Mode	4/125	0.70	SMA/pigtail	C02
Single Mode	5/125	1.00	SMA/pigtail	C03
Single Mode	6.7/125	0.35	SMA/pigtail	C04
Single Mode	8/125	0.35	SMA/pigtail	C05
Multi Mode	50/125	3.00	SMA	C06
Multi Mode	50/125	1.00	pigtail	C07
Multi Mode	62.5/125	1.25	SMA/pigtail	C08
Multi Mode	62.5/125	1.35	SMA/pigtail	C09
Multi Mode	100/125	1.20	SMA/pigtail	C10

FIBER OPTIC SYSTEM DESIGN WORKSHEET**PHASE 1. SYSTEM REQUIREMENTS ANALYSIS**

1.	<input type="checkbox"/> ANALOG <input type="checkbox"/> DIGITAL	
2.	Required BW: _____	3. Required Bit Rate: _____
4.	Transmission Distance: _____	5. Environment: <input type="checkbox"/> Indoor <input type="checkbox"/> Outdoor
6.	Required SNR: _____	7. Required BER: _____

PHASE 2: OPTICAL POWER BUDGET ANALYSIS

8.	Modulation Code: <input type="checkbox"/> RZ <input type="checkbox"/> NRZ <input type="checkbox"/> NRZI <input type="checkbox"/> MANCHESTER <input type="checkbox"/> MILLER <input type="checkbox"/> BIPHASE - M	
9.	Receiver Sensitivity: _____	10. Detector Type: _____
11.	Fiber Type: <input type="checkbox"/> Single Mode <input type="checkbox"/> Multi Mode Model #: _____	
12.	Fiber Attenuation: _____	13. Total Fiber Loss: _____
14.	Source Type: _____	15. Average Source Output: _____
16.	Splice: <input type="checkbox"/> Fusion <input type="checkbox"/> Mechanical	17. Number of Splices: _____
18.	Splice Insertion Loss: _____	19. Total Splice Loss: _____
20.	Number of Connectors: _____	21. Type: <input type="checkbox"/> Multi <input type="checkbox"/> Single # _____
22.	Connector Insertion Loss: _____	23. Total Connector Loss: _____
24.	Time Degradation Factor: _____	25. Env. Degradation Factor: _____
26.	Total Attenuation: _____	27. Total Loss Margin: _____
28.	Excess Power: _____	29. Actual Power at the Receiver: _____

FIBER OPTIC SYSTEM DESIGN WORKSHEET

Page 2

PHASE 3: SYSTEM RISE TIME ANALYSIS

30.	Required System Rise Time: _____		
31.	Fiber Bandwidth: _____	32.	Fiber Rise Time: _____
33.	Source Rise Time: _____	34.	Detector Rise Time: _____

ACTUAL SYSTEM SPECIFICATIONS

35.	Actual System Rise Time: _____
36.	Actual Bandwidth (Analog System): _____
37.	Actual Bit Rate (Digital System): _____
38.	Actual Signal-to-Noise Ratio (SNR): _____

Q4

$$Loss_{IL}^{DCI} = 10 \log \frac{P_2 + P_3}{P_1}$$

$$-1 \text{ dB} = 10 \log \frac{P_2 + P_3}{2 \text{ mW}}$$

$$-0.1 \text{ dB} = \log \frac{P_2 + P_3}{2 \text{ mW}}$$

$$\therefore \log^{-1}(-0.1 \text{ dB}) = \frac{P_2 + P_3}{2 \text{ mW}}$$

$$0.794 = \frac{P_2 + P_3}{2 \text{ mW}} \Rightarrow \therefore P_2 + P_3 \approx 1.588 \text{ mW}$$

$$\therefore N = \frac{P_3}{P_2 + P_3} \times 100\%$$

$$\frac{10}{100} = \frac{P_3}{1.588 \text{ mW}} \Rightarrow \therefore P_3 = 0.1588 \text{ mW}$$

$$\therefore P_2 = 1.588 - 0.1588 = 1.429 \text{ mW}$$

$$\underline{T_1} \quad Loss_{IL} = 10 \log \frac{P_2 + P_3}{P_1' = P_2 = 1.429 \text{ mW}}$$

$$-1.5 \text{ dB} = 10 \log \frac{P_2' + P_3'}{1.429 \text{ mW}}$$

$$\log^{-1}(-0.15 \text{ dB}) = \frac{P_2' + P_3'}{1.429 \text{ mW}}$$

$$0.707 = \frac{P_2' + P_3'}{1.429 \text{ mW}} \Rightarrow P_2' + P_3' = 1.0116 \text{ mW}$$

$$\therefore N = \frac{P_2}{P_2' + P_3'} \Rightarrow$$

$$\frac{15}{100} = \frac{P_2}{1.0116 \text{ mW}} \Rightarrow P_2 = 0.1517 \text{ mW}$$

$$\therefore P_3 = 0.8598 \text{ mW} = P_1''$$

$$\frac{DC4}{L_{ss_{IL}} = 10 \log \frac{P_2'' + P_3''}{P_1'' = P_3'}}$$

$$-1 \text{ dB} = 10 \log \frac{P_2'' + P_3''}{0.8598 \text{ mW}}$$

$$-0.1 \text{ dB} = \log \frac{P_2'' + P_3''}{0.8598 \text{ mW}}$$

$$\log^{-1}(0.1 \text{ dB}) = \frac{P_2'' + P_3''}{0.8598 \text{ mW}}$$

$$0.794 \times 0.8598 = P_2'' + P_3'' \Rightarrow P_2'' + P_3'' = 0.682 \text{ mW}$$

$$\therefore N = \frac{P_2''}{P_2'' + P_3''}$$

$$\frac{10}{100} = \frac{P_2''}{0.682 \text{ mW}} \Rightarrow P_2'' = 0.0682 \text{ mW}$$

$$\therefore P_3'' = 0.6138 \text{ mW}$$

الطاقة

Q5:

Phase 1

BME
Optoelectronics
21-5-2019

- 1-Digital 2-No. ③ $BR \gg 6 \text{ Mbs}$
4-5km 5-outdoor 6-No. π } ④
7-BER $\leq 10^{-10}$ (25 dB)

Phase 2

⑧ NRZ $\frac{1}{4}$
⑨ $P_{\min} = \frac{2eFK^2 Df}{R}$
⑩ $= \frac{2 \times 1.6 \times 10^{-19} \times 1 \times 10^2}{0.5 \times 6 \text{ MHz}}$

$K^2 = \text{Log}^{-1} [0.1 \times \text{SNR}]$
 $= \text{Log}^{-1} [0.1 \times 25 \text{ dB}]$
 $= 316.227$

$\therefore P_{\min} \approx 12 \times 10^{-10} \text{ W}$

$P_{\min} (\text{dBm}) = 10 \text{Log} \frac{12 \times 10^{-10} \text{ W}}{1 \times 10^{-3} \text{ W}}$
 $\approx -59.2 \text{ dBm}$

⑪ $\lambda = 850 \text{ nm}$

⑫ $B \times d = 6 \times 5 = 30 \text{ MHz-km}$

⑬ $\therefore F \rightarrow \lambda = 850 \text{ nm}$

⑭ $\alpha = 4.5 \text{ dB/km}$

⑬ $4.5 \times 5 \text{ km} = 22.5 \text{ dB}$

⑭ LASER 507

⑮ $P_o = 4 \text{ mW}$

$P_o (\text{dBm}) = 10 \text{Log} \frac{4 \text{ mW}}{1 \text{ mW}}$
 $= 6.02 \text{ dBm}$

⑯ Mechanical

⑰ No. of splices = 9

⑱ $I-L = 0.5 \text{ dB/splice}$

⑲ Total $I-L = 0.5 \times 9 = 4.5 \text{ dB}$

⑳ 2 Connectors

㉑ Multimode C10

㉒ 1.2 dB/Connector

㉓ $1.2 \times 2 = 2.4 \text{ dB}$

㉔

$$(24)_{\frac{1}{4}} T. Degr. = 3 \text{ dB}$$

$$(25)_{\frac{1}{4}} EV. Degr = 5 \text{ dB}$$

$$(26)_{\frac{1}{4}} \text{Total attenuation} = 22.5 + 4.5 + 2.4 + 3 + 5 = 37.4 \text{ dB}$$

$$(27)_{\frac{1}{2}} \text{Loss margin of the sys.} =$$

$$\begin{aligned} & \text{Source o/p power} - P_{\min} \\ &= 6.02 - (-59.2) \\ &= 65.22 \text{ dBm} \end{aligned}$$

$$(28)_{\frac{1}{2}} \text{EXCESS Power} = \text{Loss Margin} - \text{Total attenu.} = 65.22_{\text{dBm}} - 37.4 \text{ dBm} = 27.82 \text{ dBm}$$

$$(29)_{\frac{1}{2}} \text{Act. power at Rec.} =$$

$$\begin{aligned} & P_{\min} + \text{EXCESS Power} = -59.20 + 27.82 = -31.42 \text{ dBm} \end{aligned}$$

Phase 3

$$(30)_{\frac{1}{2}} \text{Reg. sys. rise time}$$

$$\begin{aligned} t_r &= \frac{0.7}{B \cdot R} = \frac{0.7}{6 \text{ MHz}} \\ &= 0.1166 \times 10^{-6} \text{ sec.} \\ &\approx 116.6 \text{ nsec.} \end{aligned}$$

$$(31)_{\frac{1}{2}} \text{Fiber BW} = \frac{100 \text{ MHz-km}}{5 \text{ km}} = 20 \text{ MHz}$$

$$(32)_{\frac{1}{2}} \text{Fiber } t_r = \frac{0.35}{F \cdot BW} = \frac{0.35}{20 \text{ MHz}} = 17.5 \text{ nsec}$$

$$(33)_{\frac{1}{2}} \text{Source } t_r = 1.5 \text{ nsec}$$

$$(34)_{\frac{1}{4}} \text{Detector } t_r = 1 \text{ nsec}$$

$$(35)_{\frac{1}{2}} \text{Actual sys. Spec.}$$

$$\begin{aligned} (35)_{\frac{1}{2}} \text{Act. sy. } t_r &= 1.1 \sqrt{(F \cdot t_r)^2 + (S \cdot t_r)^2 + (D \cdot t_r)^2} \\ &= 1.1 \sqrt{(17.5)^2 + (1.5)^2 + (1)^2} \\ &\approx 19.35 \text{ nsec.} \end{aligned}$$

$$(36)_{\frac{1}{2}} \text{No}$$

$$\begin{aligned}
 (37) \text{ Act. sys. bit rate} &= \frac{0.7}{\text{Act. sy. tr}} \\
 &= \frac{0.7}{19.35 \text{ nsec}} \\
 &= 36 \text{ Mbs.}
 \end{aligned}$$

$$(38) \text{ SNR} = ?$$

$$\therefore \text{Act. Power at Rec. (step 29)} = -31.42 \text{ dBm}$$

$$\therefore -31.42 \text{ dBm} = 10 \log \frac{P_{\min}(w)}{1 \text{ mW}}$$

$$\therefore \log^{-1}(-31.42) = \frac{P_{\min}(w)}{10^{-3} \text{ W}}$$

$$\therefore P_{\min}(w) = 7.21 \times 10^{-7} \text{ W}$$

$$\therefore P_{\min}(w) = \frac{2eFK^2\Delta f}{R}$$

$$\therefore K^2 = \frac{R P_{\min}(w)}{2eF\Delta f} = \frac{0.5 \times 7.21 \times 10^{-7} \text{ W}}{2 \times 1.6 \times 10^{-19} \times 1 \times 36 \text{ Mbs.}}$$

$$\approx 3.12 \times 10^4$$

$$\therefore K^2 = \log^{-1}(0.1 \times \text{SNR})$$

$$\therefore \log K^2 = 0.1 \times \text{SNR}$$

$$\log(3.12 \times 10^4) = 0.1 \times \text{SNR} \quad \therefore \text{SNR} \approx 44.9 \text{ dB}$$

$$4.494 = 0.1 \times \text{SNR} \quad \rightarrow \text{Acceptable}$$