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Exercise 1 – Serial Interface

Appendix A – Pretest and Posttest Questions and Answers
Appendix B – Faults and Circuit Modifications (CMs)
Appendix C – Board and Courseware Troubleshooting
Introduction

This Instructor Guide is divided into three sections and the appendices. It provides a unit-by-unit outline of the Fault Assisted Circuits for Electronics Training (F.A.C.E.T) curriculum.

Section 1 – Workstation Inventory and Installation contains a list and description of equipment and materials required for all units in this course of study as well as installation instructions.

Section 2 – Introduction to F.A.C.E.T Curriculum provides a description of the courseware structure, instructions on getting started with the multimedia presentation, and an explanation of student-progress assessment methods.

Section 3 – Courseware includes information that enables the instructor to gain a general understanding of the units within the course.

♦ The unit objective
♦ Unit Fundamentals questions and answers
♦ A list of new terms and words for the unit
♦ Equipment required for the unit
♦ The exercise objectives
♦ Exercise Discussion questions and answers
♦ Exercise Procedure questions and answers
♦ Review questions and answers
♦ CMs and Faults available
♦ Unit Test questions and answers
♦ Troubleshooting questions and answers (where applicable)

Appendices include the questions and answers to the Pretest and Posttest plus additional specific information on faults and circuit modifications (CMs).

Please complete and return the OWNER REGISTRATION CARD included with the CD-ROM. This will assist Lab-Volt in ensuring that our customers receive maximum support.
SECTION 1 – WORKSTATION INVENTORY AND INSTALLATION
SECTION 1 – WORKSTATION INVENTORY AND INSTALLATION

Inventory of Workstation
Use this section to identify and inventory the items needed.

Minimum Computer Requirements
100% compatible Windows® PC with Windows98 second edition or newer, NT, 2000, Me or XP; Pentium class CPU, (Pentium II or newer); 126 MB RAM; 10 GB HDD; CD-ROM drive; SVGA monitor and video card capable of 32-bit color display at 1024 x 768 resolution and sound capabilities.

Equipment and Supplies
The following equipment and supplies are needed for Fiber Optic Communications:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F.A.C.E.T. base unit</td>
</tr>
<tr>
<td>1</td>
<td>FIBER OPTIC COMMUNICATIONS circuit board</td>
</tr>
<tr>
<td>1</td>
<td>Multimeter</td>
</tr>
<tr>
<td>1</td>
<td>Oscilloscope, dual trace</td>
</tr>
<tr>
<td>1</td>
<td>Generator, sine wave</td>
</tr>
<tr>
<td>1</td>
<td>Student Workbook</td>
</tr>
<tr>
<td>1</td>
<td>Instructor Guide</td>
</tr>
</tbody>
</table>

Equipment Installation
To install the hardware, refer to the Tech-Lab (minimum version 6.x) Installation Guide.

Software Installation

Third Party Application Installation
All applications and files that the courseware launches, or that are required for the course should be installed before the courseware. Load all third party software according to the manufacturers' directions. Install this software to the default location and note that location. (Alternatively, you can install this software to a different location that you designate.) Remember to register all software as required.

No third-party software is required for this course.

Installation of Courseware and Resources
To install the courseware and resources, refer to the Tech-Lab (minimum version 6.x) and Gradepoint 2020 (minimum version 6.x) Installation Guide.
SECTION 2 – INTRODUCTION TO F.A.C.E.T CURRICULUM
SECTION 2 – INTRODUCTION TO F.A.C.E.T CURRICULUM

Overview
F.A.C.E.T curriculum is multimedia-based courseware. The curriculum gives students hands-on experience using equipment and software closely associated with industry standards. It provides students with opportunities for instruction in academic and technical skills.

All courses are activity-driven curricula. Each course consists of several units containing two or more exercises. Each unit begins with a statement explaining the overall goal of the unit (Unit Objective). This is followed by Unit Fundamentals. Next is a list of new terms and words then the equipment required for the unit. The exercises follow the unit material. When students complete all the exercises, they complete the Troubleshooting section and take the Unit Test.

The exercises consist of an exercise objective, exercise discussion, and exercise procedures. The Exercise Conclusions section provides the students with a list of their achievements. Every exercise concludes with Review Questions. Available circuit modifications (CMs) and faults are listed after the review questions. Additional specific information on CMs and faults is available in Appendix B.
Getting Started

Desktop
After the Tech-Lab System is installed, the TechLab icon appears on the desktop.

1. Click on the TechLab icon.

2. The student clicks on LOGON and selects his or her name.

3. The student enters his or her password and clicks on OK. (If he or she is creating a password, four alphanumeric characters must be entered. The system will ask for the password to be entered again for verification. Keep a record of the students' passwords.)

4. The previous two steps are repeated until all members of the student team have logged on. Click on Complete and then Yes.

5. When the Available Courses menu appears, students click on the course name.

6. A window with the name of the course and a list of units for that course appears. Students click on the unit name. The unit title page appears and the students are ready to begin.

Selecting Other Courses and Exiting the Courseware
1. Clicking on Exit when in a unit returns the student to the list of units for that course.

2. If students wish to select another unit, they click on it.

3. If students wish to exit F.A.C.E.T, they click on the X symbol in the upper right corner.

4. If students wish to select another course, they click on the Course Menu button. The Available Courses menu screen appears. They may also exit F.A.C.E.T from this screen by clicking on the LOGOFF button.
Screen Buttons

If you click on the F.A.C.E.T logo on the top right of the unit title page the About screen appears. It acknowledges the copyright holder(s) of video and/or screen-capture material used in the topic.

The **Menu** button calls these menus:
- when on an exercise menu screen, it calls the **Unit Menu**.
- when on an exercise screen, it calls the **Exercise Menu**.
- when on a unit screen, it calls the **Unit Menu**.

The **Bookmark** button marks the current screen. A student can click on the button at any time in the lesson. The second time the student clicks on the button, the page displayed when the button was first clicked will return to the screen. Any bookmarks used during a lesson are not saved when the student logs out of the lesson.

The **Application Launch** button opens third-party software.

Click on the **Resources** button to view a pop-up menu. The pop-up menu includes access to a calculator, a student journal, new terms and words, a print current screen option, the Lab-Volt authored Internet Website, and a variety of F.A.C.E.T help screens.

The **Help** button aids students with system information. On certain screens the **Help** button appears to be depressed. On these screens, clicking on the **Help** button will access Screen Help windows (context-sensitive help).

The **Internet** button opens an Internet browser. Students will have unrestricted access to all search engines and web sites unless the school administration has restricted this usage.

Use the **Exit** button to exit the course.

The right arrow ⇒ button moves you forward to the next screen.
The left arrow ⇐ button moves you backward to the previous screen.
F.A.C.E.T Help Screens and Resources

There are three ways to access F.A.C.E.T help screens and other resources.

**System Help**
Students access System Help by clicking on the **Help** button at the bottom of the screen when the button does not appear to be depressed. The menu selections access a variety of system help, navigation, and information windows.

**Screen Help**
On certain screens, the **Help** button appears to be depressed. On these screens, clicking on the **Help** button will access Screen Help windows. This is information specific to the content of that particular screen.

**Resources**
Students click on the **Resources** button to access the following windows.

- Calculator
- F.A.C.E.T 32-Bit Microprocessor Help
- F.A.C.E.T Analog Communications Setup Procedure
- F.A.C.E.T Digital Communications Help
- F.A.C.E.T Electronics and Troubleshooting Help
- F.A.C.E.T Fiber Optic Communications Help
- F.A.C.E.T Math Help
- Internet Link
- New Terms and Words
- Print Current Page
- Student Journal
Internet Access

There are two ways for students to access the Internet:

The **Internet** button opens an Internet browser. Students have unrestricted access to all search engines and websites unless the school administration has restricted this usage.

The **Resources** button pops up a menu that includes access to the Lab-Volt authored Internet website. If students wish to access this site when they are not in the lesson, then they must go to http://learning.labvolt.com.

**NOTE:** The Lab-Volt Internet site does not have content-filtering software to block access to objectionable or inappropriate websites.

Instructor Annotation Tool

The annotation tool gives the instructor the ability to add comments or additional information onscreen. Refer to the Tech-Lab and GradePoint 2020 Installation Guide for detailed information.

Student Journal

The student journal is an online notebook that each student can access while they are logged into TechLab. The journal allows students to share notes with other students in their workgroups. When used in conjunction with GradePoint 2020, the instructor may post messages, review, edit, or delete any journal note.
Assessing Progress

Assessment Tools
Student assessment is achieved in several ways:

♦ Exercise questions
♦ Unit tests
♦ Pretest and Posttest
♦ Troubleshooting questions

Exercise and Troubleshooting Questions
Throughout the unit material, exercise discussion, exercise procedure, and troubleshooting sections there are several types of questions with instant feedback. These questions occur in the following formats:

♦ Multiple choice
♦ True-false
♦ Real-number entry

In most cases, when your students encounter a question set, they must answer these questions before continuing. However, there are cases where students may progress to the next screen without answering the questions. Lab-Volt recommends that you encourage your students to complete all questions. In this way, students reinforce the material that's presented, verify that they understand this material, and are empowered to decide if a review of this material is required.

Review Questions
At the end of each exercise, there are review questions. The student receives feedback with each entry. Feedback guides the student toward the correct answer.

Unit Tests
A unit test appears at the end of each unit. The test consists of 10 multiple-choice questions with the option of having feedback. The Tech-Lab System defaults to no feedback, but the instructor can configure the test so that students receive feedback after taking the test. You can randomize questions in the unit test. Use the Tech-Lab Global Configurator to make feedback available, randomize questions, and select other configuration options if desired. Refer to the Tech Lab Quick-Start Guide for detailed information.
Pretest and Posttest
Every course includes a pretest and a posttest. These are multiple choice tests. Refer to the Tech Lab Quick-Start Guide for detailed information on how to record student competency gains.

Grading
Student grades are based on exercise questions, troubleshooting questions, a unit test, and a posttest. The default weighting value of the unit test and the threshold for passing the unit test can be adjusted by using the Global Configurator of the Tech-Lab System. Refer to the Tech Lab Quick-Start Guide for detailed information.

Student Progress and Instructor Feedback
Unit progress is available through the Unit menu. The Progress window allows the instructor and student to view the percentage of the unit completed, number of sessions, and time spent on that unit. The Progress window shows whether the Unit Test was completed. If the test was completed, it indicates whether the student passed based on the scoring criteria.
Real-Number Questions and Answers

Throughout F.A.C.E.T courses students may encounter real-number questions such as the one shown below. Answers to real-number questions are graded correct if they fall within an acceptable tolerance range.

The answer to the question posed in the illustration above does not involve a recall value from a previous question. It appears in the Instructor Guide (IG) as shown in the box below.

The information in the IG tells you where the question is located and the range of acceptable answers. In this case, the acceptable answers fall within the range of the nominal answer plus or minus 5 percent tolerance: (15 ± 5%).

e1p1 stands for Exercise 1 Procedure screen 1

Location: Exercise Procedure page: e1p1, Question ID: e1p1a

VS = Vdc

Recall Label for this Question: V1
Nominal Answer: 15.0
Min/Max Value: (14.25) to (15.75)
Value Calculation: 15.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

This is the name the computer uses internally to identify the input value. In this case, 14.5 will be stored under the name V1.

NOTE: The recall value V1 is not the same as the voltage V1. The recall label does not appear onscreen.

In this case, the answer to this question is not based on a value recalled from a previous question. Therefore, the Value Calculation is equal to the Nominal Answer.

The word "true" tells you that the tolerance is calculated as a percent.
A second example (shown below) illustrates an answer that the computer grades using a value recalled from a previous question.

When a real-number question is based on a recall value from a previous question, the Min/Max Value shown in the Instructor Guide is based upon a calculation using the lowest and highest possible recall value. It represents the theoretical range of answers that could be accepted by the computer. (It is not the nominal answer plus or minus the tolerance.)

To find the actual range of answers that the computer will accept onscreen, you must use the actual recall value (14.5 in this example) in your calculations; see below.

<table>
<thead>
<tr>
<th>Location: Exercise Procedure page: se1p5, Question ID: e1p5c</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT = mA</td>
</tr>
<tr>
<td>Recall Label for this Question: #V1#</td>
</tr>
<tr>
<td>Nominal Answer: 9.091</td>
</tr>
<tr>
<td>*Min/Max Value: (6.477) to (11.93)</td>
</tr>
<tr>
<td>Value Calculation: #V1#/1650*1000</td>
</tr>
<tr>
<td>Correct Tolerance Percent = true</td>
</tr>
<tr>
<td>Correct Minus Tolerance = 25</td>
</tr>
<tr>
<td>Correct Plus Tolerance = 25</td>
</tr>
</tbody>
</table>

Any letter enclosed in "#" signs refers to a recall value from a previous question.

Since the value for #V1# is 14.5, the computer will accept answers in the following range as correct:

14.5/1650*1000 ± 25% or
8.79 ± 25% or
6.59 to 10.99

This calculated range is different from the Min/Max Value shown in the IG, which was based upon a calculation using the lowest and highest possible recall value.

NOTE: After four incorrect answers, students will be prompted to press <Ins> to insert the correct answer if this feature has been enabled in the configuration settings. When the question is based on a value recalled from a previous question, answers obtained using the Insert key may not match the nominal answers in this guide.
Recall Values in Text

Sometimes numbers displayed on screen are values recalled from input on previous screens. Because these numbers are recall values, they will change for each student.

The value of 10 was recalled from a previous screen.

The Instructor Guide lists the recall label in place of a number in this question.

\[ I_{R2} = \frac{V_{R2}}{R2} = \frac{#V4#/3.3 \text{ k}\Omega}{\text{mA}} \]

Recall Label for this Question: I1

Nominal Answer: 2.818
Min/Max Value: (2.489) to (3.164)
Value Calculation: #V4#/3.3
Correct Tolerance Percent = true
Correct Minus Tolerance = 4
Correct Plus Tolerance = 4
Safety

Safety is everyone’s responsibility. All must cooperate to create the safest possible working environment. Students must be reminded of the potential for harm, given common sense safety rules, and instructed to follow the electrical safety rules.

Any environment can be hazardous when it is unfamiliar. The F.A.C.E.T computer-based laboratory may be a new environment to some students. Instruct students in the proper use of the F.A.C.E.T equipment and explain what behavior is expected of them in this laboratory. It is up to the instructor to provide the necessary introduction to the learning environment and the equipment. This task will prevent injury to both student and equipment.

The voltage and current used in the F.A.C.E.T Computer-Based Laboratory are, in themselves, harmless to the normal, healthy person. However, an electrical shock coming as a surprise will be uncomfortable and may cause a reaction that could create injury. The students should be made aware of the following electrical safety rules.

1. Turn off the power before working on a circuit.
2. Always confirm that the circuit is wired correctly before turning on the power. If required, have your instructor check your circuit wiring.
3. Perform the experiments as you are instructed: do not deviate from the documentation.
4. Never touch “live” wires with your bare hands or with tools.
5. Always hold test leads by their insulated areas.
6. Be aware that some components can become very hot during operation. (However, this is not a normal condition for your F.A.C.E.T. course equipment.) Always allow time for the components to cool before proceeding to touch or remove them from the circuit.
7. Do not work without supervision. Be sure someone is nearby to shut off the power and provide first aid in case of an accident.
8. Remove power cords by the plug, not by pulling on the cord. Check for cracked or broken insulation on the cord.
SECTION 3 – COURSEWARE
UNIT 1 – INTRODUCTION TO FIBER OPTICS

UNIT OBJECTIVE
Identify the different circuit blocks on the FIBER OPTIC COMMUNICATIONS circuit board and describe the basic parts of a fiber-optic communication link.

FUNDAMENTALS
There are no questions for this section.

CMS AVAILABLE
None

FAULTS AVAILABLE
None

NEW TERMS AND WORDS
fiber optics - the technique of conveying light through optical fibers.
optical fibers - (or optical waveguides, or light pipes) thin glass or plastic flexible rods through which light can propagate. These consist of an inner core and an outer cladding, and are found inside fiber-optic cables.
data link - a communication link that allows the transfer of digital data.
handshaking - a method of data-flow control between two stations during the exchange of information.
manchester - a method of biphase line coding where data bits are combined with the bit clock through an exclusive-OR (XOR) function. Manchester encoding produces a signal transition during each bit time.
FPGA - a high-density integrated-circuit (IC) that can be user-configured to create a custom IC with user-defined logic functions.
infrared - a form of radiant energy with wavelengths between 770 nm and 1 mm, which is just below the visible light region of the electromagnetic spectrum; a type of invisible light.
IRED - an LED type of output transducer that emits infrared light instead of visible light when forward biased.
multimode fibers - types of optical fibers that provide many propagation paths for light. They are used with an LED light source.
simplex cables - a type of fiber-optic cable that contains only one optical fiber.
phototransistor - a light-sensitive transistor whose collector current is directly related to light intensity.
photodiode - a light-sensitive diode whose conduction is directly related to light intensity.
EQUIPMENT REQUIRED

F.A.C.E.T. base unit
FIBER OPTIC COMMUNICATIONS circuit board
Multimeter
Oscilloscope, dual trace
Signal Generator, sine wave
Exercise 1 – Familiarization

EXERCISE OBJECTIVE
Describe and locate the different circuit blocks on the FIBER OPTIC COMMUNICATIONS circuit board.

EXERCISE DISCUSSION

Location: Exercise Discussion page: se1d4, Question ID: e1d4a
How would you adjust the audio amplifier's listening level?
a. by disabling the SPEAKER
b. by turning the VOLUME control pot
c. by turning the power off

Location: Exercise Discussion page: se1d11, Question ID: e1d11a
Which position of the FOR jumper would you short to connect the Fiber Optic Receiver to the ANALOG RECEIVER's input jack R-IN?
a. DIGITAL
b. ANALOG

EXERCISE PROCEDURE

Location: Exercise Procedure page: se1p1, Question ID: e1p1a
2. Does the POWER LED turn on and off?
a. yes
b. no

Location: Exercise Procedure page: se1p2, Question ID: e1p2a
\[ +V_S = V_{dc} \]
Recall Label for this Question: a1
Nominal Answer: 5.0
Min/Max Value: (4.5) to (5.5)
Value Calculation: 5.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 10
Correct Plus Tolerance = 10
Location: Exercise Procedure page: se1p2, Question ID: e1p2c

\[-V_S = V_{dc}\]

Recall Label for this Question: a2
Nominal Answer: -5.0
Min/Max Value: (-5.5) to (-4.5)
Value Calculation: -5.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 10
Correct Plus Tolerance = 10

Location: Exercise Procedure page: se1p3, Question ID: e1p3a

12. Can you hear your actions in the SPEAKER?
   a. yes
   b. no

Location: Exercise Procedure page: se1p4, Question ID: e1p4a

\[R_{a1} = \text{ohms}\]

Recall Label for this Question: a2.5
Nominal Answer: 2.5
Min/Max Value: (0) to (5)
Value Calculation: 2.500
Correct Tolerance Percent = true
Correct Minus Tolerance = 100
Correct Plus Tolerance = 100

Location: Exercise Procedure page: se1p7, Question ID: e1p7a

21. The CATHODE and ANODE of the Fiber Optic Transmitter must be configured. In which two positions should you place the two-post connectors when connecting the CATHODE and ANODE to the ANALOG TRANSMITTER circuit block?
   a. ANALOG
   b. DIGITAL

Location: Exercise Procedure page: se1p8, Question ID: e1p8a

23. What kind of waveform do you observe on CH 2 of your oscilloscope display?
   a. a sine wave
   b. a square wave
   c. a triangle wave
   d. no waveform
Location: Exercise Procedure page: se1p8, Question ID: e1p8c

24. Remove the optical fiber. Now what waveform do you observe on CH 2 of your oscilloscope?
   a. a sine wave
   b. a square wave
   c. a triangle wave
   d. no waveform

Location: Exercise Procedure page: se1p10, Question ID: e1p10a

V_{red} = mVdc

Recall Label for this Question: a3
Nominal Answer: 112.0
Min/Max Value: (11.2) to (212.8)
Value Calculation: 112.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 90
Correct Plus Tolerance = 90

Location: Exercise Procedure page: se1p10, Question ID: e1p10c

30. As you observe your meter's display, move the RANGE shunt to its HI position. What happened to the dc voltage level as the shunt was moved to its HI position?
   a. decreases
   b. increased
   c. disappeared
   d. no change

Location: Exercise Procedure page: se1p11, Question ID: e1p11a

V_{green} = mVdc

Recall Label for this Question: a4
Nominal Answer: 17.0
Min/Max Value: (1.7) to (32.3)
Value Calculation: 17.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 90
Correct Plus Tolerance = 90
Location: Exercise Procedure page: se1p11, Question ID: e1p11c

\[ V_{\text{infrared}} = V_{\text{dc}} \]

Recall Label for this Question: a5

**Nominal Answer: 2.2**

Min/Max Value: (0.22) to (4.18)

Value Calculation: 2.200

Correct Tolerance Percent = true

Correct Minus Tolerance = 90

Correct Plus Tolerance = 90

Location: Exercise Procedure page: se1p11, Question ID: e1p11e

37. Which light source gave you the highest voltage reading at the phototransistor's emitter?
   
   a. red
   
   b. green
   
   c. infrared

Location: Exercise Procedure page: se1p12, Question ID: e1p12a

39. Locate the DIGITAL RECEIVER circuit block. Where would its input signal normally come from?

   a. the MIC AMPLIFIER circuit block
   
   b. the Fiber Optic Receiver
   
   c. the AUDIO AMPLIFIER's output

Location: Exercise Procedure page: se1p15, Question ID: e1p15a

44. The CATHODE and ANODE of the Fiber Optic Transmitter must be configured. In which two positions should you place two-post connectors when connecting the CATHODE and ANODE to the DIGITAL TRANSMITTER circuit block?

   a. ANALOG
   
   b. DIGITAL

Location: Exercise Procedure page: se1p15, Question ID: e1p15c

46. What kind of signal do you observe on CH 2 of your oscilloscope display?

   a. a dc level of +5V
   
   b. a dc level of 0V
   
   c. a sine wave
   
   d. a square wave
48. What kind of signal do you observe on CH 2 of your oscilloscope display?
   a. a dc level of +5V
   b. a dc level of 0V
   c. a sine wave
   d. a square wave

50. Is your transmitted logical HIGH observed on CH 2 of your scope?
   a. yes
   b. no

55. Observe the TX and RX LEDs. What is the condition of the TX and RX signals?
   a. both are HIGH.
   b. both are LOW.
   c. TX is HIGH and RX is LOW.
   d. TX is LOW and RX is HIGH.

57. Observe the TX and RX LEDs. What is the condition of the TX and RX signals?
   a. both are HIGH.
   b. both are LOW.
   c. TX is HIGH and RX is LOW.
   d. TX is LOW and RX is HIGH.

59. What kind of waveform do you observe on CH 1 of your scope's display?
   a. a square wave
   b. four channels demultiplexed
   c. four channels multiplexed into one signal
REVIEW QUESTIONS

Location: Review Questions page: se1r1, Question ID: e1r1

1. In order to use the AUDIO AMPLIFIER circuit block, in which position must the POWER SUPPLY's +5V shunt be?
   a. POWER
   b. DIGITAL
   c. HIGH
   d. ANALOG

Location: Review Questions page: se1r2, Question ID: e1r2

2. The PHOTO TRANSISTOR circuit block is used to make relative measurements of light
   a. power.
   b. wavelength.
   c. frequency.
   d. color.

Location: Review Questions page: se1r3, Question ID: e1r3

3. The MIC AMPLIFIER circuit block is used to amplify audible signals at the MICROPHONE. To which circuit block's input is its audio output (MIC OUT) normally connected?
   a. ANALOG RECEIVER
   b. DIGITAL RECEIVER
   c. ANALOG TRANSMITTER
   d. DIGITAL TRANSMITTER

Location: Review Questions page: se1r4, Question ID: e1r4

4. How many two-post connectors are required to configure the Fiber Optic Transmitter?
   a. one
   b. two
   c. three
   d. four
5. How many circuit blocks have a potentiometer that may require adjustment?
   a. one
   b. two
   c. three
   d. four

CMS AVAILABLE
None

FAULTS AVAILABLE
None
Exercise 2 – Fiber Optic Communications

EXERCISE OBJECTIVE
Describe the basic parts of a fiber-optic communication link. Demonstrate the operation of an analog and a digital fiber-optic communication link.

EXERCISE DISCUSSION

Location: Exercise Discussion page: se2d7, Question ID: e2d7a
The glass optical fiber supplied with your board is type 62.5/125, which means it has a core diameter of 62.5 µm and a
a. jacket diameter of 125 µm.
b. cladding diameter of 125 µm.

EXERCISE PROCEDURE

Location: Exercise Procedure page: se2p2, Question ID: e2p2a
9. By adjusting this pot, what did you set to unity gain?
a. the ANALOG RECEIVER gain
b. the communication link gain
c. the ANALOG TRANSMITTER gain
d. the Fiber Optic Receiver gain

Location: Exercise Procedure page: se2p4, Question ID: e2p4a
15. Can you hear your actions in the SPEAKER?
a. yes
b. no

Location: Exercise Procedure page: se2p5, Question ID: e2p5a
18. Can you hear yourself in the SPEAKER?
a. yes
b. no
28. Observe the four RED status LEDs associated with the four input signals at TP2. Are the four RED LEDs flashing ON and OFF?
   a. yes
   b. no

30. Observe the seven RED status LEDs associated with the four input signals and three output signals. Does the status of each output LED follow its input LED?
   a. yes
   b. no

31. What would happen if you removed the optical fiber from the transmitter?
   a. Nothing would change.
   b. All the LEDs would flash ON and OFF.
   c. The output LEDs would stop flashing.

1. Which is not a necessary part of a fiber-optic communication link?
   a. light source
   b. optical fiber
   c. RS-232 interface
   d. light detector

2. The Fiber Optic Transmitter on your circuit board contains a
   a. driver circuit.
   b. light source.
   c. light detector.
   d. fiber-to-detector connector.
3. The Fiber Optic Receiver on your circuit board contains a
   a. driver circuit.
   b. light source.
   c. source-to-fiber connector.
   d. light detector.

4. On your circuit board, a fiber-to-detector connector can be found on the
   a. Fiber Optic Transmitter.
   b. Fiber Optic Receiver.
   c. LIGHT EMITTING DIODES circuit block.
   d. ANALOG TRANSMITTER circuit block.

5. Which can be transmitted over a fiber-optic communication link?
   a. audio frequency
   b. composite video
   c. pulses and data
   d. All of the above.
UNIT TEST

Location: Unit Test Question page: sut1, Question ID: ut1
Which part of the optical fibers supplied with your circuit board has the smallest outer diameter?
  a. plastic fiber's core
  b. glass fiber's core
  c. plastic fiber's jacket
  d. glass fiber's cladding

Location: Unit Test Question page: sut2, Question ID: ut2
In order to transmit composite video signals over the fiber-optic link on your circuit board, in which position must the POWER SUPPLY's -5V shunt be?
  a. VIDEO
  b. DIGITAL
  c. AUDIO
  d. ANALOG

Location: Unit Test Question page: sut3, Question ID: ut3
A phototransistor can be used to make relative measurements of light
  a. power.
  b. wavelength.
  c. frequency.
  d. color.

Location: Unit Test Question page: sut4, Question ID: ut4
Which LED in the LIGHT EMITTING DIODES circuit block emits the most light power?
  a. red
  b. yellow
  c. green
  d. infrared

Location: Unit Test Question page: sut5, Question ID: ut5
Which is not a basic part of a fiber-optic communication link?
  a. speaker
  b. light source
  c. optical fiber
  d. output circuit
The Fiber Optic Transmitter on your circuit board contains
a. an output circuit.
**b. a light source.**
c. a light detector.
d. a fiber-to-detector connector.

In a fiber-optic communication link, a fiber-to-detector connection can be found at the output of a(n)
a. driver circuit.
b. light source.
**c. optical fiber.**
d. light detector.

Which is not a basic part of a fiber-optic transmitting system?
a. driver circuit
b. light source
c. source-to-fiber connection
d. output circuit

Which is not a common term in fiber optics?
a. optical fiber
b. fiber-optic cable
**c. light cable**
d. light pipe

What cannot be sent over a fiber-optic communication link?
a. telephone messages
b. cable TV signals
c. computer data
d. electric power
UNIT 2 – FIBER-OPTIC CABLE & OPTICAL FIBER

UNIT OBJECTIVE
Describe how light propagates through an optical fiber and demonstrate light attenuation due to: numerical aperture, fiber, area, connector, and bending losses.

UNIT FUNDAMENTALS

Location: Unit Fundamentals Page: sf2, Question ID: f2a
What is the range of frequencies in the visible light spectrum?
- a. 770 nm to 390 nm
- b. 770 x 10^12 Hz to 390 x 10^12 Hz
- c. 770 nHz to 390 nHz

Location: Unit Fundamentals Page: sf5, Question ID: f5a
What is the basic unit of electromagnetic power?
- a. watt
- b. volt

Location: Unit Fundamentals Page: sf9, Question ID: f9a
What is the index of refraction for this piece of glass?
- a. 0.67
- b. 1.5
- c. 200,000 km/s

CMS AVAILABLE
None

FAULTS AVAILABLE
None
NEW TERMS AND WORDS

- **electromagnetic spectrum** - the range of electromagnetic wavelengths where radiant energy oscillates between electric and magnetic fields.
- **wave front** - a set of points that are in phase and perpendicular to the direction of wave travel.
- **angle of incidence** - the approach angle of a light ray. The angle between a light ray in the first material to a line normal to the change in refraction index.
- **angle of refraction** - the angle between a light ray in the second material to a line normal to the change in refraction index.
- **fresnal reflections** - a portion of light that is always reflected off a change in refraction index.
- **critical angle** - the largest angle of incidence which permits the refraction of light.
- **waveguide** - boundaries that direct electromagnetic energy.
- **cladding** - a coating surrounding the optical-fiber core that has a lower refractive index.
- **absorption** - power loss from the conversion of light energy to heat.
- **scattering** - misdirecting or spreading of light power.
- **microbends** - small bends in the core to cladding surface caused by the fiber manufacturing process.
- **concentric** - having the same center.
- **lapping films** - abrasive films used for fine polishing (lapping).
- **lateral displacement** - moved to one side. Distance off center.
- **pistoning** - the movement of an optical fiber within a ferrule or connector.
- **acceptance angle** - the angle between light and the fiber axis at which the fiber power output is reduced by half. Sometimes confused with acceptance cone.
- **acceptance cone** - a three dimensional representation of light acceptance defined by rotating the fiber acceptance angle around the fiber axis.
- **numerical aperture (NA)** - a number that represents an optical fiber's acceptance angle.
- **unintercepted illumination** - light that does not fall on the fiber's core.
- **modes** - paths taken by light. An electromagnetic field distribution.
- **dispersion** - the spreading of energy in time.
- **modal dispersion** - the spreading of power in time caused by differing mode path lengths.
- **multimode fiber** - an optical fiber that allows many light modes to propagate.
- **chromatic dispersion** - the spreading of energy in time caused by differing light wavelengths (color).

EQUIPMENT REQUIRED

- F.A.C.E.T. base unit
- FIBER OPTIC COMMUNICATIONS circuit board
  with the FIBER OPTIC POLISHING KIT
- Multimeter
- Oscilloscope, dual trace
- Generator, sine wave
Exercise 1 – Scattering and Absorption Losses

EXERCISE OBJECTIVE
Understand the attenuation that occurs when light travels through a fiber-optic cable and calculate and measure the power loss through an optical fiber.

EXERCISE DISCUSSION

Location: Exercise Discussion Page: se1d6, Question ID: e1d6a
How does a step index fiber guide the light through its core?
  a. by refraction
  b. by reflection

Location: Exercise Discussion Page: se1d8, Question ID: e1d8a
Which part of the glass fiber has the highest refractive index?
  a. the core
  b. the cladding

Location: Exercise Discussion Page: se1d9, Question ID: e1d9a
How does graded index fiber guide light through its core?
  a. by refraction
  b. by reflection and refraction

Location: Exercise Discussion Page: se1d13, Question ID: e1d13a
What is the expected attenuation for this plastic fiber when it is used at a wavelength of 820 nm?
  a. 2000 dB/m
  b. 200 dB/m
  c. 2 dB/m
EXERCISE PROCEDURE

**Location:** Exercise Procedure Page: se1p2, Question ID: e1p2a

1m940 = \[ \text{mV} \]

Recall Label for this Question: a1

**Nominal Answer:** 1000.0

Min/Max Value: (50) to (1950)

Value Calculation: 1000.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 95

Correct Plus Tolerance = 95

---

**Location:** Exercise Procedure Page: se1p3, Question ID: e1p3a

5m940 = \[ \text{mV} \]

Recall Label for this Question: a2

**Nominal Answer:** 25.0

Min/Max Value: (.063) to (95.06)

Value Calculation: \# a1 \#/ 40

Correct Tolerance Percent = true

Correct Minus Tolerance = 95

Correct Plus Tolerance = 95

---

**Location:** Exercise Procedure Page: se1p4, Question ID: e1p4a

PR940 = \[ \text{dB} \]

Recall Label for this Question: a3

**Nominal Answer:** 16.02

Min/Max Value: (-2.65) to (47.15)

Value Calculation: 10 * log (# a1 # / # a2 # )

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

---

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
**Location: Exercise Procedure Page: se1p5, Question ID: e1p5a**

$$\text{LOSS}_{940} = \quad \text{dB/m}$$

Recall Label for this Question: a4  
**Nominal Answer: 4.00**  
*Min/Max Value: (-0.63) to (12.376)  
Value Calculation: # a3 / 4 #  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 5  
Correct Plus Tolerance = 5

**Location: Exercise Procedure Page: se1p6, Question ID: e1p6a**

$$\text{LOSS}_{\text{exp}} = \quad \text{dB/m}$$

Recall Label for this Question: a5  
**Nominal Answer: 4.0**  
Min/Max Value: (3.8) to (4.2)  
Value Calculation: 4.000  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 5  
Correct Plus Tolerance = 5

**Location: Exercise Procedure Page: se1p7, Question ID: e1p7a**

10. Is the observed value of # a4 # dB/m within ±0.5 dB of the # a5 # dB/m expected value?  
   a. yes  
   b. no

**Location: Exercise Procedure Page: se1p8, Question ID: e1p8a**

$$\text{I}_{m635} = \quad \text{mV}$$

Recall Label for this Question: a6  
**Nominal Answer: 400.0**  
Min/Max Value: (20) to (780)  
Value Calculation: 400.000  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 95  
Correct Plus Tolerance = 95

---

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se1p9, Question ID: e1p9a

5m_{635} = \text{mV}

Recall Label for this Question: a7
Nominal Answer: 307.7
*Min/Max Value: (9.231) to (840)
Value Calculation: \# a6 / 1.3 #
Correct Tolerance Percent = true
Correct Minus Tolerance = 40
Correct Plus Tolerance = 40

Location: Exercise Procedure Page: se1p10, Question ID: e1p10a

\text{LOSS}_{635} = \text{dB/m}

Recall Label for this Question: a8
Nominal Answer: 0.285
*Min/Max Value: (-3.85) to (5.058)
Value Calculation: \frac{10 \times \log \left( \frac{\# a6}{\# a7} \right)}{4}
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se1p11, Question ID: e1p11a

16. Does the observed \#a8\# dB/m attenuation agree with the expected value?
   a. yes
   b. no

Location: Exercise Procedure Page: se1p12, Question ID: e1p12a

1m_{565} = \text{mV}

Recall Label for this Question: a9
Nominal Answer: 70.0
Min/Max Value: (3.5) to (136.5)
Value Calculation: 70.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 95
Correct Plus Tolerance = 95

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se1p13, Question ID: e1p13a

5m565 = mV

Recall Label for this Question: a10
Nominal Answer: 58.33
*Min/Max Value: (1.75) to (159.3)
Value Calculation: # a9 / 1.2 #
Correct Tolerance Percent = true
Correct Minus Tolerance = 40
Correct Plus Tolerance = 40

Location: Exercise Procedure Page: se1p14, Question ID: e1p14a

LOSS565 = dB/m

Recall Label for this Question: a11
Nominal Answer: 0.198
*Min/Max Value: (-3.896) to (5.035)
Value Calculation: 10 * log ( # a9 # / # a10 # ) / 4
Correct Tolerance Percent = true
Correct Minus Tolerance = 6
Correct Plus Tolerance = 6

Location: Exercise Procedure Page: se1p15, Question ID: e1p15a

22. Did the observed optical power loss agree with the expected value?
   a. yes
   b. no

Location: Exercise Procedure Page: se1p16, Question ID: e1p16a

23. Is fiber attenuation dependent on wavelength?
   a. yes
   b. no

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se1p16, Question ID: e1p16c

24. Which wavelength is expected to produce the least power loss in the plastic fiber?
   a. 940 nm
   b. 635 nm
   c. 565 nm

Location: Exercise Procedure Page: se1p17, Question ID: e1p17a

1m940 = mV

Recall Label for this Question: a12

Nominal Answer: 2000.0
Min/Max Value: (200) to (3800)
Value Calculation: 2000.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 90
Correct Plus Tolerance = 90

Location: Exercise Procedure Page: se1p18, Question ID: e1p18a

5m940 = mV

Recall Label for this Question: a13

Nominal Answer: 1998.0
*Min/Max Value: (158.4) to (4558)
Value Calculation: # a12 - 2 #
Correct Tolerance Percent = true
Correct Minus Tolerance = 20
Correct Plus Tolerance = 20

Location: Exercise Procedure Page: se1p19, Question ID: e1p19a

PR940 = dB

Recall Label for this Question: a14

Nominal Answer: 0.0043
*Min/Max Value: (-12.89) to (14.49)
Value Calculation: 10 * log (# a12 # / # a13 #)
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se1p20, Question ID: e1p20a

\[ \text{LOSS}\exp = \quad \text{dB/m} \]

Recall Label for this Question: a15
Nominal Answer: 0.002
Min/Max Value: (0.0017) to (0.0023)
Value Calculation: 0.002
Correct Tolerance Percent = true
Correct Minus Tolerance = 15
Correct Plus Tolerance = 15

Location: Exercise Procedure Page: se1p21, Question ID: e1p21a

32. What is the most likely cause for the relative power loss between the 1m and 5m glass cables?
   a. fiber attenuation
   b. connector attenuation

Location: Exercise Procedure Page: se1p22, Question ID: e1p22a

\[ \text{LOSS} = \quad \text{dB} \]

Recall Label for this Question: a16
Nominal Answer: 1.04
Min/Max Value: (0.988) to (1.092)
Value Calculation: 1.040
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se1p23, Question ID: e1p23a

33. Which type of fiber has the least attenuation per unit length?
   a. glass
   b. plastic
REVIEW QUESTIONS

Location: Review Questions Page: se1r1, Question ID: e1r1
1. How can you reduce the losses in a fiber-optic system using a 10 km length of 62.5/125 glass fiber operating at 940 nm?
   a. Use a longer fiber.
   b. Use plastic fiber.
   c. Operate at 1500 nm.
   d. None of the above.

Location: Review Questions Page: se1r2, Question ID: e1r2
2. How can you reduce the attenuation in a fiber-optic system using a plastic fiber operating at 940 nm?
   a. Use a cable with a lower dB/km at 940 nm.
   b. Use a shorter fiber.
   c. Operate at 565 nm.
   d. All of the above.

Location: Review Questions Page: se1r3, Question ID: e1r3
Which equation represents the fiber attenuation in dB/m?
   a. \( (10 \times \log(10 \mu W/1 \mu W))/(8m - 2m) \)
   b. \( (20 \times \log(10 \mu W/1 \mu W))/(8m - 2m) \)
   c. \( (10 \times \log(8m/2m))/(10 \mu W - 1 \mu W) \)
   d. \( (20 \times \log(10 \mu W/1 \mu W))/8m \)

Location: Review Questions Page: se1r4, Question ID: e1r4
4. Light attenuation in an optical fiber is caused by
   a. an ideal waveguide.
   b. scattering and absorption.
   c. resistance and capacitance.
   d. wavelength.
Location: Review Questions Page: se1r5, Question ID: e1r5

5. The DVM reading taken at the phototransistor's 1 kΩ emitter resistor represents
   a. Q1's supply voltage.
   b. the relative light power at Q1.
   c. the fiber's attenuation in dB/km.
   d. None of the above.

CMS AVAILABLE
None

FAULTS AVAILABLE
None
Exercise 2 – Connectors & Polishing

EXERCISE OBJECTIVE
Cut and polish plastic fiber-optic cable. Identify losses in optical connections using visual inspection and power measurements.

EXERCISE DISCUSSION

Location: Exercise Discussion Page: se2d1, Question ID: e2d1a
How could both light rays pass into the second fiber?
   a. align the fiber ends
   b. change the wavelength

Location: Exercise Discussion Page: se2d8, Question ID: e2d8a
What is the angle of refraction ($\theta_2$) when a light ray encounters the cladding with a $77^\circ$ angle of incidence ($\theta_1$).
   a. $13^\circ$
   b. $68^\circ$
   c. $77^\circ$
   d. None of the above.

Location: Exercise Discussion Page: se2d10, Question ID: e2d10a
What is the angle of refraction ($\theta_2$) when a light ray encounters the cladding with a $70^\circ$ angle of incidence ($\theta_1$).
   a. $70^\circ$
   b. $77^\circ$
   c. $82^\circ$
   d. None of the above.
**EXERCISE PROCEDURE**

**Location: Exercise Procedure Page: se2p4, Question ID: e2p4a**

Unpolished = mV

Recall Label for this Question: b1

**Nominal Answer: 100.0**

Min/Max Value: (10) to (190)

Value Calculation: 100.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 90

Correct Plus Tolerance = 90

**Location: Exercise Procedure Page: se2p5, Question ID: e2p5a**

Terminated = mV

Recall Label for this Question: b2

**Nominal Answer: 600.0**

*Min/Max Value: (12) to (2052)*

Value Calculation: # b1 * 6 #

Correct Tolerance Percent = true

Correct Minus Tolerance = 80

Correct Plus Tolerance = 80

**Location: Exercise Procedure Page: se2p6, Question ID: e2p6a**

9. Which cable delivered the most light to the phototransistor?

a. unpolished

b. terminated

**Location: Exercise Procedure Page: se2p6, Question ID: e2p6c**

PR = dB

Recall Label for this Question: b3

**Nominal Answer: 7.78**

*Min/Max Value: (-11.396) to (24.278)*

Value Calculation: 10 * log (# b2 / # b1 #)

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
18. Is the surface polished without cracks or tool marks?
   a. yes  
   b. no

Unterminated (600) = mV

Recall Label for this Question: b4

Nominal Answer: 170.0

*Min/Max Value: (6.8) to (516.8)

Value Calculation: # b1 * 1.7 #

Correct Tolerance Percent = true

Correct Minus Tolerance = 60

Correct Plus Tolerance = 60

21. Will polishing the exit end of the fiber reduce the cable’s attenuation?
   a. yes  
   b. no

25. Is there a good polish without any cracks or tool marks?
   a. yes  
   b. no

Unterminated (600) = mV

Recall Label for this Question: b6

Nominal Answer: 255.0

*Min/Max Value: (6.12) to (1085)

Value Calculation: # b4 * 1.5 #

Correct Tolerance Percent = true

Correct Minus Tolerance = 40

Correct Plus Tolerance = 40

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se2p22, Question ID: e2p22a

Unterminated (3 μm) = mV

Recall Label for this Question: b7

Nominal Answer: 382.5

*Min/Max Value: (5.508) to (2279)

Value Calculation: # b6 * 1.5 #

Correct Tolerance Percent = true

Correct Minus Tolerance = 40

Correct Plus Tolerance = 40

Location: Exercise Procedure Page: se2p23, Question ID: e2p23a

PR = dB

Recall Label for this Question: b8

Nominal Answer: 1.955

*Min/Max Value: (-21.647) to (26.998)

Value Calculation: 10 * log (# b2/# b7 #)

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se2p26, Question ID: e2p26a

38. Does the light power delivered to the phototransistor change as you adjust the fiber end alignment?
   a. yes
   b. no

Location: Exercise Procedure Page: se2p27, Question ID: e2p27a

40. Does the light power delivered to the phototransistor increase as you increase the distance between the fibers?
   a. yes
   b. no

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se2p28, Question ID: e2p28a
What will happen when the fiber end moves away from the ferrule end?

a. attenuation decreases
b. attenuation increases

Location: Exercise Procedure Page: se2p31, Question ID: e2p31a
44. Calculate the proportion of light reflected (ρ) from the air (η₁ = 1) to core (η₂ = 1.492) boundary.

ρ =

Recall Label for this Question: b9
Nominal Answer: 0.039
Min/Max Value: (0.037) to (0.041)
Value Calculation: 0.039
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se2p33, Question ID: e2p33a
Coupled = mV

Recall Label for this Question: b10
Nominal Answer: 229.5
*Min/Max Value: (1.652) to (2051)
Value Calculation: # b7 * 0.6 #
Correct Tolerance Percent = true
Correct Minus Tolerance = 50
Correct Plus Tolerance = 50

Location: Exercise Procedure Page: se2p34, Question ID: e2p34a
LOSS = dB

Recall Label for this Question: b11
Nominal Answer: 4.174
*Min/Max Value: (-21.21) to (32.489)
Value Calculation: 10 * log ( # b2 # / # b10 # )
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
**Location:** Exercise Procedure Page: se2p35, Question ID: e2p35a

fiber = dB/m

Recall Label for this Question: b12  
**Nominal Answer:** 0.3  
Min/Max Value: (0.285) to (0.315)  
Value Calculation: 0.300  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 5  
Correct Plus Tolerance = 5

**Location:** Exercise Procedure Page: se2p36, Question ID: e2p36a

LOSS = dB

Recall Label for this Question: b13  
**Nominal Answer:** 3.874  
*Min/Max Value: (-12.906) to (45.06)  
Value Calculation: # b11 - 0.3 #  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 40  
Correct Plus Tolerance = 40

**Location:** Exercise Procedure Page: se2p37, Question ID: e2p37a

LOSS = dB

Recall Label for this Question: b14  
**Nominal Answer:** 1.919  
*Min/Max Value: (-37.909) to (70.04)  
Value Calculation: # b13 - b8 #  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 5  
Correct Plus Tolerance = 5

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se2p43, Question ID: e2p43a

\[ P_R = \text{nW} \]

Recall Label for this Question: b15

**Nominal Answer: 100.0**

Min/Max Value: (95) to (105)

Value Calculation: 100.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

---

**REVIEW QUESTIONS**

Location: Review Questions Page: se2r1, Question ID: e2r1

1. Which polish will produce the largest Fresnel reflection?
   a. Flat polish
   b. PC polish
   c. Super PC polish
   d. Ultra PC polish

Location: Review Questions Page: se2r2, Question ID: e2r2

2. How can the attenuation of a connection be reduced?
   a. Increase the lateral displacement.
   b. Increase the end separation.
   c. Decrease the angular misalignment.
   d. All of the above.

Location: Review Questions Page: se2r3, Question ID: e2r3

3. Pistoning increases attenuation by
   a. increasing the ferrule's angular misalignment.
   b. **increasing fiber end separation.**
   c. increasing lateral displacement.
   d. causing the fiber ends to have physical contact.

Location: Review Questions Page: se2r4, Question ID: e2r4

4. What is the insertion loss for the additional optical connection?
   a. 2.5 dB
   b. **1.5 dB**
   c. 0.75 dB
   d. 0.375 dB
Location: Review Questions Page: se2r5, Question ID: e2r5

5. Which of the following will reduce the attenuation of fiber-optic cable assembly?
   a. Using ferrules to align the fiber ends.
   b. Polishing the fiber ends.
   c. Using the least number of connectors.
   d. All of the above.

CMS AVAILABLE
None

FAULTS AVAILABLE
None
Exercise 3 – Numerical Aperture & Core Area

EXERCISE OBJECTIVE
Explain how numerical aperture (NA) affects attenuation and how attenuation is affected by fiber core area. Calculate attenuation due to numerical aperture and core area mismatches and verify results using relative power measurements.

EXERCISE DISCUSSION

Location: Exercise Discussion Page: se3d4, Question ID: e3d4a
What is the critical angle ($\theta_c$) for this plastic optical fiber?
- a. 90°
- b. 71.8°
- c. 18.2°
- d. Undefined

Location: Exercise Discussion Page: se3d9, Question ID: e3d9a
What is the NA of this fiber?
- a. 0.82
- b. 0.46
- c. 0.31
- d. 0.24
EXERCISE PROCEDURE

Location: Exercise Procedure Page: se3p6, Question ID: e3p6a

θ = °

Recall Label for this Question: c1
Nominal Answer: 55.0
Min/Max Value: (38.5) to (71.5)
Value Calculation: 55.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

Location: Exercise Procedure Page: se3p14, Question ID: e3p14a

14. Measure the voltage between the phototransistor Emitter and GND to determine the relative optical power delivered by the plastic cable.
PLASTIC = mV

Recall Label for this Question: c2
Nominal Answer: 400.0
Min/Max Value: (20) to (780)
Value Calculation: 400.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 95
Correct Plus Tolerance = 95

Location: Exercise Procedure Page: se3p16, Question ID: e3p16a

17. Is there an NA mismatch at the plastic to glass fiber connection?
  a. yes
  b. no
18. Calculate the expected attenuation ($\text{LOSS}_\text{NA}$) caused by the NA mismatch between the plastic and glass cables.

$$\text{LOSS}_\text{NA} = \text{dB}$$

Recall Label for this Question: c3
Nominal Answer: 4.3
Min/Max Value: (4.085) to (4.515)
Value Calculation: 4.300
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

19. Measure the relative light power delivered to the phototransistor by the combination plastic-glass cable.

$$\text{PLASTIC-GLASS} = \text{mV}$$

Recall Label for this Question: c4
Nominal Answer: 100.0
Min/Max Value: (10) to (190)
Value Calculation: 100.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 90
Correct Plus Tolerance = 90

20. Calculate the attenuation between the plastic and plastic-glass cables.

$$\text{LOSS} = \text{dB}$$

Recall Label for this Question: c5
Nominal Answer: 26.02
Min/Max Value: (9.712) to (40.867)
Value Calculation: $10 \times \log \left( \frac{\text{# c2}}{\text{# c4} / 100} \right)$
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
21. Subtract the expected NA mismatch attenuation of 4.3 dB from the observed attenuation of #c5# dB.

\[
\text{LOSS} = \quad \text{dB}
\]

Recall Label for this Question: c6

**Nominal Answer:** -4.3

*Min/Max Value: (-4.52) to (-4.52)

Value Calculation: #c5# - 4.3

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se3p24, Question ID: e3p24a

\[
\text{LOSS}_{UI} = \quad \text{dB}
\]

Recall Label for this Question: c7

**Nominal Answer:** 23.9

Min/Max Value: (22.71) to (25.1 )

Value Calculation: 23.900

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se3p25, Question ID: e3p25a

23. Correct for the area mismatch by subtracting the expected attenuation of 23.9 dB from the observed loss of #c6# dB.

\[
\text{LOSS} = \quad \text{dB}
\]

Recall Label for this Question: c7a

**Nominal Answer:** -28.2

*Min/Max Value: (-29.61) to (-26.79)

Value Calculation: #c6# - 23.9

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
24. Which of the following accounts for the remaining loss (or gain)?
   a. Fresnal reflections
   b. measurement errors
   c. fiber alignment
   d. All of the above.

26. Measure the relative light power detected by the phototransistor.
   GLASS = mV
   Recall Label for this Question: c8
   Nominal Answer: 112.0
   Min/Max Value: (11.2) to (212.8)
   Value Calculation: 112
   Correct Tolerance Percent = true
   Correct Minus Tolerance = 90
   Correct Plus Tolerance = 90

28. Measure the relative light power delivered to the phototransistor by the combination glass-plastic cable.
   GLASS-PLASTIC = mV
   Recall Label for this Question: c9
   Nominal Answer: 100.0
   *Min/Max Value: (7) to (247)
   Value Calculation: # c4 #
   Correct Tolerance Percent = true
   Correct Minus Tolerance = 30
   Correct Plus Tolerance = 30

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se3p29, Question ID: e3p29a

29. Calculate the attenuation between the plastic and glass-plastic cables.

\[
\text{LOSS} = \quad \text{dB}
\]

Recall Label for this Question: c10

Nominal Answer: 0.492

*Min/Max Value: (-13.43) to (14.83)

Value Calculation: \(10 \times \log \left( \frac{\# c8}{\# c9} \right)\)

Correct Tolerance Percent = true

Correct Minus Tolerance = 7

Correct Plus Tolerance = 7

Location: Exercise Procedure Page: se3p30, Question ID: e3p30a

30. The observed attenuation has losses that are due to

a. NA mismatch.
b. area mismatch.
c. the fiber connection.
d. both area and NA mismatches.

REVIEW QUESTIONS

Location: Review Questions Page: se3r1, Question ID: e3r1

1. What is the acceptance angle of a fiber that has an NA of 0.40?

a. 47.2°
b. 40°
c. 23.6°
d. 0.014°

Location: Review Questions Page: se3r2, Question ID: e3r2

2. What is the area mismatch loss when light travels from a fiber with a 50 µm diameter core into a 62.5 µm core diameter?

a. 15 dB
b. 1.9 dB
c. 0 dB
d. -1.9 dB

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
3. What is the NA mismatch attenuation?
   a. 0 dB
   b. 5.5 dB
   c. 11 dB
   d. -5.5 dB

4. To prevent NA mismatch losses in a fiber-optic system, light should pass into fibers with
   a. an NA lower than or equal to, the previous fiber.
   b. an NA greater than, or equal to, the previous fiber.
   c. an area greater than, or equal to, the previous fiber.
   d. All of the above.

5. Which factors determine a fiber's acceptance angle?
   a. the refractive index of the cladding
   b. the refractive index of the core
   c. the fiber's critical angle
   d. All of the above.

CMS AVAILABLE
None

FAULTS AVAILABLE
None
Exercise 4 – Bending Loss & Modal Dispersion

EXERCISE OBJECTIVE
Explain why fiber bending increases attenuation, how propagation modes affect dispersion, and why dispersion limits fiber bandwidth. Calculate the bandwidth for a length of fiber and verify bending losses using relative power measurements.

EXERCISE DISCUSSION

Location: Exercise Discussion Page: se4d3, Question ID: e4d3a
What is the difference between the path lengths of the longest and shortest modes?
- a. 95%
- b. 9.5%
- c. 5%

Location: Exercise Discussion Page: se4d5, Question ID: e4d5a
How long will it take for 635 nm light to travel through 1 km of this plastic fiber, propagating in the shortest mode?
- a. 5 ns
- b. 5 µs
- c. 2 ms
- d. None of the above.

Location: Exercise Discussion Page: se4d6, Question ID: e4d6a
How long will it take a pulse propagating in the longest modes to pass through the 1 km of cable?
- a. 5.25 µs
- b. 5 µs
- c. 4.75 µs

Location: Exercise Discussion Page: se4d10, Question ID: e4d10a
Which of these fibers will have the least modal dispersion?
- a. plastic
- b. glass
How could a fiber have a kilometer bandwidth above 200 MHz?

a. use more than 1800 modes  
**b. use a single mode**  
c. increase the NA

**EXERCISE PROCEDURE**

4. Measure the voltage between the phototransistor EMITTER and GND to determine the relative optical power delivered by the plastic cable (REF).

REF = V

Recall Label for this Question: d1  
**Nominal Answer: 3.7**  
Min/Max Value: (0.37) to (7.03)  
Value Calculation: 3.700  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 90  
Correct Plus Tolerance = 90

7. Is the current bend radius of 0.8 inches exceeding the cable specification for minimum bend radius?

a. yes  
**b. no**

8. Measure the relative optical power delivered by the bent plastic cable.

B8 = V

Recall Label for this Question: d2  
**Nominal Answer: 3.589**  
*Min/Max Value: (.323) to (7.501)*  
Value Calculation: # d1 # * .97  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 10  
Correct Plus Tolerance = 10

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
9. Calculate the attenuation caused by the 0.8 inches radius bend.
\[ \text{LOSS}_8 = \quad \text{dB} \]

Recall Label for this Question: d7
**Nominal Answer: 0.132**
*Min/Max Value: (-12.416) to (14.047)*
Value Calculation: \(10 \times \log\left(\frac{\# d1\ #}{\# d2\ #}\right)\)
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

11. Is the current bend radius of 0.6 inches exceeding the cable specification for minimum bend radius?
   a. yes
   b. no

12. Measure relative optical power delivered by the bent plastic cable.
\[ B_6 = \quad \text{V} \]

Recall Label for this Question: d3
**Nominal Answer: 3.441**
*Min/Max Value: (.31) to (7.192)*
Value Calculation: \(\# d1\ # \times .93\)
Correct Tolerance Percent = true
Correct Minus Tolerance = 10
Correct Plus Tolerance = 10

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
13. Calculate the attenuation caused by the 0.6 inches radius bend.
\[ \text{LOSS}_6 = \quad \text{dB} \]
Recall Label for this Question: d4
Nominal Answer: 3.441
*Min/Max Value: (-12.243) to (14.234)
Value Calculation: \( 10 \times \log \left( \frac{\text{# d1} \ #}{\text{# d3} \ #} \right) \)
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

15. Measure relative optical power delivered by the bent plastic cable.
\[ \text{B}_4 = \quad \text{V} \]
Recall Label for this Question: d5
Nominal Answer: 2.886
*Min/Max Value: (.26) to (6.032)
Value Calculation: \( \text{# d1} \ # \times .78 \)
Correct Tolerance Percent = true
Correct Minus Tolerance = 10
Correct Plus Tolerance = 10

17. Calculate the attenuation caused by the 0.4 inches radius bend.
\[ \text{LOSS}_4 = \quad \text{dB} \]
Recall Label for this Question: d6
Nominal Answer: 1.079
*Min/Max Value: (-11.517) to (15.036)
Value Calculation: \( 10 \times \log \left( \frac{\text{# d1} \ #}{\text{# d5} \ #} \right) \)
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
18. How can you reduce the attenuation of this plastic cable in a fiber-optic system?
   a. Use bends that have a radius below 0.67 inches.
   b. Use bends that are above 0.67 inches in diameter.
   c. Use a bend radius well above 0.67 inches.
   d. All of the above.

19. What is the bandwidth (BW) of the 5m multi-mode 62.5/125 glass cable?
   BW = ______ MHz

   Recall Label for this Question: d10
   **Nominal Answer: 40000.0**
   Min/Max Value: (38000) to (42000)
   Value Calculation: 40000.000
   Correct Tolerance Percent = true
   Correct Minus Tolerance = 5
   Correct Plus Tolerance = 5

20. How long is this cable if it has a bandwidth (BW) of 10 MHz?
   length = ______ km

   Recall Label for this Question: d11
   **Nominal Answer: 20.0**
   Min/Max Value: (19) to (21)
   Value Calculation: 20.000
   Correct Tolerance Percent = true
   Correct Minus Tolerance = 5
   Correct Plus Tolerance = 5
REVIEW QUESTIONS

Location: Review Questions Page: se4r1, Question ID: e4r1
1. The attenuation of a cable bend is reduced by
a. increasing the bend radius.
b. decreasing the bend radius.
c. adding additional bends.
d. None of the above.

Location: Review Questions Page: se4r2, Question ID: e4r2
2. A cable with a minimum bend radius of 2 cm can
a. be wound on a spool with a 3 cm diameter.
b. bend 180° in less than 4 cm.
c. be used for a bend with a radius above 2 cm.
d. All of the above.

Location: Review Questions Page: se4r3, Question ID: e4r3
3. Which of these fibers has the least modal dispersion?
   a. Single-Mode Glass (NA = .13, Core DIA. = 5 µm)
   b. Multi-Mode Glass (NA = .26, Core DIA. = 62.5 µm)
   c. Multi-Mode Plastic (NA = .46, Core DIA. = 980 µm)
   d. Multi-Mode Plastic (NA = .5, Core DIA. 485 µm)

Location: Review Questions Page: se4r4, Question ID: e4r4
4. What is the bandwidth of a multi-mode fiber 15 km long that has a 200 MHzkm bandwidth specification?
   a. 3000 MHz
   b. 200 MHz
   c. 15 MHz
   d. 13 MHz
5. Increasing a fiber's length
   a. decreases its dispersion.. increases its dispersion.
   c. increases its bandwidth.
   d. decreases its attenuation.

CMS AVAILABLE
None

FAULTS AVAILABLE
None
UNIT TEST

Location: Unit Test Page: sut1, Question ID: ut1
What is the fiber attenuation?
  a. 1 dB/km
  b. 0.86 dB/km
  c. 1.7 dB/km
  d. 2 dB/km

Location: Unit Test Page: sut2, Question ID: ut2
How can the losses be reduced in a fiber optic system using a 20 km length of 62.5/125 glass fiber operating at 940 nm?
  a. operate at a higher frequency
  b. operate at a longer wavelength
  c. add more fiber
  d. bend the fiber

Location: Unit Test Page: sut3, Question ID: ut3
What is the insertion loss for the additional optical connection?
  a. .5 dB
  b. 1 dB
  c. 1.76 dB
  d. 2 dB

Location: Unit Test Page: sut4, Question ID: ut4
Which end finish will produce the smallest Fresnel reflection?
  a. Flat polish
  b. PC polish
  c. no polish (unpolished)
  d. None of the above.

Location: Unit Test Page: sut5, Question ID: ut5
What is the area mismatch (UI) loss when light travels from a fiber with a 62.5 µm diameter core into a 980 µm core diameter?
  a. 62.5 dB
  b. 24 dB
  c. 0 dB
  d. -24 dB
Location: Unit Test Page: sut6, Question ID: ut6
What is the NA mismatch attenuation?

a. 4.3 dB
b. 2.6
c. 0 dB
d. -2.6 dB

Location: Unit Test Page: sut7, Question ID: ut7
What is the acceptance angle of a fiber that has an NA of 0.5?

a. 0.009°
b. 0.5°
c. 30°
d. 50°

Location: Unit Test Page: sut8, Question ID: ut8
What is the bandwidth of a 980 µm, 0.46 NA plastic fiber 24 km long that has a 6 MHzkm bandwidth specification at 650 nm.

a. 144 MHz
b. 6 MHz
c. 4 MHz
d. 250 kHz

Location: Unit Test Page: sut9, Question ID: ut9
The attenuation of a cable bend is reduced by

a. increasing the bend radius.
b. decreasing the bend radius.
c. adding additional bends.
d. None of the above.

Location: Unit Test Page: sut10, Question ID: ut10
Which of the following will reduce the attenuation of fiber-optic cable assembly?

a. Using ferrules that align the fiber ends.
b. Polishing the fiber ends.
c. Using the least number of connections.
d. All of the above.
UNIT 3 – FIBER OPTIC TRANSMITTER

UNIT OBJECTIVE
Identify, describe, and demonstrate the parts of a fiber-optic transmitter.

UNIT FUNDAMENTALS

Location: Unit Fundamentals Page: sf1, Question ID: f1a
A photon of red light having a wavelength of 650 nm, a frequency of 461.5 THz (terahertz = Hz x 10^{12}), contains about 3 x 10^{-19} watts (0.0000003 pW) of energy. Which light type possesses even less energy than this?
- a. infrared at 319 THz
- b. green at 531 THz

Location: Unit Fundamentals Page: sf7, Question ID: f7a
What is a common unit of measure for radiant emittance? HINT: Access the Fiber Optic Communications Help by pressing Resources.
- a. µW/sr
- b. mW/cm^2
- c. cd/cm^2

CMS AVAILABLE
None

FAULTS AVAILABLE
None
NEW TERMS AND WORDS

photometric - a system or parameter used to specify visible properties of electromagnetic radiation.

radiometric - a system or parameter used to specify physical properties of electromagnetic radiation.


point source - a light source whose diameter is at least ten times smaller than the distance between the source and detector.

photons - elementary quantities of radiant energy, which can be considered to be particles of light.

radiation - the emission of electromagnetic energy.

chromatic dispersion - the spreading of energy in time caused by differing light wavelengths (color).

radiation efficiency - the ratio input power of radiant power to a light source.

steradian - a unit of measure for a solid angle.

luminous efficacy - an efficiency rating of a visible light source equal to the ratio of luminous power to radiant power in lumens per watt (lm/W).

quiescent - a stable, inactive operating point or condition.

EQUIPMENT REQUIRED

F.A.C.E.T. base unit
FIBER OPTIC COMMUNICATIONS circuit board
Multimeter
Oscilloscope, dual-trace
Signal Generator, sine/square wave
Exercise 1 – Light Source

EXERCISE OBJECTIVE
Describe light sources used in fiber-optic systems that convert an electrical signal into an optical signal.

EXERCISE DISCUSSION

Location: Exercise Discussion Page: se1d6, Question ID: e1d6a
If original peak output power were 5 mW, what value would signify the end of the LED's life?
a. 1 mW  
b. 2 mW  
c. 2.5 mW

Location: Exercise Discussion Page: se1d13, Question ID: e1d13a
What is the spectral bandwidth (FWHM) of the infrared LED?
a. 25 nm  
b. **50 nm**  
c. 100 nm

Location: Exercise Discussion Page: se1d14, Question ID: e1d14a
The Fiber Optic Transmitter (FOT) on your circuit board has a peak wavelength of 820 nm. Its typical spectral bandwidth (FWHM) is 45 nm. At what two wavelengths is the FOT's output 50% lower than its typical peak output?
a. 45 and 90 nm  
b. 333 and 666 nm  
c. **797.5 and 842.5 nm**  
d. 775.0 and 865.0 nm

Location: Exercise Discussion Page: se1d17, Question ID: e1d17a
\[ BW_{\text{max}} = 0.35/\tau_r \]
The LED in your Fiber Optic Transmitter (FOT) has a typical rise time of 3 ns. Approximately what is the FOT's maximum bandwidth?
a. about 1 GHz  
b. **117 MHz**  
c. 12 MHz  
d. about 1 MHz
EXERCISE PROCEDURE

Location: Exercise Procedure Page: se1p1, Question ID: e1p1a

\[ VR_{39} = V_{dc} \]

Recall Label for this Question: a1
Nominal Answer: 3.1
Min/Max Value: (2.17) to (4.03)
Value Calculation: 3.100
Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

Location: Exercise Procedure Page: se1p2, Question ID: e1p2a

\[ IR_{39} = mA \]

Recall Label for this Question: a2
Nominal Answer: 17.22
*Min/Max Value: (11.69) to (23.06)
Value Calculation: \# a1 / 180 *1000 \#
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se1p2, Question ID: e1p2c

\[ VR_{40} = V_{dc} \]

Recall Label for this Question: a3
Nominal Answer: 2.8
Min/Max Value: (1.96) to (3.64)
Value Calculation: 2.800
Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
**Location:** Exercise Procedure Page: se1p2, Question ID: e1p2e

\[ I_{R40} = \text{mA} \]

Recall Label for this Question: a4  
**Nominal Answer:** 15.56  
*Min/Max Value: (10.56) to (20.83)  
Value Calculation: \# a3 / 180 *1000 \#  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 3  
Correct Plus Tolerance = 3

**Location:** Exercise Procedure Page: se1p2, Question ID: e1p2g

\[ V_{R41} = V_{dc} \]

Recall Label for this Question: a5  
**Nominal Answer:** 3.8  
Min/Max Value: (2.66) to (4.94)  
Value Calculation: 3.800  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 30  
Correct Plus Tolerance = 30

**Location:** Exercise Procedure Page: se1p2, Question ID: e1p2i

\[ I_{R41} = \text{mA} \]

Recall Label for this Question: a6  
**Nominal Answer:** 21.11  
*Min/Max Value: (14.33) to (28.27)  
Value Calculation: \# a5 / 180 *1000 \#  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 3  
Correct Plus Tolerance = 3

---

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se1p4, Question ID: e1p4a
\[ V_f (\text{red}) = V_{dc} \]
Recall Label for this Question: a7
**Nominal Answer:** 1.9
Min/Max Value: (1.14) to (2.66)
Value Calculation: 1.900
Correct Tolerance Percent = true
Correct Minus Tolerance = 40
Correct Plus Tolerance = 40

Location: Exercise Procedure Page: se1p4, Question ID: e1p4c
\[ P_f(\text{red}) = mW \]
Recall Label for this Question: a8
**Nominal Answer:** 32.72
*Min/Max Value: (12.93) to (63.18)
Value Calculation: \# a2 * a7 \#
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se1p4, Question ID: e1p4e
\[ V_f (\text{green}) = V_{dc} \]
Recall Label for this Question: a9
**Nominal Answer:** 2.2
Min/Max Value: (1.32) to (3.08)
Value Calculation: 2.200
Correct Tolerance Percent = true
Correct Minus Tolerance = 40
Correct Plus Tolerance = 40

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
Location: Exercise Procedure Page: se1p4, Question ID: e1p4g

\[
P_i \text{ (green)} = \text{ mW}
\]

Recall Label for this Question: a10

**Nominal Answer: 34.23**

*Min/Max Value: (13.52) to (66.08)*

Value Calculation: \# a4 * a9 \#

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

----------

Location: Exercise Procedure Page: se1p5, Question ID: e1p5a

\[
V_f \text{ (infrared)} = \text{ Vdc}
\]

Recall Label for this Question: a11

**Nominal Answer: 1.2**

Min/Max Value: (0.72) to (1.68)

Value Calculation: 1.200

Correct Tolerance Percent = true

Correct Minus Tolerance = 40

Correct Plus Tolerance = 40

----------

Location: Exercise Procedure Page: se1p5, Question ID: e1p5c

\[
P_i \text{ (infrared)} = \text{ mW}
\]

Recall Label for this Question: a12

**Nominal Answer: 25.33**

*Min/Max Value: (10.01) to (48.92)*

Value Calculation: \# a6 * a11 \#

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

----------

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
Location: Exercise Procedure Page: se1p6, Question ID: e1p6a

14. What can you conclude about the three LEDs?
   a. They have significantly different input power.
   b. They all have about the same input power.

Location: Exercise Procedure Page: se1p9, Question ID: e1p9a

\[ V_{\text{red}} = \text{mVdc} \]

Recall Label for this Question: a13
Nominal Answer: 112.0
Min/Max Value: (11.2) to (212.8)
Value Calculation: 112.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 90
Correct Plus Tolerance = 90

Location: Exercise Procedure Page: se1p10, Question ID: e1p10a

\[ V_{\text{green}} = \text{mVdc} \]

Recall Label for this Question: a14
Nominal Answer: 17.0
Min/Max Value: (1.7) to (32.3)
Value Calculation: 17.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 90
Correct Plus Tolerance = 90

Location: Exercise Procedure Page: se1p10, Question ID: e1p10c

\[ V_{\text{infrared}} = \text{Vdc} \]

Recall Label for this Question: a15
Nominal Answer: 2.2
Min/Max Value: (0.22) to (4.18)
Value Calculation: 2.200
Correct Tolerance Percent = true
Correct Minus Tolerance = 90
Correct Plus Tolerance = 90
Location: Exercise Procedure Page: se1p11, Question ID: e1p11a

VC_{red} = \text{mV}

Recall Label for this Question: a16
Nominal Answer: 224.0
*Min/Max Value: (21.73) to (438.4)
Value Calculation: \# a13 *(100 / 50) \#
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se1p11, Question ID: e1p11c

VC_{green} = \text{mV}

Recall Label for this Question: a17
Nominal Answer: 56.67
*Min/Max Value: (5.497) to (110.9)
Value Calculation: \# a14 * (100 / 30) \#
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se1p11, Question ID: e1p11c

VC_{infrared} = \text{mV}

Recall Label for this Question: a18
Nominal Answer: 2588.0
*Min/Max Value: (251.1) to (5065)
Value Calculation: (\# a15 \# * 1000 ) * ( 100 / 85 )
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
27. Is the output power the same for each LED?
   a. yes
   b. no

Location: Exercise Procedure Page: se1p14, Question ID: e1p14a

Location: Exercise Procedure Page: se1p16, Question ID: e1p16a

\[ PR_{\text{r/i}} = 10 \times \log \left( \frac{V_{\text{red}}}{V_{\text{infrared}}} \right) \]
\[ PR_{\text{r/i}} = \text{dB} \]

Recall Label for this Question: a21
Nominal Answer: -7.617
*Min/Max Value: (-20.045) to (5.594)
Value Calculation: \( 10 \times \log \left( \frac{\text{a16} \times 2}{\text{a18}} \right) \)
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se1p16, Question ID: e1p16c

\[ PR_{\text{g/i}} = 10 \times \log \left( \frac{V_{\text{green}}}{V_{\text{infrared}}} \right) \]
\[ PR_{\text{g/i}} = \text{dB} \]

Recall Label for this Question: a22
Nominal Answer: -13.586
*Min/Max Value: (-25.835) to (-0.555)
Value Calculation: \( 10 \times \log \left( \frac{\text{a17} \times 2}{\text{a18}} \right) \)
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se1p17, Question ID: e1p17a

\[ I_V (\text{red}) = I_V (\text{typ}) \times (80\%/100\%) \]
\[ I_V (\text{red}) = \text{mcd} \]

Recall Label for this Question: a23
Nominal Answer: 36.0
Min/Max Value: (35.28) to (36.72)
Value Calculation: 36.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 2
Correct Plus Tolerance = 2

Location: Exercise Procedure Page: se1p17, Question ID: e1p17c

\[ I_V (\text{green}) = I_V (\text{typ}) \times (75\%/100\%) \]
\[ I_V (\text{green}) = \text{mcd} \]

Recall Label for this Question: a24
Nominal Answer: 34.0
Min/Max Value: (33.32) to (34.68)
Value Calculation: 34.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 2
Correct Plus Tolerance = 2

Location: Exercise Procedure Page: se1p19, Question ID: e1p19a

32. Which of the two visible LEDs has the highest radiant intensity, \( I_e \), for the same electrical input power? HINT: \( I_e = I_V / h_V \)
   a. red
   b. green
**Location: Exercise Procedure Page: se1p20, Question ID: e1p20a**

\[ I_e(\text{red}) = \mu W/\text{sr} \]

Recall Label for this Question: a25

**Nominal Answer: 248.3**

*Min/Max Value: (236. ) to (260.8)

Value Calculation: \# a23 \# / 145 *1000

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

**Location: Exercise Procedure Page: se1p20, Question ID: e1p20c**

\[ I_e(\text{green}) = \mu W/\text{sr} \]

Recall Label for this Question: a26

**Nominal Answer: 57.14**

*Min/Max Value: (54.32) to (60.03)

Value Calculation: \# a24 \# / 595 * 1000

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

**Location: Exercise Procedure Page: se1p21, Question ID: e1p21a**

\[ PR_{r/i}(\exp) = \text{dB} \]

Recall Label for this Question: a27

**Nominal Answer: 8.839**

*Min/Max Value: (8.552) to (9.126)

Value Calculation: 10 * log ( \# a25 \# / 3600 )

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

---

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
Location: Exercise Procedure Page: se1p21, Question ID: e1p21c

PR_{g/i}(exp) = 10 \times \log \left( \frac{I_e(\text{green})}{I_e(\text{infrared})} \right)

PR_{g/i}(exp) =  \text{dB}

Recall Label for this Question: a28

Nominal Answer: -17.994

*Min/Max Value: (-18.312) to (-17.667)

Value Calculation: 10 \times \log \left( \frac{\text{# a26 #}}{3600} \right)

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se1p22, Question ID: e1p22a

38. Were your power ratios similar to the expected power ratios?
   a. yes
   b. no

REVIEW QUESTIONS

Location: Review Questions Page: se1r1, Question ID: e1r1

1. Why did the infrared LED emit the most power (3600 mW/sr), even though it was the least visible?
   a. It was the most efficient photometrically, but not radiometrically.
   b. It was the most efficient radiometrically, but not photometrically.
   c. It had the least luminous efficacy.
   d. It had the most input power.

Location: Review Questions Page: se1r2, Question ID: e1r2

2. Why is the luminous intensity of the red and green LEDs the same, even though the radiant intensity is different?
   a. The red LED is more efficient photometrically, but not radiometrically.
   b. The green LED is more efficient radiometrically, but not photometrically.
   c. Our eyes are most sensitive to green light.
   d. Our eyes are most sensitive to red light.

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Review Questions Page: se1r3, Question ID: e1r3
3. What is the least important characteristic of a fiber-optic light source?
   a. color
   b. intensity
   c. bandwidth
   d. resistance

Location: Review Questions Page: se1r4, Question ID: e1r4
4. Which is not a radiometric measure of power?
   a. W (watt)
   b. 1m/W (lumens per watt)
   c. uW/sr (microwatts per steradian)
   d. mW/cm² (milliwatts per square centimeter)

Location: Review Questions Page: se1r5, Question ID: e1r5
5. When comparing two power levels in fiber optics, you can use
   a. either the actual ratio (P2/P1) or decibels (dB).
   b. the ratio (P2/P1) only.
   c. decibels (dB) only.
   d. None of the above.

CMS AVAILABLE
None

FAULTS AVAILABLE
None
Exercise 2 – Driver Circuit

EXERCISE OBJECTIVE
Describe the circuits used to interface an analog and a digital signal to a fiber-optic light source.

EXERCISE DISCUSSION

Location: Exercise Discussion Page: se2d12, Question ID: e2d12a
What type of driver circuit is this?
a. series 
b. shunt 
c. series with peaking
d. shunt with peaking

Location: Exercise Discussion Page: se2d12, Question ID: e2d12c
Is the LED pre-biased?
a. yes 
b. no
EXERCISE PROCEDURE

Location: Exercise Procedure Page: se2p2, Question ID: e2p2a
With a logic LOW at DATA IN, is the LED on or off?
a. on
b. off

Location: Exercise Procedure Page: se2p3, Question ID: e2p3a
\[ V_F(\text{off}) = V_{dc} \]
Recall Label for this Question: b1
Nominal Answer: 0.9
Min/Max Value: (0.63) to (1.17)
Value Calculation: 0.900
Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

Location: Exercise Procedure Page: se2p4, Question ID: e2p4a
5. If pre-bias were not used (diode shorted) in this driver circuit, what would the voltage be across the LED when it is off?
a. the same as with pre-biasing, \( V_F(\text{off}) \)
b. near the transistor saturation voltage, \( V_{CE(sat)} \)
c. near the supply voltage

Location: Exercise Procedure Page: se2p5, Question ID: e2p5a
\[ V_F(\text{on}) = V_{dc} \]
Recall Label for this Question: b2
Nominal Answer: 1.57
Min/Max Value: (1.099) to (2.041)
Value Calculation: 1.570
Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30
Location: Exercise Procedure Page: se2p6, Question ID: e2p6a

\[ V_{R16} = V_{dc} \]

Recall Label for this Question: b3
Nominal Answer: 1.72
Min/Max Value: (1.204) to (2.236)
Value Calculation: 1.720
Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

Location: Exercise Procedure Page: se2p6, Question ID: e2p6c

\[ I_{R16} = mA \]

Recall Label for this Question: b4
Nominal Answer: 36.6
Min/Max Value: (24.85) to (49.0)
Value Calculation: \( \frac{b3}{47} \times 1000 \)
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se2p6, Question ID: e2p6e

\[ P_{IN} = mW \]

Recall Label for this Question: b5
Nominal Answer: 57.46
Min/Max Value: (26.49) to (103.0)
Value Calculation: \( \frac{b2 \times b4}{b3} \)
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se2p7, Question ID: e2p7a

\[ P_{\text{OUT}} = P_R \times P_O(60 \text{ mA}) \]
\[ P_{\text{OUT}} = \mu\text{W} \]

Recall Label for this Question: b15

**Nominal Answer: 14.79**

*Min/Max Value: (7.696) to (24.3 )

Value Calculation: \(0.4403 \times (\# b4 \# - 3)\)

Correct Tolerance Percent = true

Correct Minus Tolerance = 20

Correct Plus Tolerance = 20

---

Location: Exercise Procedure Page: se2p8, Question ID: e2p8a

15. What is the frequency of the CLK signal on CH 1?
   a. 0.5 MHz
   b. 1 MHz
   c. 2 MHz

---

Location: Exercise Procedure Page: se2p9, Question ID: e2p9a

16. Are the rise and fall times of the output signal (D-OUT on CH 2) about the same as the input signal (DATA IN on CH 1)?
   a. yes
   b. no

---

Location: Exercise Procedure Page: se2p11, Question ID: e2p11a

20. Compare the LED drive-signal rise and fall times (CH 1) with the FOR output-signal rise and fall times (CH 2). Are they about the same?
   a. yes
   b. no

---

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
22. Calculate the time it takes for capacitor C24 to fully charge (5 time constants).
\[ t_{CHG} = 5 \times R_{16} \parallel R_{15} \times C_{24} \]
\[ t_{CHG} = \text{ns} \]

Recall Label for this Question: b6

**Nominal Answer:** 12.0

Min/Max Value: (11.64) to (12.36)

Value Calculation: 12.000

Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

---

**Location:** Exercise Procedure Page: se2p15, Question ID: e2p15a

\[ V_{F(q)} = V_{dc} \]

Recall Label for this Question: b7

**Nominal Answer:** 1.54

Min/Max Value: (1.078) to (2.002)

Value Calculation: 1.540

Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

---

**Location:** Exercise Procedure Page: se2p16, Question ID: e2p16a

\[ I_{F(q)} = \text{mA} \]

Recall Label for this Question: b8

**Nominal Answer:** 28.9

Min/Max Value: (20.23) to (37.57)

Value Calculation: 28.900

Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30
**Location:** Exercise Procedure Page: se2p17, Question ID: e2p17a

\[ P_{IN} = \text{mW} \]

Recall Label for this Question: b9

**Nominal Answer:** 44.51

*Min/Max Value: (21.15) to (77.47)

Value Calculation: \# b7 \# \* \# b8 \#

Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

**Location:** Exercise Procedure Page: se2p20, Question ID: e2p20a

34. Observe CH 1 on your scope. Is the signal the same amplitude and frequency as the input signal at T-IN?
   a. yes
   b. no

**Location:** Exercise Procedure Page: se2p21, Question ID: e2p21a

\[ V_{OUT} = \text{mV}_{pk-pk} \]

Recall Label for this Question: b10

**Nominal Answer:** 800.0

Min/Max Value: (560) to (1040)

Value Calculation: 800.000

Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

**Location:** Exercise Procedure Page: se2p21, Question ID: e2p21c

\[ V_{LED} = \text{mV}_{pk-pk} \]

Recall Label for this Question: b11

**Nominal Answer:** 150.0

Min/Max Value: (105) to (195)

Value Calculation: 150.000

Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se2p22, Question ID: e2p22a

\[ VR9 = VOUT - VLED \]
\[ VR9 = b10 - b11 \]
\[ VR9 = mV_{pk-pk} \]

Recall Label for this Question: b12
Nominal Answer: 650.0
*Min/Max Value: (354.1) to (963.1)
Value Calculation: b10 - b11
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se2p22, Question ID: e2p22c

\[ IR9 = \frac{VR9}{22} \Omega \]
\[ IR9 = \frac{b12 mV_{pk-pk}}{22} \Omega \]
\[ IR9 = mA_{pk-pk} \]

Recall Label for this Question: b13
Nominal Answer: 29.54
*Min/Max Value: (15.61) to (45.09)
Value Calculation: b12 / 22
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se2p24, Question ID: e2p24a

\[ IF(+) = mA_{pk} \]

Recall Label for this Question: b14
Nominal Answer: 43.68
*Min/Max Value: (27.19) to (61.92)
Value Calculation: b8 + ( b13 / 2 )
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se2p24, Question ID: e2p24c

\[ I_f(-) = mA_{pk} \]

Recall Label for this Question: b16
Nominal Answer: 14.13
Min/Max Value: (-2.38) to (30.66)
Value Calculation: \# b8 # - ( \# b13 # / 2 )
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se2p25, Question ID: e2p25a

\[ P_{R(+)} = pk \]

Recall Label for this Question: b17
Nominal Answer: 0.714
Min/Max Value: (.339) to (1.24)
Value Calculation: 0.01754 * ( \# b14 # - 3)
Correct Tolerance Percent = true
Correct Minus Tolerance = 20
Correct Plus Tolerance = 20

Location: Exercise Procedure Page: se2p25, Question ID: e2p25c

\[ P_{R(-)} = pk \]

Recall Label for this Question: b18
Nominal Answer: 0.195
Min/Max Value: (-.11) to (.582)
Value Calculation: 0.01754 * ( \# b16 # - 3)
Correct Tolerance Percent = true
Correct Minus Tolerance = 20
Correct Plus Tolerance = 20

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se2p25, Question ID: e2p25e

\[ P_R = \text{pk-pk} \]

Recall Label for this Question: b19

Nominal Answer: 0.519

*Min/Max Value: (-.25) to (1.391)
Value Calculation: \# b17 \# - \# b18 \#
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se2p26, Question ID: e2p26a

\[ P_{OUT} = P_R \times P_O(60 \text{ mA}) \]
\[ P_{OUT} = \mu W_{pk-pk} \]

Recall Label for this Question:

Nominal Answer: 13.03

*Min/Max Value: (-6.46) to (35.96)
Value Calculation: \# b19 \# \times 25.1
Correct Tolerance Percent = true
Correct Minus Tolerance = 3
Correct Plus Tolerance = 3

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
REVIEW QUESTIONS

1. The driver circuit can control an FOT's
   a. forward current.
   b. radiant power.
   c. switching speed.
   d. All of the above.

2. What does the rise and fall time of an output signal indicate about its driver circuit?
   a. amplitude
   b. bandwidth
   c. power
   d. None of the above.

3. What is the largest signal that can be input to the analog driver circuit without distorting the optical output from the LED?
   a. 0.5 Vpk-pk
   b. 1.0 Vpk-pk
   c. 1.5 Vpk-pk
   d. 2.0 Vpk-pk

4. Which is not a basic type of driver circuit?
   a. series
   b. parallel
   c. delta
   d. shunt
5. What are two techniques used to increase the switching speed of a digital driver circuit?
   a. constant-peaking and pre-biasing
   b. **pre-biasing and current-peaking**
   c. constant-biasing and pre-peaking
   d. All of the above.

CMS AVAILABLE
None

FAULTS AVAILABLE
None
Exercise 3 – Source-to-Fiber Connection

EXERCISE OBJECTIVE
Describe the factors that introduce losses in a fiber-optic transmitter's source-to-fiber connection.

EXERCISE DISCUSSION

Location: Exercise Discussion Page: se3d6, Question ID: e3d6a
If the separation distance is decreased, the UI loss would
a. increase.
b. decrease.

Location: Exercise Discussion Page: se3d10, Question ID: e3d10a
What is the NA of the glass optical fiber (NA2)?
a. 0.139
b. 0.275
c. 0.287
d. 0.961
EXERCISE PROCEDURE

Location: Exercise Procedure Page: se3p2, Question ID: e3p2a

\[ \text{FOT} = \frac{\text{Vdc}}{} \]

Recall Label for this Question: c16

Nominal Answer: 0.77

Min/Max Value: (0.077) to (1.463)

Value Calculation: 0.770

Correct Tolerance Percent = true

Correct Minus Tolerance = 90

Correct Plus Tolerance = 90

Location: Exercise Procedure Page: se3p4, Question ID: e3p4a

\[ \text{IRED} = \frac{\text{Vdc}}{} \]

Recall Label for this Question: c17

Nominal Answer: 2.2

Min/Max Value: (0.22) to (4.18)

Value Calculation: 2.200

Correct Tolerance Percent = true

Correct Minus Tolerance = 90

Correct Plus Tolerance = 90

Location: Exercise Procedure Page: se3p4, Question ID: e3p4c

\[ \text{IRED} = \frac{\# \text{c17} \# \text{Vdc}}{} \]

10. Divide this value by 100 to compensate for the HI to LO RANGE change.

\[ \text{IRED} = \frac{\# \text{c17} \# \text{Vdc}}{} \]

Recall Label for this Question: c18

Nominal Answer: 0.022

Min/Max Value: (0.002) to (0.049)

Value Calculation: # c17 # / 100

Correct Tolerance Percent = true

Correct Minus Tolerance = 17

Correct Plus Tolerance = 17

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se3p6, Question ID: e3p6a

DP = \text{dB}

Recall Label for this Question: c19

\textbf{Nominal Answer: 11.544}

*Min/Max Value: (10.86) to (13.893)

Value Calculation: 10 \times \log\left(\frac{\text{c16}}{\text{c18}}\right)

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se3p8, Question ID: e3p8a

\text{LOSS}_{UI} (in \text{dB}) = 20 \times \log\left(\frac{D_1}{D_2}\right)

\text{LOSS}_{UI} (\text{FOT/glass}) = \text{dB}

Recall Label for this Question: c1

\textbf{Nominal Answer: 13.3}

Min/Max Value: (12.9) to (13.7)

Value Calculation: 13.300

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se3p8, Question ID: e3p8c

\text{LOSS}_{UI} (in \text{dB}) = 20 \times \log\left(\frac{D_1}{D_2}\right)

\text{LOSS}_{UI} (\text{IRED/glass}) = \text{dB}

Recall Label for this Question: c2

\textbf{Nominal Answer: 36.1}

Min/Max Value: (35.02) to (37.18)

Value Calculation: 36.100

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

\* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se3p9, Question ID: e3p9a

\[ \text{LOSS}_{NA} \text{ (in dB)} = 20 \times \log \left( \frac{\text{NA}_1}{\text{NA}_2} \right) \]

\[ \text{LOSS}_{NA} \text{ (FOT/glass)} = \quad \text{dB} \]

Recall Label for this Question: c3

**Nominal Answer: 5.0**

Min/Max Value: (4.85) to (5.15)

Value Calculation: 5.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

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Location: Exercise Procedure Page: se3p10, Question ID: e3p10a

\[ \text{LOSS}_{NA} \text{ (IRED/glass)} = \quad \text{dB} \]

Recall Label for this Question:

**Nominal Answer: 0.0**

Min/Max Value: (0) to (0)

Value Calculation: 0.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 0

Correct Plus Tolerance = 0

---

Location: Exercise Procedure Page: se3p11, Question ID: e3p11a

\[ \rho \text{ (air/glass)} = \]

Recall Label for this Question: c5

**Nominal Answer: 0.04**

Min/Max Value: (.039) to (.041)

Value Calculation: 0.040

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3
Location: Exercise Procedure Page: se3p11, Question ID: e3p11c

\[
\text{LOSS}_R \text{ (air/glass)} = \quad \text{dB}
\]

Recall Label for this Question:

**Nominal Answer: 0.18**

Min/Max Value: (0.175) to (0.185)

Value Calculation: 0.180

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

---

Location: Exercise Procedure Page: se3p12, Question ID: e3p12a

Coupling losses (IRED/glass) = \quad \text{dB}

Recall Label for this Question: c8

**Nominal Answer: 36.8**

\*Min/Max Value: (34.65) to (39.02)

Value Calculation: \# c2 \# + 0 + 0.7

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

---

Location: Exercise Procedure Page: se3p13, Question ID: e3p13a

Coupling losses (FOT/glass) = \quad \text{dB}

Recall Label for this Question: c7

**Nominal Answer: 19.0**

\*Min/Max Value: (17.9) to (20.14)

Value Calculation: \# c1 \# + \# c3 \# + 0.7

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

---

\* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se3p15, Question ID: e3p15a

IF(q) = mA

Recall Label for this Question: c9
Nominal Answer: 28.9
Min/Max Value: (20.23) to (37.57)
Value Calculation: 28.900
Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

Location: Exercise Procedure Page: se3p16, Question ID: e3p16a

Po(FOT) = PR x Po(60 mA)
P0(FOT) = µW

Recall Label for this Question: c10
Nominal Answer: 11.41
*Min/Max Value: (6.073) to (18.28)
Value Calculation: ( 0.4406 * ( # c9 # - 3 ) )
Correct Tolerance Percent = true
Correct Minus Tolerance = 20
Correct Plus Tolerance = 20

Location: Exercise Procedure Page: se3p17, Question ID: e3p17a

Po(FOT) = dBm

Recall Label for this Question:
Nominal Answer: -19.427
*Min/Max Value: (-24.383) to (-15.163)
Value Calculation: 10 * log ( ( # c10 # / 1000) ,10)
Correct Tolerance Percent = true
Correct Minus Tolerance = 10
Correct Plus Tolerance = 10

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
25. Did you calculate an FOT output power, $P_0$(FOT), within the range of the values in the table above?
   a. yes
   b. no

**Location: Exercise Procedure Page: se3p18, Question ID: e3p18a**

VR41 = $V_{dc}$

Recall Label for this Question: c11a

**Nominal Answer: 3.8**

Min/Max Value: (2.66) to (4.94)

Value Calculation: 3.800

Correct Tolerance Percent = true

Correct Minus Tolerance = 30

Correct Plus Tolerance = 30

**Location: Exercise Procedure Page: se3p19, Question ID: e3p19c**

IR41 = $mA$

Recall Label for this Question:

**Nominal Answer: 21.11**

*Min/Max Value: (14.33) to (28.27)

Value Calculation: $\# c11a \# / 180 \times 1000$

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

**Location: Exercise Procedure Page: se3p20, Question ID: e3p20a**

$\Phi_e (20 \ mA) = \ \ \ \ dBm$

Recall Label for this Question:

**Nominal Answer: 3.0**

Min/Max Value: (2.91) to (3.09)

Value Calculation: 3.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

---

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se3p21, Question ID: e3p21a

\[ P_\text{O(IRED)} = \Phi_e(20 \text{ mA}) - \text{Coupling losses (IRED/glass)} \]

\[ P_\text{O(IRED)} = \text{dBm} \]

Recall Label for this Question: c13

**Nominal Answer:** -33.8

*Min/Max Value: (-37.1) to (-32.6)

Value Calculation: 3 - # c8 #

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se3p21, Question ID: e3p21c

\[ P_\text{O(IRED)} = \mu\text{W} \]

Recall Label for this Question: c14

**Nominal Answer:** 0.417

*Min/Max Value: (.189) to (.566)

Value Calculation: \( (10 ^ {(# c13 \# / 10) \times 1000} \)

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

Location: Exercise Procedure Page: se3p22, Question ID: e3p22a

\[ \text{DP} = \text{dB} \]

Recall Label for this Question: c15

**Nominal Answer:** 14.38

*Min/Max Value: (9.997) to (20.451)

Value Calculation: \( 10 \times \log (\# c10 \# / \# c14 \#) \)

Correct Tolerance Percent = true

Correct Minus Tolerance = 3

Correct Plus Tolerance = 3

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se3p23, Question ID: e3p23a
33. Are they similar?
   a. yes
   b. no

Location: Exercise Procedure Page: se3p24, Question ID: e3p24a
35. As the distance between the light source and optical fiber increased, the coupled power
   a. increased.
   b. decreased.
   c. did not change.

REVIEW QUESTIONS

Location: Review Questions Page: se3r1, Question ID: e3r1
1. Based on the procedure, which light source on your trainer exhibits the highest coupling loss
to the glass fiber-optic cable?
   a. FOT
   b. infrared LED (IRED)
   c. green LED
   d. red LED

Location: Review Questions Page: se3r2, Question ID: e3r2
2. The FOT-to-glass connection is more efficient than the IRED-to-glass due to its lower
   a. UI loss.
   b. R loss.
   c. Finish loss.
   d. IRED output power.

Location: Review Questions Page: se3r3, Question ID: e3r3
3. Using the plastic fiber-optic cable, what is the UI loss at the FOT source-to-fiber connection?
   a. 5.3 dB
   b. 10.6 dB
   c. 21.2 dB
   d. No UI loss
Location: Review Questions Page: se3r4, Question ID: e3r4

4. Using the plastic fiber-optic cable, what is the NA loss at the FOT source-to-fiber connection?
   a. 0.20 dB
   b. **0.36 dB**
   c. 0.50 dB
   d. 0.65 dB

Location: Review Questions Page: se3r5, Question ID: e3r5

5. What is the total coupling loss at a source-to-fiber connection that exhibits the above losses?
   a. 6.5 dB
   b. 13.5 dB
   c. **26.5 dB**
   d. 53.0 dB

CMS AVAILABLE
None

FAULTS AVAILABLE
None
UNIT TEST

Location: Unit Test Page: sut1, Question ID: ut1
Which is the least important characteristic of a fiber-optic light source?
   a. color
   b. intensity
   c. bandwidth
   d. resistance

Location: Unit Test Page: sut2, Question ID: ut2
Which parameter is not used for a light source?
   a. radiometric
   b. photometric
   c. electrographic
   d. None of the above.

Location: Unit Test Page: sut3, Question ID: ut3
Which is not an important characteristic of a fiber-optic light source?
   a. power
   b. speed
   c. directivity
   d. None of the above.

Location: Unit Test Page: sut4, Question ID: ut4
The driver circuit controls FOT
   a. forward current.
   b. radiant power.
   c. switching speed.
   d. All of the above.

Location: Unit Test Page: sut5, Question ID: ut5
What does the rise and fall time of an output signal describe about its driver circuit?
   a. amplitude
   b. bandwidth
   c. power
   d. None of the above.
Location: Unit Test Page: sut6, Question ID: ut6
What techniques increase the switching speed of a digital driver circuit?
a. constant-peaking and pre-biasing 
**b. pre-biasing and current-peaking** 
c. constant-biasing and pre-peaking 
d. All of the above.

Location: Unit Test Page: sut7, Question ID: ut7
Which is not a component of a fiber-optic transmitter?
a. driver circuit 
b. light source 
c. source-to-fiber connection 
d. optical fiber

Location: Unit Test Page: sut8, Question ID: ut8
What is the UI loss of this source-to-fiber connection?
a. 0 dB 
b. 5 dB 
c. **10 dB** 
d. 15 dB

Location: Unit Test Page: sut9, Question ID: ut9
How would you determine the coupling loss at a source-to-fiber connection?
**a. add the UI, NA, R, and Finish losses** 
b. subtract the UI, NA, R, and Finish losses 
c. multiply the UI, NA, R, and Finish losses 
d. average the UI, NA, R, and Finish losses

Location: Unit Test Page: sut10, Question ID: ut10
What kind of coupling loss does this source-to-fiber connection illustrate?
**a. UI loss** 
b. NA loss 
c. R loss 
d. no loss
UNIT 4 – THE FIBER OPTIC RECEIVER

UNIT OBJECTIVE
Describe and demonstrate the parts of a fiber-optic receiver.

UNIT FUNDAMENTALS

Location: Unit Fundamentals page: sf5, Question ID: f5a
What do these light transducers have in common?
  a. both output light
  b. both have forward current gain
  c. both allow photocurrent
  d. both have a base to collector junction

CMS AVAILABLE
None

FAULTS AVAILABLE
None

NEW TERMS AND WORDS
PN - a semiconductor diode that uses two doped regions (positive-negative).
PIN - a semiconductor diode that uses an intrinsic (not doped) region between two doped regions (positive-intrinsic-negative).
transducer - a device that converts energy from one form to another.
effective light-sensitive area. - the light-sensitive area at the surface of the optical fiber end.
effective light-sensitive diameter - the diameter of the effective light-sensitive area.
responsivity (Rp) - the ratio of an optical input transducer's electrical output to the incident radiant power.
transimpedance amplifier - an active circuit intended to change the impedance of a signal.
noise floor - (noise equivalent power) the optical signal that would produce a signal-to-noise ratio of 0 dB.
differential amplifier - an active circuit whose output signal is proportional to the algebraic difference between the two input signals.
hysteresis - a small amount of positive feedback that provides stability.
EQUIPMENT REQUIRED
F.A.C.E.T. base unit
FIBER OPTIC COMMUNICATIONS circuit board
Multimeter
Oscilloscope, dual trace
Generator, sine wave
Exercise 1 – Light Detectors

EXERCISE DISCUSSION

Location: Exercise Discussion page: se1d2, Question ID: e1d2a
What type of transducers are used as fiber-optic light detectors?
  a. light emitting diodes
  b. phototransistors
  c. photodiodes
  d. Both b and c.

Location: Exercise Discussion page: se1d7, Question ID: e1d7a
What is the responsivity ($R_p$) of this phototransistor at 635 nm if the responsivity is 2 mA/µW at 880 nm (100%)?
  a. 4 mA/µW
  b. 2 mA/µW
  c. 1 mA/µW
  d. 0.5 mA/µW
EXERCISE PROCEDURE

Location: Exercise Procedure page: se1p3, Question ID: e1p3a
6. Measure the DC voltage (V\text{FOR}) at the FOR output.
\[ V_{\text{FOR}} = \text{mV} \]
Recall Label for this Question: a1
Nominal Answer: 650.0
Min/Max Value: (390) to (910)
Value Calculation: 650.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 40
Correct Plus Tolerance = 40

Location: Exercise Procedure page: se1p4, Question ID: e1p4a
7. Disconnect the fiber-optic cable from the FOR and measure the FOR output voltage (V\text{FOR}).
\[ V_{\text{FOR}} = \text{mV} \]
Recall Label for this Question: a2
Nominal Answer: 730.0
*Min/Max Value: (399.5) to (1139)
Value Calculation: (#a1#+80)
Correct Tolerance Percent = true
Correct Minus Tolerance = 15
Correct Plus Tolerance = 15

Location: Exercise Procedure page: se1p5, Question ID: e1p5a
\[ \Delta V = \text{mV} \]
Recall Label for this Question: a3
Nominal Answer: 80.0
*Min/Max Value: (-536) to (786.5)
Value Calculation: (#a2# - #a1#)
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure page: se1p6, Question ID: e1p6a

9. What are the NA and UI coupling losses at the fiber-to-detector connection?
   a. 14 dB
   b. 12 dB
   c. 0 dB
   d. -14 dB

Location: Exercise Procedure page: se1p7, Question ID: e1p7a

10. Assume that the actual FOT output power is near the typical value of 11.4 µW and calculate the receiver responsivity (Rp).

   \[ Rp = \frac{mV}{\mu W} \]

   Recall Label for this Question: a4
   Nominal Answer: 7.017
   *Min/Max Value: (-49.4) to (72.44)
   Value Calculation: \# a3 \#/11.4
   Correct Tolerance Percent = true
   Correct Minus Tolerance = 5
   Correct Plus Tolerance = 5

Location: Exercise Procedure page: se1p8, Question ID: e1p8a

11. Did you determine the actual FOR responsivity (Rp)?
   a. yes
   b. no

Location: Exercise Procedure page: se1p9, Question ID: e1p9a

\[ \Delta V_{(min)} = \text{mVdc} \]

Recall Label for this Question: a5
Nominal Answer: 25.5
Min/Max Value: (24.23) to (26.78)
Value Calculation: 25.500
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
Location: Exercise Procedure page: se1p10, Question ID: e1p10a

\[ V_{(max)} = \text{mVdc} \]

Recall Label for this Question: a6
Nominal Answer: 218.0
Min/Max Value: (207.1) to (228.9)
Value Calculation: 218.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Location: Exercise Procedure page: se1p11, Question ID: e1p11a

14. Is the observed value of \( \Delta V \) between \( \Delta V_{(min)} \) and \( \Delta V_{(max)} \)  ?
a. yes
b. no

Location: Exercise Procedure page: se1p12, Question ID: e1p12a

15. Is your observed value of \( V_{odc} \) consistent with the fiber-optic receiver specifications?
a. yes
b. no

Location: Exercise Procedure page: se1p14, Question ID: e1p14a

16. Calculate the typical noise floor (\( P_N \)) for this receiver.
\[ P_N = \mu W \]

Recall Label for this Question: a7
Nominal Answer: 0.043
Min/Max Value: (.041) to (.045)
Value Calculation: 0.043
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5
17. Calculate the typical receiver output voltage ($V_{\text{OUT}}$) when $\Phi_e$ is 55 $\mu$W.

$$V_{\text{OUT}} = \quad \text{mV}$$

Recall Label for this Question: a8
Nominal Answer: 315.0
Min/Max Value: (299.3) to (330.8)
Value Calculation: 315.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

22. What is the phase relationship between the FOR optical input and the electrical output?
   a. 0°
   b. 45°
   c. 90°
   d. 180°

24. Calculate the typical bandwidth for this receiver.

$$\text{BW} = \quad \text{MHz}$$

Recall Label for this Question: a9
Nominal Answer: 25.0
Min/Max Value: (23.75) to (26.25)
Value Calculation: 25.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Location: Exercise Procedure page: se1p21, Question ID: e1p21a

$$\text{BW} = \quad \text{MHz}$$

Recall Label for this Question: a10
Nominal Answer: 17.9
Min/Max Value: (17.01) to (18.8 )
Value Calculation: 17.900
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5
26. Is the input signal fall time (CH 1) similar to the corresponding receiver output rise time (CH 2)?
   a. yes
   b. no

28. Carefully measure the rise time of the signal displayed on CH 2.
   \( t_r = \) \hspace{0.5cm} ns
   
   Recall Label for this Question: a11
   Nominal Answer: 8000.0
   Min/Max Value: (3200) to (12800)
   Value Calculation: 8000.000
   Correct Tolerance Percent = true
   Correct Minus Tolerance = 60
   Correct Plus Tolerance = 60

29. Calculate the pulse width at the FOR output?
   a. 8 ns
   b. 6 ns
   c. 4 ns
   d. 2 ns
REVIEW QUESTIONS

Location: Review Questions page: se1r1, Question ID: e1r1

1. Using a light detector with an increased bandwidth
   a. decreases pulse width.
   b. increases fall time.
   c. decreases rise time.
   d. increases coupling loss.

Location: Review Questions page: se1r2, Question ID: e1r2

2. The fiber optic receiver (FOR) on the FIBER OPTIC COMMUNICATIONS circuit board
   a. uses a photodiode.
   b. converts photocurrent to voltage.
   c. has an inverting output.
   d. All of the above.

Location: Review Questions page: se1r3, Question ID: e1r3

3. Which is a measure of detector response to optical power?
   a. responsivity
   b. bandwidth
   c. equivalent optical noise input power
   d. equivalent diameter

Location: Review Questions page: se1r4, Question ID: e1r4

4. A phototransistor has an input power of 2 µW and a photocurrent of 20 mA. What is the
   transistor's responsivity?
   a. 10 mV/µW
   b. 10 mA/µW
   c. 0.1 mV/µW
   d. 0.1 mA/µW
5. What is the attenuation due to UI when a 100/140 µm glass fiber is coupled to an FOR with a 110 µm effective diameter?
   a. -2.1 dB
   b. 0 dB
   c. 0.83 dB
   d. 2.1 dB

CMS AVAILABLE
None

FAULTS AVAILABLE
None
Exercise 2 – Receiver Output Circuits

EXERCISE OBJECTIVE
Describe analog and digital circuits used to interface the light detector.

EXERCISE DISCUSSION

Location: Exercise Discussion page: se2d5, Question ID: e2d5a
Why do the analog and digital receiver output circuits invert?
  a. To cancel the FOR inversion.
  b. The system requires inverted signals.

EXERCISE PROCEDURE

Location: Exercise Procedure page: se2p3, Question ID: e2p3a
θ = °
Recall Label for this Question: b1
Nominal Answer: 180.0
Min/Max Value: (144) to (216)
Value Calculation: 180.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 20
Correct Plus Tolerance = 20

Location: Exercise Procedure page: se2p4, Question ID: e2p4a
6. Which capacitor passes the ac signal into the analog receiver output circuit?
  a. 47 µF
  b. 330 pF

Location: Exercise Procedure page: se2p6, Question ID: e2p6a
7. What is the dc bias voltage at the amplifier inputs?
  a. depends on the supply voltage
  b. same as the signal source (GEN)
  c. 0 Vdc
  d. None of the above.
Location: Exercise Procedure page: se2p7, Question ID: e2p7a

9. Is the amplifier output bias (CH 2) near 0 Vdc?
   a. yes
   b. no

Location: Exercise Procedure page: se2p8, Question ID: e2p8a

10. Reconnect the signal source (GEN) to R-IN and measure the amplifier voltage gain (Av), ignoring phase shift.
    Av =
    Recall Label for this Question: b2
    Nominal Answer: 20.0
    Min/Max Value: (16) to (24)
    Value Calculation: 20.000
    Correct Tolerance Percent = true
    Correct Minus Tolerance = 20
    Correct Plus Tolerance = 20

Location: Exercise Procedure page: se2p12, Question ID: e2p12a

14. Measure the high logic voltage level at DATA OUT (CH 2).
    DATA OUT = V
    Recall Label for this Question: b4
    Nominal Answer: 3.5
    Min/Max Value: (2.1) to (4.9)
    Value Calculation: 3.500
    Correct Tolerance Percent = true
    Correct Minus Tolerance = 40
    Correct Plus Tolerance = 40

Location: Exercise Procedure page: se2p13, Question ID: e2p13a

15. Measure the low logic voltage level at DATA OUT (CH 2).
    DATA OUT = V
    Recall Label for this Question: b5
    Nominal Answer: 0.25
    Min/Max Value: (0) to (0.5)
    Value Calculation: 0.250
    Correct Tolerance Percent = true
    Correct Minus Tolerance = 100
    Correct Plus Tolerance = 100
18. Use the voltage divider formula to calculate the voltage at the comparator noninverting input \((V_{IN+})\).
\[
V_{IN+} = \frac{62.5 \times \text{#b5#}}{\text{mV}}
\]
Recall Label for this Question: b6
Nominal Answer: 15.63
*Min/Max Value: (0) to (32.81)
Value Calculation: (62.5* # b5 #)
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

19. Calculate the voltage at the inverting comparator input \((V_{IN-})\).
\[
V_{IN-} = \frac{62.5 \times \text{#b4#}}{\text{mV}}
\]
Recall Label for this Question: b7
Nominal Answer: 218.8
*Min/Max Value: (124.7) to (321.6)
Value Calculation: (62.5 * # b4 #)
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

20. Calculate the comparator differential input voltage.
\[
V_{DIFF} = \frac{(\text{# b6#} - \text{# b7#})}{\text{mV}}
\]
Recall Label for this Question: b8
Nominal Answer: -203.0
*Min/Max Value: (-338) to (-96.5)
Value Calculation: (# b6 # - # b7 #)
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
21. Use a DVM and measure $V_{\text{DIFF}}$ at the 1 kΩ resistors.

$V_{\text{DIFF}} = \text{mV}$

Recall Label for this Question: b9

Nominal Answer: -203.0

*Min/Max Value: (-406) to (-116)

Value Calculation: # b8 #

Correct Tolerance Percent = true

Correct Minus Tolerance = 20

Correct Plus Tolerance = 20

22. Will the dc feedback voltage ($V_{\text{DIFF}}$) change in the same direction as the comparator output voltage?

a. yes

b. no

23. Why does the non-inverting preamp output drive the inverting comparator input?

a. provide hysteresis

b. increase the dc levels

c. to invert the comparator output levels

24. ∆$V_{\text{IN}}$ = \text{mV}

Recall Label for this Question: b10

Nominal Answer: 1.015

*Min/Max Value: (0.458) to (1.775)

Value Calculation: $((-1\times # b8 #) / 200)$

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
Location: Exercise Procedure page: se2p27, Question ID: e2p27a

\[ V_{\text{DIFF}} = V \]

Recall Label for this Question: b11

**Nominal Answer:** 20.0

*Min/Max Value: (19) to (21)

Value Calculation: 20.000  
Correct Tolerance Percent = true  
Correct Minus Tolerance = 5  
Correct Plus Tolerance = 5

Location: Exercise Procedure page: se2p28, Question ID: e2p28a

28. Is the actual \( V_{\text{DIFF}} \) (CH 2) greater than the \# (\(-1 \times b8\)) \# mV required to switch the comparator output state?
   - a. yes
   - b. no

Location: Exercise Procedure page: se2p30, Question ID: e2p30a

30. Is the clipping at the preamplifier output (CH 2) adversely affecting the digital receiver output circuit operation?
   - a. yes
   - b. no

**REVIEW QUESTIONS**

Location: Review Questions page: se2r1, Question ID: e2r1

1. Which components set the upper cutoff frequency of this analog output circuit?
   - a. 2.2 k\(\Omega\) and 47 \(\mu\)F  
   - b. 100\(\Omega\) and 47 \(\mu\)F  
   - c. 5 k\(\Omega\) and 330 \(\mu\)F  
   - d. 100\(\Omega\) and 2.2 k\(\Omega\) and 330 \(\mu\)F

Location: Review Questions page: se2r2, Question ID: e2r2

2. Why is the analog receiver output circuit gain adjustable?
   - a. improve the receiver noise performance
   - b. correct for system power losses
   - c. insure compatible 7400 series logic levels
   - d. increase \(\Phi_e\)

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Review Questions page: se2r3, Question ID: e2r3
3. What are the 15 kΩ resistors for?
   a. reduce comparator gain
   b. negative feedback
   c. hysteresis
   d. ac coupling

Location: Review Questions page: se2r4, Question ID: e2r4
4. What is the purpose of the MC1733 amplifier?
   a. provide hysteresis
   b. reduce noise
   c. improve sensitivity
   d. None of the above.

Location: Review Questions page: se2r5, Question ID: e2r5
5. What is the purpose of a receiver output circuit?
   a. provide system-compatible output
   b. convert optical signals to electrical signals
   c. convert electrical signals to optical signals
   d. provide adjustable gain

CMS AVAILABLE
None

FAULTS AVAILABLE
None
UNIT TEST

Location: Unit Test Question page: sut1, Question ID: ut1
In a fiber optic receiver the light detector
a. is a pulse detector.
b. cannot have coupling losses.
c. has an optical output.
d. has an electrical output signal.

Location: Unit Test Question page: sut2, Question ID: ut2
A photodiode has an input power of 5 µW and a photo current of 25 mA. What is the diode's responsivity?
a. 125 mA·µW 
b. 20 mA·µW 
c. 5 mA/µW 
d. 0.2 µW/mA

Location: Unit Test Question page: sut3, Question ID: ut3
Decreasing the bandwidth of the light detector
a. decreases pulse width.
b. increases fall time.
c. decreases rise time.
d. increases coupling loss.

Location: Unit Test Question page: sut4, Question ID: ut4
Calculate the maximum noise floor (P_N) for this receiver.
a. 0.04 µW 
b. 0.05 µW 
c. 0.07 µW 
d. 0.09 µW

Location: Unit Test Question page: sut5, Question ID: ut5
What is the UI loss when an optical fiber with a 980 µm core diameter is coupled to this light detector?
a. 11.9 dB 
b. 5.9 dB 
c. 1.2 dB 
d. 0 dB
Location: Unit Test Question page: sut6, Question ID: ut6
What is the purpose of a receiver output circuit?
- a. provide system compatible output
- b. match impedance
- c. provide compatible voltage levels
- d. All of the above.

Location: Unit Test Question page: sut7, Question ID: ut7
Ac coupling in a digital receiver output circuit
- a. prevents pulse detection.
- b. limits high frequency response.
- c. removes dc drift.
- d. All of the above.

Location: Unit Test Question page: sut8, Question ID: ut8
In a digital receiver output circuit, the preamplifier
- a. has a series 7400 compatible output.
- b. increases sensitivity.
- c. increases the hysteresis voltage.
- d. uses positive feedback.

Location: Unit Test Question page: sut9, Question ID: ut9
The voltage comparator in a digital receiver output circuit
- a. has a digital output.
- b. uses positive feedback.
- c. provides hysteresis.
- d. All of the above.

Location: Unit Test Question page: sut10, Question ID: ut10
Why are RC filters used at the input to the analog and digital receiver output circuits?
- a. hysteresis
- b. reduce noise
- c. increase bandwidth
- d. increase gain
UNIT 5 – FIBER-OPTIC SYSTEMS

UNIT OBJECTIVE

Explain and demonstrate tests and measurements performed on fiber-optic systems and an optical power budget for a fiber-optic link. Verify results by using an oscilloscope, voltmeter, and visual observations.

UNIT FUNDAMENTALS

Location: Unit Fundamentals Page: sf5, Question ID: f5a
What adjustments can you make to help keep the system within budget?
   a. increase transmitter power
   b. choose a receiver with better sensitivity
   c. eliminate some cables or connectors from the link
   d. All of the above.

Location: Unit Fundamentals Page: sf7, Question ID: f7a

\[ t_{\text{tr(trans)}} = \text{ns} \]

Recall Label for this Question:
Nominal Answer: 14.25
*Min/Max Value: (13.97) to (14.54)
Value Calculation: 14.250
Correct Tolerance Percent = true
Correct Minus Tolerance = -2
Correct Plus Tolerance = 2

CMS AVAILABLE
None

FAULTS AVAILABLE
None

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
NEW TERMS AND WORDS

optical power budget - the difference between the minimum transmitter power (PTmin) and the input power required for a LOW output voltage (PR(L)): OPB = PTmin - PR(L)min.

optical power margin (OPM) - the difference between the transmitter optical power, less system losses, and the receiver sensitivity.

rise time budget - a budget that ensures that the rise times of all components in a fiber optic link meet the bandwidth requirements of the application.

EQUIPMENT REQUIRED

F.A.C.E.T. base unit
FIBER-OPTIC circuit board
Multimeter
Oscilloscope, dual trace
Generator, sine wave
Exercise 1 – Optical Power Budget

EXERCISE OBJECTIVE
Explain an optical power budget applied to a fiber-optic link on the circuit board. Verify results by using an oscilloscope and visual observations.

EXERCISE DISCUSSION

Location: Exercise Discussion Page: se1d3, Question ID: e1d3a
What can account for losses at a connection point?
   a. NA mismatch
   b. area mismatch
   c. connector mechanics
   d. All of the above.

Location: Exercise Discussion Page: se1d6, Question ID: e1d6a
OPM = dB
Recall Label for this Question:
Nominal Answer: 5.0
Min/Max Value: (5) to (5)
Value Calculation: 5.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 0
Correct Plus Tolerance = 0

Location: Exercise Discussion Page: se1d6, Question ID: e1d6c
What does your calculated margin of 5 dB indicate?
   a. The system has exceeded the optical power budget.
   b. The system is within the optical power budget.
EXERCISE PROCEDURE

Location: Exercise Procedure Page: se1p4, Question ID: e1p4a

\[ f_{CLK} = \text{MHz} \]

Recall Label for this Question:
Nominal Answer: 1.0
Min/Max Value: (0.8) to (1.2)
Value Calculation: 1.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 20
Correct Plus Tolerance = 20

Location: Exercise Procedure Page: se1p7, Question ID: e1p7a

sensitivity(dBm) = dBm

Recall Label for this Question:
Nominal Answer: -29.3
Min/Max Value: (-29.3) to (-29.3)
Value Calculation: -29.300
Correct Tolerance Percent = true
Correct Minus Tolerance = 0
Correct Plus Tolerance = 0

Location: Exercise Procedure Page: se1p7, Question ID: e1p7c

sensitivity(\(\mu\)W) = \(\mu\)W

Recall Label for this Question:
Nominal Answer: 1.175
Min/Max Value: (1.116) to (1.234)
Value Calculation: 1.175
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se1p9, Question ID: e1p9a

9. Transmitter output power is given for forward currents of 60 and 100 mA. What is the minimum power output in dBm for a 60 mA drive current?
   a. -14
   b. -16.0
   c. -17.5
   d. -19.0
Location: Exercise Procedure Page: se1p9, Question ID: e1p9c

\[ P_{\text{min}}(60 \text{ mA}) = \quad \mu \text{W} \]

Recall Label for this Question:

**Nominal Answer: 12.59**

- Min/Max Value: (11.96) to (13.22)
- Value Calculation: 12.590
- Correct Tolerance Percent = true
- Correct Minus Tolerance = 5
- Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se1p9, Question ID: e1p9e

\[ P_{\text{min}}(35 \text{ mA}) = \quad \mu \text{W} \]

Recall Label for this Question:

**Nominal Answer: 7.34**

- Min/Max Value: (6.973) to (7.707)
- Value Calculation: 7.340
- Correct Tolerance Percent = true
- Correct Minus Tolerance = 5
- Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se1p10, Question ID: e1p10a

\[ P_{\text{min}}(35 \text{ mA}) = \quad \text{dBm} \]

Recall Label for this Question:

**Nominal Answer: -21.3**

- Min/Max Value: (-22.365) to (-20.235)
- Value Calculation: -21.300
- Correct Tolerance Percent = true
- Correct Minus Tolerance = 5
- Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se1p12, Question ID: e1p12a

13. The receiver has an optical port diameter of 250 µm. There is no optical power loss due to area mismatch because the light flows from a

a. smaller to a larger diameter.

b. larger to a smaller diameter.
Location: Exercise Procedure Page: se1p14, Question ID: e1p14a

OPM =   dB

Recall Label for this Question:
Nominal Answer: 4.0
Min/Max Value: (4) to (4)
Value Calculation: 4.000
Correct Tolerance Percent =  true
Correct Minus Tolerance =  0
Correct Plus Tolerance =  0

Location: Exercise Procedure Page: se1p14, Question ID: e1p14c

15. If the glass fiber attenuation is 3 dB/km, what length results in a 3 dB loss?
L_max =   km

Recall Label for this Question:
Nominal Answer: 1.0
Min/Max Value: (0.95) to (1.05)
Value Calculation: 1.000
Correct Tolerance Percent =  true
Correct Minus Tolerance =  5
Correct Plus Tolerance =  5

Location: Exercise Procedure Page: se1p17, Question ID: e1p17a

VO(max) =   mV

Recall Label for this Question:
Nominal Answer: 228.8
Min/Max Value: (217.4) to (240.2)
Value Calculation: 228.800
Correct Tolerance Percent =  true
Correct Minus Tolerance =  5
Correct Plus Tolerance =  5

Location: Exercise Procedure Page: se1p19, Question ID: e1p19a

18. Measure the output voltage.
VO =   mVpk-pk

Recall Label for this Question: v1
Nominal Answer: 130.0
Min/Max Value: (32.5) to (227.5)
Value Calculation: 130.000
Correct Tolerance Percent =  true
Correct Minus Tolerance =  75
Correct Plus Tolerance =  75
19. Is your measured value of \(v_1\) mV within the specified minimum and maximum values?
   a. yes
   b. no

**Location: Exercise Procedure Page: se1p20, Question ID: e1p20a**

**Location: Exercise Procedure Page: se1p21, Question ID: e1p21a**

\[
\text{OPM(min)} = 10 \times \log\left[\frac{V_o(\text{min})}{\text{sensitivity(mV)}}\right] = \text{dBm}
\]

Recall Label for this Question:

**Nominal Answer: 7.2**

Min/Max Value: (6.84) to (7.56)

Value Calculation: 7.200

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

**Location: Exercise Procedure Page: se1p21, Question ID: e1p21c**

\[
\text{OPM(measured)} = \text{dB}
\]

Recall Label for this Question: \(m1\)

**Nominal Answer: 11.013**

*Min/Max Value: (4.756) to (14.115)

Value Calculation: \(10 \times \log \left( \frac{#v_1#}{5.16} \right) - 3\)

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

**Location: Exercise Procedure Page: se1p21, Question ID: e1p21e**

22. What can you conclude from the actual margin (#\(m1\)# dB)?
   a. The system is within the optical power budget.
   b. The system has exceeded the optical power budget.

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
24. Measure the receiver output voltage.

\[ V_O = mV_{pk-pk} \]

Recall Label for this Question: v2

**Nominal Answer: 100.0**

Min/Max Value: (25) to (175)

Value Calculation: 100.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 75

Correct Plus Tolerance = 75

\[ \Delta P(dB) = 10 \times \log\left[ \frac{V_O(1 \ mg)}{V_O(1 \ mg + 5 \ mg)} \right] \]

\[ = dB \]

Recall Label for this Question: d1

**Nominal Answer: 1.139**

*Min/Max Value: (-6.946) to (10.069)*

Value Calculation: \( 10 \times \log \left( \frac{\# \ v1 \ #}{\# \ v2 \ #} \right) \)

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

26. The \# d1 \# dBm power loss you calculated is due to the addition of the 5m glass cable and the optical coupler. Which of these accounts for more power loss?

a. connector

b. fiber

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
27. If the cable attenuation is 3 dB/km, what length of glass cable results in a loss of # (m - 1) dBm?

\[ L_{(\text{max})} = \text{km} \]

Recall Label for this Question: c1
Nominal Answer: 3.338
*Min/Max Value: (1.189) to (4.591)
Value Calculation: (m - 1)/3
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Vo = mV pk-pk

Recall Label for this Question: v3
Nominal Answer: 5.0
Min/Max Value: (1.25) to (8.75)
Value Calculation: 5.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 75
Correct Plus Tolerance = 75

\[ \Delta P(\text{dB}) = 10 \times \log \left[ \frac{V_0(1 \text{mg})}{V_0(1 \text{mg} + 1 \text{mp})} \right] \]

\[ = \text{dB} \]

Recall Label for this Question: d2
Nominal Answer: 14.15
*Min/Max Value: (5.414) to (23.731)
Value Calculation: 10 * \log (\# v1 \#/\# v3 \#)
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se1p32, Question ID: e1p32a

\[
\text{loss}_{\text{fiber}} = \text{dB}
\]

Recall Label for this Question:

**Nominal Answer: 0.2**

Min/Max Value: (0.2) to (0.2)

Value Calculation: 0.200

Correct Tolerance Percent = true

Correct Minus Tolerance = 0

Correct Plus Tolerance = 0

---

Location: Exercise Procedure Page: se1p33, Question ID: e1p33a

32. Compare the NA and diameter values of the plastic fiber and the receiver. Which would result in a greater power loss?

a. area mismatch

b. NA mismatch

---

**REVIEW QUESTIONS**

Location: Review Questions Page: se1r1, Question ID: e1r1

1. To determine a system power budget, you must account for all optical power loss from
   
a. connectors.
b. fiber attenuation.
c. NA and area mismatches.
d. **All of the above.**

Location: Review Questions Page: se1r2, Question ID: e1r2

2. The optical power margin is the difference between available transmitter power after losses and the
   
a. receiver responsivity.
b. **receiver sensitivity.**
c. transmitter LED degradation.
d. fiber-to-detector mismatch loss.

Location: Review Questions Page: se1r3, Question ID: e1r3

3. What does a designer use to ensure that the components of a fiber-optic system operate fast enough to meet the bandwidth requirements of an application?
   
a. Ohm's law
b. optical power budget
c. frequency budget
d. **rise time budget**
Location: Review Questions Page: se1r4, Question ID: e1r4

4. A fiber-optic transmitter is connected to a receiver with a 1500m length of glass cable terminated at both ends with an ST connector. What is the optical power margin?
   a. 2.8 dB
   b. 9 dB
   c. 12 dB
   d. 11.5 dB

Location: Review Questions Page: se1r5, Question ID: e1r5

5. A fiber-optic system has an optical power margin of 16 dB. What is the maximum length of plastic optical fiber that can be added before the receiver sensitivity is reached? [NOTE: Assume that no connectors are added.]
   a. 80m
   b. 80 km
   c. 12.5 km
   d. Cannot be determined.

CMS AVAILABLE
None

FAULTS AVAILABLE
None
**Exercise 2 – Fiber-Optic Equipment**

**EXERCISE OBJECTIVE**
Describe the test equipment and techniques used to service fiber-optic systems.

**EXERCISE DISCUSSION**

*Location: Exercise Discussion Page: se2d5, Question ID: e2d5a*
How much light power is propagating through this cable?
- a. -20.2 µW
- b. -20.2 dBm
- c. None of the above.

*Location: Exercise Discussion Page: se2d9, Question ID: e2d9a*
How far along the cable is the connection that caused the indicated Fresnel reflection?
- a. 35 km
- b. 3.5 km
- c. 3.5 µs
- d. None of the above.

*Location: Exercise Discussion Page: se2d11, Question ID: e2d11a*
What is the fiber attenuation of this length of cable?
- a. 2 dB/km
- b. 1 dB/km
- c. 0.5 dB/km
- d. None of the above.
EXERCISE PROCEDURE

Location: Exercise Procedure Page: se2p3, Question ID: e2p3a
4. How can you verify that the 5m glass optical cable is within specification?
   a. Measure the cable output with an optical power meter.
   b. Use a fiber-optic light source and power meter to test the cable.
   c. Replace the FOT with a fiber-optic light source.

Location: Exercise Procedure Page: se2p5, Question ID: e2p5a
6. What is the optical power measurement displayed on the DVM?
   1m = \( V \)
   Recall Label for this Question: b1
   **Nominal Answer: 1.3**
   Min/Max Value: (0.13) to (2.47)
   Value Calculation: 1.300
   Correct Tolerance Percent = true
   Correct Minus Tolerance = 90
   Correct Plus Tolerance = 90

Location: Exercise Procedure Page: se2p7, Question ID: e2p7a
8. What is the relative optical power displayed on the DVM?
   1m5m = \( V \)
   Recall Label for this Question: b2
   **Nominal Answer: 1.105**
   *Min/Max Value: (.083) to (2.624)
   Value Calculation: \# b1 - ( b1 * .15 ) \#
   Correct Tolerance Percent = true
   Correct Minus Tolerance = 25
   Correct Plus Tolerance = 25

*NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.*
Location: Exercise Procedure Page: se2p9, Question ID: e2p9a

\[ \text{loss} = \quad \text{dB} \]

Recall Label for this Question: b3

**Nominal Answer: 0.705**

*Min/Max Value: (-12.397) to (15.473)*

Value Calculation: \( 10 \times \log \left( \frac{b1}{b2} \right) \)

Correct Tolerance Percent = true

Correct Minus Tolerance = 5

Correct Plus Tolerance = 5

---

Location: Exercise Procedure Page: se2p12, Question ID: e2p12a

11. Use the phototransistor to measure the relative power at the end of the 1m glass cable.

\[ 1m = \quad \text{mV} \]

Recall Label for this Question: b4

**Nominal Answer: 500.0**

Min/Max Value: (50) to (950)

Value Calculation: 500.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 90

Correct Plus Tolerance = 90

---

Location: Exercise Procedure Page: se2p14, Question ID: e2p14a

13. Use a DVM to measure the voltage between FOR and ground.

\[ 5m = \quad \text{mV} \]

Recall Label for this Question: b5

**Nominal Answer: 650.0**

Min/Max Value: (455) to (845)

Value Calculation: 650.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 30

Correct Plus Tolerance = 30

---

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se2p15, Question ID: e2p15a

14. Disconnect the 5m glass cable from the FIBER OPTIC TRANSMITTER and measure the voltage between FOR and GND.

0m = mV

Recall Label for this Question: b6

Nominal Answer: 700.0

Min/Max Value: (560) to (840)

Value Calculation: 700.000

Correct Tolerance Percent = true

Correct Minus Tolerance = 20

Correct Plus Tolerance = 20

REVIEW QUESTIONS

Location: Review Questions Page: se2r1, Question ID: e2r1

1. What equipment will indicate the distance to a faulty fiber-optic connection?
   a. fiber-optic light source
   b. fiber-optic power meter
   c. optical time-domain reflectometer
   d. digital volt meter

Location: Review Questions Page: se2r2, Question ID: e2r2

2. Which would you use to test a fiber-optic transmitter?
   a. fiber-optic light source
   [ b. fiber-optic power meter ]
   c. optical time-domain reflectometer
   d. ammeter

Location: Review Questions Page: se2r3, Question ID: e2r3

3. Fiber-optic power meters are usually calibrated in
   a. microwatts.
   b. dBm.
   c. volts.
   d. a or b.

Location: Review Questions Page: se2r4, Question ID: e2r4

What is the loss of the 1 km cable?
   a. 20 dB
   b. 15 dB
   c. 5 dB
   d. None of the above.
Location: Review Questions Page: se2r5, Question ID: e2r5

What is the likely cause?

a. the source-to-fiber connection
b. a connector at 1.5 km
c. a break in the cable at 3 km
d. None of the above.

CMS AVAILABLE
None

FAULTS AVAILABLE
None
UNIT TEST

Location:  Unit Test Page: sut1, Question ID: ut1
Which of the following does not affect an optical power budget?
- a. LED degradation
- b. fiber attenuation
- c. fiber bandwidth
- d. receiver sensitivity

Location:  Unit Test Page: sut2, Question ID: ut2
Two fiber-optic cables are connected between a transmitter and receiver to form a link as shown. At which connection point do NA and area mismatch losses occur?
- a. source-to-fiber
- b. fiber-to-fiber
- c. fiber-to-detector
- d. None of the above.

Location:  Unit Test Page: sut3, Question ID: ut3
In a fiber-optic system, responsivity is a parameter of the
- a. receiver.
- b. transmitter.
- c. cable.
- d. connectors.

Location:  Unit Test Page: sut4, Question ID: ut4
What is a typical power loss budgeted for a fiber-optic connector?
- a. 0.1 dB
- b. 1 dB
- c. 10 dB
- d. 100 dB

Location:  Unit Test Page: sut5, Question ID: ut5
What units are typically used in calculating an optical power budget?
- a. mW
- b. µW
- c. mV
- d. dB
Location: Unit Test Page: sut6, Question ID: ut6

A fiber-optic system has an optical power margin of 6 dB. What added to the system would cause the margin to be exceeded?

a. three connectors  
b. 50m of plastic fiber  
c. 1500m of glass fiber  
d. None of the above.

Location: Unit Test Page: sut7, Question ID: ut7

What is the loss of the 1 km cable?

a. 8 dB  
b. 10 dB  
c. 18 dB  
d. None of the above.

Location: Unit Test Page: sut8, Question ID: ut8

An OTDR can be used to

a. measure reflections.  
b. determine distance.  
c. evaluate fiber loss.  
d. All of the above.

Location: Unit Test Page: sut9, Question ID: ut9

Which fiber-optic test equipment would you use to test a fiber-optic receiver?

a. light source  
b. power meter  
c. optical time-domain reflectometer  
d. All of the above.

Location: Unit Test Page: sut10, Question ID: ut10

What is the likely cause?

a. the fiber-optic receiver  
b. the connector at 1.5 km  
c. a break at 2 km  
d. a break at 4 km
UNIT 6 – FIBER OPTIC COMMUNICATION SYSTEMS

UNIT OBJECTIVE
Describe and demonstrate fiber-optic communication links.

UNIT FUNDAMENTALS
There are no questions for this section.

CMS AVAILABLE
None

FAULTS AVAILABLE
None

NEW TERMS AND WORDS:
composite video signal - a baseband signal that contains color picture and sync information.
National Television System Committee (NTSC) - An American organization of television standards.
cutoff frequency - the frequency at which the output amplitude of a filter circuit is attenuated to its half-power point (-3dB).
EIA - (Electronic Industries Association) An American organization of electronics standards.
time-division multiplexing (TDM) - a method of transmitting many digital message signals over the same line by assigning time slots that are synchronized on the transmitting and receiving ends.
simplex cable - a type of fiber-optic cable that contains only one optical fiber.
field-programmable gate array (FPGA) - a high-density integrated-circuit (IC) that can be user-configured to create a custom IC with user-defined logic functions.
duplex cable - a type of fiber-optic cable that contains two optical fibers.
manchester-encoded - a method of biphase line coding where data bits are combined with the bit clock through an exclusive-OR (XOR) function. Manchester encoding produces a signal transition during each bit time.
sync-encrypted - (Sync-encoded) a signal that is encoded with synchronization information.
EQUIPMENT REQUIRED
F.A.C.E.T. base unit
FIBER OPTIC COMMUNICATIONS circuit board
Multimeter
Oscilloscope, dual trace
Generator, sine wave
Exercise 1 – Analog Communications

EXERCISE OBJECTIVE
Describe and demonstrate the important characteristics of an analog fiber-optic link.

EXERCISE DISCUSSION

Location: Exercise Discussion Page: se1d4, Question ID: e1d4a
The total bandwidth required for the combined video and audio signals is equal to
a. 4.500 MHz.
b. 4.525 MHz.
c. 4.200 MHz.

Location: Exercise Discussion Page: se1d5, Question ID: e1d5a
For optimum video signal transfer, input impedance of the fiber-optic transmitter should be
a. 50Ω.
b. infinite.
c. 75Ω.

Location: Exercise Discussion Page: se1d7, Question ID: e1d7a
length = km
Recall Label for this Question: f8
Nominal Answer: 5.56
Min/Max Value: (5.282) to (5.838)
Value Calculation: 5.560
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Location: Exercise Discussion Page: se1d8, Question ID: e1d8a
Why is the fiber-optic receiver passband limited to 5 MHz?
a. the fiber cable reduces the bandwidth to 5 MHz
b. to increase the signal-to-noise (S/N) ratio at the output of the receiver.
c. to decrease the signal-to-noise (S/N) ratio at the output of the receiver
EXERCISE PROCEDURE

Location: Exercise Procedure Page: se1p5, Question ID: e1p5a
10. In this fiber-optic link, which type of coupling is used at the inputs of amplifiers U1 and U5?
   a. direct coupling
   b. ac coupling

Location: Exercise Procedure Page: se1p6, Question ID: e1p6a
\[ f_{1t} = \frac{1}{2\pi R_2 C_1} \times 0.8 \]

Recall Label for this Question: \( f_1 \)
Nominal Answer: 26.6
Min/Max Value: (25.27) to (27.93)
Value Calculation: 26.600
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se1p7, Question ID: e1p7a
\[ f_{1r} = \frac{1}{2\pi (R_7 + R_8) C_4} \]

Recall Label for this Question: \( f_2 \)
Nominal Answer: 1.47
Min/Max Value: (1.397) to (1.544)
Value Calculation: 1.470
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5
Location: Exercise Procedure Page: se1p8, Question ID: e1p8a

\[ f_{\text{mea}} = \text{Hz} \]

Recall Label for this Question: f3
Nominal Answer: 32.0
Min/Max Value: (19.2) to (44.8)
Value Calculation: 32.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 40
Correct Plus Tolerance = 40

Location: Exercise Procedure Page: se1p9, Question ID: e1p9a

15. Which high-pass coupling circuit determines the lower cutoff frequency \( f_1 \) of this fiber-optic communications link?
   a. ANALOG TRANSMITTER
   b. ANALOG RECEIVER

Location: Exercise Procedure Page: se1p11, Question ID: e1p11a

\[ f_2 = \frac{1}{2\pi \times C_5 \times R_7 \parallel R_8} \]

\[ f_2 = \text{MHz} \]

Recall Label for this Question: f4
Nominal Answer: 5.04
Min/Max Value: (4.788) to (5.292)
Value Calculation: 5.040
Correct Tolerance Percent = true
Correct Minus Tolerance = 5
Correct Plus Tolerance = 5

Location: Exercise Procedure Page: se1p12, Question ID: e1p12a

18. Why is a low-pass filter added to limit the high cutoff frequency \( f_2 \) to \# f_4 \# MHz?
   a. to reduce the noise appearing at the output of the receiver
   b. increase the low cutoff frequency \( f_1 \)
   c. to increase the overall bandwidth
19. Does the output signal waveform follow the shape of the 200 kHz, 1 V pk-pk input sine wave?
   a. yes
   b. no

24. Can you hear the results of your action in the speaker?
   a. yes
   b. no

VMIC OUT = V pk-pk
Recall Label for this Question: f5
Nominal Answer: 2.0
Min/Max Value: (1.4) to (2.6)
Value Calculation: 2.000
Correct Tolerance Percent = true
Correct Minus Tolerance = 30
Correct Plus Tolerance = 30

Gain =
Recall Label for this Question: f6
Nominal Answer: 200.0
*Min/Max Value: (126) to (286)
Value Calculation: # f5 # /0.01
Correct Tolerance Percent = true
Correct Minus Tolerance = 10
Correct Plus Tolerance = 10

* NOTE: Min/Max Values shown are based upon a calculation using the absolute lowest and highest recall value. By using the actual input in your calculations, you will determine the correct value.
Location: Exercise Procedure Page: se1p23, Question ID: e1p23a
33. What is the voltage gain of U7?
   a. 20
   b. 200

Location: Exercise Procedure Page: se1p24, Question ID: e1p24a
35. Does the output signal waveform follow the shape of the 1 kHz, 1 Vpk-pk input sine wave?
   a. yes
   b. no

REVIEW QUESTIONS

Location: Review Questions Page: se1r1, Question ID: e1r1
1. In this fiber-optic communication link, which input coupling circuit determines the low frequency cutoff?
   a. C5,R8
   b. C1,R2 and C2,R3
   c. C3,R6
   d. C4,R7 and R8

Location: Review Questions Page: se1r2, Question ID: e1r2
2. What is the maximum fiber length that would insure less than 8 dB of attenuation?
   a. 2.75 km
   b. 4.44 km
   c. 8.69 km
   d. not enough information given

Location: Review Questions Page: se1r3, Question ID: e1r3
3. For optimum video coupling, the input impedance of the FOR should be
   a. very small.
   b. 50Ω.
   c. 75Ω.
   d. very large.
4. To increase the gain of this audio fiber-optic link
   a. remove C8 from U6
   b. add a capacitor between pin 5 and common on U7.
   c. reduce the value of C12.
   d. add a capacitor between pin 1 and 8 on U7.

5. In this fiber-optic link, a 5 MHz signal arriving at the input of the scope is phase shifted by the
   a. 10 meter glass optical fiber (200 MHzkm).
   b. transmitter's high-pass filter.
   c. receiver's low-pass filter.
   d. coax cable.

CMS AVAILABLE
None

FAULTS AVAILABLE
None
**Exercise 2 – Digital Communications**

**EXERCISE OBJECTIVE**
Describe and demonstrate a digital fiber-optic link using a time-division Manchester-encoded RS-232 digital signal.

**EXERCISE DISCUSSION**

Location: Exercise Discussion Page: se2d10, Question ID: e2d10a
What is the frequency of the CLK signal?
- a. 8 MHz
- b. 4 MHz
- c. 2 MHz
- d. 1 MHz

Location: Exercise Discussion Page: se2d23, Question ID: e2d23a
What will the receiver output be if the RS-232 input is unterminated (open-circuit)?
- a. LOW
- b. HIGH

**EXERCISE PROCEDURE**

Location: Exercise Procedure Page: se2p3, Question ID: e2p3a
5. What is the logic level of the #TX line?
- a. LOW
- b. HIGH

Location: Exercise Procedure Page: se2p5, Question ID: e2p5a
11. What time slot (or channel) is at a logic LOW?
- a. 1
- b. 2
- c. 3
- d. 4
9. Does each centimeter on your scope graticule represent a full bit-time?
   a. yes
   b. no

13. Observe the TDATA signal on CH 1 of your scope. What is the data at time slot 1 (TS1)?
   a. 0
   b. 1

14. What is the data at TS2?
   a. 0
   b. 1

15. What is the data at TS3?
   a. 0
   b. 1

16. What is the data at TS4?
   a. 0
   b. 1

20. Is the recovered clock signal (RECCLK) identical to the original clock signal (CLK)?
   a. yes
   b. no

21. Does the RECSYNC pulse occur every fourth time slot (TS1)?
   a. yes
   b. no
25. Observe the received Manchester-encoded data signal (RDATA) on your scope. What is the data on MUX channel 2 (TS2)?
   a. 0
   b. 1

27. Observe the demodulated, multiplexed data signal (DEMOD) on your scope. What is the data on MUX channel 2 (TS2)?
   a. 0
   b. 1

28. What signal from the demultiplexer (DEMUX) should be LOW?
   a. TX
   b. #TX
   c. RX
   d. #RX

30. Is the #RX signal LOW?
   a. yes
   b. no

32. Are you receiving the logic HIGH at #RX now?
   a. yes
   b. no
REVIEW QUESTIONS

1. What original signal is identical to the received DEMOD signal?
   a. TDATA
   b. SYNC
   c. CLK
   d. MNRZ

2. Manchester-encoded data is present at the
   a. reference edge of the clock.
   b. first half of each bit-time.
   c. second half of each bit-time.
   d. end of each bit-time.

3. What technique is used to keep track of the first channel in a multiplexed, Manchester-encoded fiber-optic signal?
   a. TDM
   b. Manchester-encoding
   c. sync-encryption
   d. None of the above.

4. Why is Manchester-encoding used for transmitting data in a digital fiber-optic communication link?
   a. to send data and timing information
   b. to send synchronization information
   c. to convert logic levels
   d. to provide a more power
Location: Review Questions Page: se2r5, Question ID: e2r5

5. Why is time-division multiplexing used for transmitting data in a digital fiber-optic communication link?
   a. to send synchronization information
   b. to convert logic levels
   c. to provide a reference
   d. to send multiple signals

CMS AVAILABLE
None

FAULTS AVAILABLE
None
UNIT TEST

Location: Unit Test Page: sut1, Question ID: ut1
The passband of a wide-band analog fiber-optic receiver is limited in order to
a. amplify the signal.
b. increase the S/N ratio.
c. improve bandwidth.
d. amplify noise.

Location: Unit Test Page: sut2, Question ID: ut2
What signal can be transmitted over an analog baseband fiber-optic communication link?
a. NTSC
b. color video
c. audio
d. All of the above.

Location: Unit Test Page: sut3, Question ID: ut3
In a fiber-optic communication link, what part determines the lower cutoff frequency?
a. receiver output circuit
b. transmitter driver circuit
c. Both a and b.
d. transmitter light source

Location: Unit Test Page: sut4, Question ID: ut4
Optimum power can be coupled into the video input of a fiber-optic transmitter if the input impedance is equal to the
a. video source characteristic impedance.
b. light source dynamic resistance.
c. light detector resistance.
d. None of the above.

Location: Unit Test Page: sut5, Question ID: ut5
In analog fiber-optic communication links, audio amplifiers are used to boost
a. color video signals.
b. NTSC signals.
c. voice signals.
d. All of the above.
Location: Unit Test Page: sut6, Question ID: ut6

What technique is used to send multiple signals over a single optical fiber?

a. Manchester-encoding  
b. sync-encryption  
c. TDM  
d. None of the above.

Location: Unit Test Page: sut7, Question ID: ut7

An RS-232 transceiver IC

a. inverts signals.  
b. shifts levels.  
c. Both a and b.  
d. filters signals.

Location: Unit Test Page: sut8, Question ID: ut8

What technique is used to locate channel 1 of a multiplexed, Manchester-encoded fiber-optic signal?

a. Manchester-encoding  
b. sync-encryption  
c. TDM  
d. None of the above.

Location: Unit Test Page: sut9, Question ID: ut9

Manchester-encoding is used to send data in a digital fiber-optic communication link in order to

a. send synchronization information.  
b. convert logic levels.  
c. provide more power.  
d. send data and timing information.

Location: Unit Test Page: sut10, Question ID: ut10

What is the data pattern in this Manchester-encoded signal?

a. 01101  
b. **10010**  
c. 00110  
d. 10101
UNIT 7 – TROUBLESHOOTING

TROUBLESHOOTING

Location: Troubleshooting page: ttrba2, Question ID: trba2a
3. Is the circuit operating properly?
   a. yes
   b. no

Location: Troubleshooting page: ttrba3, Question ID: trba3
5. A circuit fault is a defective
   a. ANALOG TRANSMITTER.
   b. MIC AMPLIFIER.
   c. FIBER OPTIC TRANSMITTER.
   d. ANALOG RECEIVER.

Location: Troubleshooting page: ttrbb2, Question ID: trbb2a
3. Is the circuit operating properly?
   a. yes
   b. no

Location: Troubleshooting page: ttrbb3, Question ID: trbb3
5. A circuit fault is a defective
   a. FIBER OPTIC RECEIVER.
   b. ANALOG RECEIVER.
   c. FIBER OPTIC TRANSMITTER.
   d. AUDIO AMPLIFIER.

Location: Troubleshooting page: ttrbc2, Question ID: trbc2a
3. Is the circuit operating properly?
   a. yes
   b. no
Location: Troubleshooting page: ttrbc3, Question ID: trbc3
5. A circuit fault is a defective
a. MIC AMPLIFIER.
b. ANALOG TRANSMITTER.
c. FIBER OPTIC TRANSMITTER.
d. ANALOG RECEIVER.

Location: Troubleshooting page: ttrbd2, Question ID: trbd2a
3. Is the circuit operating properly?
a. yes
b. no

Location: Troubleshooting page: ttrbd3, Question ID: trbd3
5. A circuit fault is a defective
a. FIBER OPTIC RECEIVER.
b. FIBER OPTIC CABLE.
c. FIBER OPTIC TRANSMITTER.
d. ANALOG RECEIVER.

Location: Troubleshooting page: ttrbe2, Question ID: trbe2a
3. Is the circuit operating properly?
a. yes
b. no

Location: Troubleshooting page: ttrbe3, Question ID: trbe3
5. A circuit fault is a defective
a. FIBER OPTIC RECEIVER.
b. FIBER OPTIC CABLE.
c. FIBER OPTIC TRANSMITTER.
d. ANALOG RECEIVER.

Location: Troubleshooting page: ttrbf2, Question ID: trbf2a
3. Is the circuit operating properly?
a. yes
b. no
5. The circuit fault is a defective
   a. FIBER OPTIC RECEIVER circuit.
   b. DEMUX circuit.
   c. DIGITAL TRANSMITTER circuit.
   d. DIGITAL RECEIVER circuit.

3. Is the circuit operating properly?
   a. yes
   b. no

5. The circuit fault is a defective
   a. DIGITAL TRANSMITTER circuit.
   b. TX inverter circuit.
   c. #RX inverter circuit.
   d. DTR inverter circuit.

3. Is the circuit operating properly?
   a. yes
   b. no

5. The circuit fault is a defective
   a. DEMUX/DEMOD circuit.
   b. #CTS inverter circuit.
   c. DIGITAL RECEIVER circuit.
   d. #RX inverter circuit.

3. Is the circuit operating properly?
   a. yes
   b. no
Location: Troubleshooting page: ttrbi3, Question ID: trbi3
5. The circuit fault is a defective
   a. DEMUX #RX output circuit.
   b. #CTS inverter circuit.
   c. DIGITAL RECEIVER circuit.
   d. DEMUX/DEMOD circuit.

Location: Troubleshooting page: ttrbj2, Question ID: trbj2a
3. Is the circuit operating properly?
   a. yes
   b. no

Location: Troubleshooting page: ttrbj3, Question ID: trbj3
5. The circuit fault is a defective
   a. FIBER OPTIC TRANSMITTER circuit.
   b. TX inverter circuit.
   c. DIGITAL TRANSMITTER circuit.
   d. MUX/MOD circuit.

Location: Troubleshooting page: ttrbk2, Question ID: trbk2a
3. Is the circuit operating properly?
   a. yes
   b. no

Location: Troubleshooting page: ttrbk3, Question ID: trbk3
5. The circuit fault is a defective
   a. #DCD R inverter circuit.
   b. DEMOD #DSR output circuit.
   c. DSR inverter.
   d. DIGITAL RECEIVER circuit.
CMS AVAILABLE
None

FAULTS AVAILABLE
Fault 2
Fault 9
Fault 7
Fault 3
Fault 1
Fault 4
Fault 12
Fault 8
Fault 11
Fault 5
Fault 10
UNIT 8 – (OPTIONAL) MICROPROCESSOR INTERFACE

NOTE: This unit is optional and is designed to work with the F.A.C.E.T. 32-Bit Microprocessor circuit board and some additional equipment (see equipment list). If you do not have this circuit board and wish to incorporate it into your curriculum or would like more information, please contact your Lab-Volt representative or call 1-800-522-8658

UNIT OBJECTIVE

Explain and demonstrate the transmission and reception of digital data from a microprocessor via the RS-232 port of the FIBER OPTIC COMMUNICATIONS circuit board and fiber optic cables.

UNIT FUNDAMENTALS

Location: Unit Fundamentals page: sf1, Question ID: f1a

What type of communication is shown between the interfaces?
- a. simplex
- b. half-duplex
- c. full-duplex

Location: Unit Fundamentals page: sf2, Question ID: f2a

Which circuit boards are connected by fiber-optic cables?
- a. the 32-BIT MICROPROCESSOR & FIBER OPTIC boards
- b. the two FIBER OPTIC circuit boards
- c. the FIBER OPTIC board and the PERIPHERAL
CMS AVAILABLE
None

FAULTS AVAILABLE
None

NEW TERMS AND WORDS
None

EQUIPMENT REQUIRED
F.A.C.E.T. base unit
FIBER OPTIC COMMUNICATIONS circuit board
32-BIT MICROPROCESSOR circuit board
Oscilloscope, dual trace
RS-232 cable
Exercise 1 – Serial Interface

EXERCISE OBJECTIVE
Interface the FIBER OPTIC COMMUNICATIONS circuit board with the 32-BIT MICROPROCESSOR circuit board and demonstrate the transmission and reception of microprocessor data via an RS-232 port and a fiber-optic communication link.

EXERCISE DISCUSSION

Location: Exercise Discussion page: se1d3, Question ID: e1d3a
Over which RS-232 line is data transferred back to the MICROPROCESSOR board?
   a. TX
   b. RX
   c. RTS
   d. CTS

EXERCISE PROCEDURE

Location: Exercise Procedure page: se1p3, Question ID: e1p3a
8. Turn on the power switch on the 32-BIT MICROPROCESSOR circuit board. Does the message "Lab-Volt 32 bit μProc. Trainer" appear in the LCD display?
   a. yes
   b. no

Location: Exercise Procedure page: se1p9, Question ID: e1p9a
13. What data byte is sent and received?
   a. B0H
   b. OFH
   c. E4H
   d. 50H

Location: Exercise Procedure page: se1p12, Question ID: e1p12a
18. Does a digital waveform appear on the scope?
   a. yes
   b. no
20. What is the voltage swing of the waveform?
   a. 0 to 10V
   b. 0 to -10V
   c. -10V to +10V

21. What hex byte is displayed on the scope?
   a. 10H
   b. 01H
   c. 0FH
   d. F0H

23. By comparing the TX and RX waveforms, you can conclude that the microprocessor is receiving the
   a. same data that is transmitted.
   b. complement of the data that is transmitted.

24. Remove the ST connector from the FOR. What happens to the RX signal on CH 2?
   a. The signal does not change.
   b. The signal disappears.
   c. The data bits are inverted.
REVIEW QUESTIONS

Location: Review Questions page: se1r1, Question ID: e1r1
1. The fiber-optic connection from the FOT to the FOR
   a. shifts the RS-232 levels to 5V logic levels.
   b. shifts the 5V logic levels to RS-232 levels.
   c. causes the data received from the CPU to be sent back to the CPU.
   d. causes the same data received from the peripheral to be sent back to the peripheral.

Location: Review Questions page: se1r2, Question ID: e1r2
2. What signal is transferred over the optical fiber?
   a. data
   b. TX
   c. RTS
   d. All of the above.

Location: Review Questions page: se1r3, Question ID: e1r3
3. In order for the microprocessor to communicate with the peripheral in the system above, which block(s) should have an RS-232 port?
   a. microprocessor
   b. both fiber-optic boards
   c. peripheral
   d. All of the above.

Location: Review Questions page: se1r4, Question ID: e1r4
4. The data that passes between the microprocessor board and the fiber-optic board is in what form?
   a. serial
   b. parallel
   c. light pulses
   d. None of the above.
5. What RS-232 signal is used for handshaking?
   a. TX
   b. CTS
   c. RTS
   d. both b. and c.
UNIT TEST

Location: Unit Test Question page: sut1, Question ID: ut1
In the system shown, two fiber-optic boards are used to interface a microprocessor board to a peripheral. Which RS-232 signal at the microprocessor interface request data from the peripheral?
a. TX
b. RX
c. RTS
d. CTS

Location: Unit Test Question page: sut2, Question ID: ut2
What block converts digital signals into light pulses for transmission to the peripheral?
a. FOT (FIBER OPTIC board A)
b. FOT (FIBER OPTIC board B)
c. RS-232 interface (FIBER OPTIC board B)
d. RS-232 interface (PERIPHERAL)

Location: Unit Test Question page: sut3, Question ID: ut3
Which RS-232 port receives parallel data from the CPU?
a. FIBER OPTIC board A
b. FIBER OPTIC board B
c. PERIPHERAL
d. None of the above.

Location: Unit Test Question page: sut4, Question ID: ut4
What is the function of the RS-232 port in FIBER OPTIC board B?
a. send data to the PERIPHERAL
b. receive data from the PERIPHERAL
c. Both of the above.
d. None of the above.

Location: Unit Test Question page: sut5, Question ID: ut5
What RS-232 signal from the MICROPROCESSOR board is transferred on the upper optical fiber but not on the lower optical fiber?
a. CTS
b. RX
c. TX
d. All of the above.
**Location:** Unit Test Question page: sut6, Question ID: ut6

The TX and RTS signals from the MICROPROCESSOR board are transferred to
a. FIBER OPTIC board A only.
b. both fiber-optic boards but not the PERIPHERAL.
c. both fiber-optic boards and the PERIPHERAL.
d. None of the above.

**Location:** Unit Test Question page: sut7, Question ID: ut7

In this figure, the MICROPROCESSOR board sends data to a FIBER OPTIC board. The FOT is
looped back to the FOR to send the same data back to the microprocessor. What type of
communication takes place on the optical fibers.
a. simplex
b. half-duplex
c. full-duplex
d. parallel

**Location:** Unit Test Question page: sut8, Question ID: ut8

What function is not performed by the RS-232 INTERFACE on the FIBER OPTIC board?
a. multiplexing TX and RTS onto the output channel
b. demultiplexing RX and CTS from the input channel
c. serial-to-parallel conversion
d. converting the RX-232 logic levels to 5V logic levels

**Location:** Unit Test Question page: sut9, Question ID: ut9

The CTS signal indicates that the FIBER OPTIC board is ready to
a. receive serial data.
b. transmit serial data.
c. receive parallel data.
d. transmit parallel data.

**Location:** Unit Test Question page: sut10, Question ID: ut10

An interface between a computer and peripheral communicating over fiber-optic cables
a. converts digital signals to light pulses.
b. converts light pulses to digital signals.
c. multiplexes data with control signals.
d. All of the above.
APPENDIX A – PRETEST AND POSTTEST QUESTIONS AND ANSWERS

Depending on configurator settings, these questions may be randomized onscreen.

1. Which is not a necessary part of a fiber-optic communication link?
   a. RS-232 interface
   b. optical fiber
   c. light source
   d. light detector

2. Which can be transmitted over a fiber-optic link?
   a. audio frequency
   b. composite video
   c. pulses and data
   d. all of the above

3. A phototransistor can be used to make relative measurements of light
   a. wavelength.
   b. power.
   c. frequency.
   d. color.

4. Which is not a basic part of a fiber-optic communication link?
   a. light source
   b. speaker
   c. optical fiber
   d. output circuit

5. In a fiber-optic communication link, a fiber-to-detector connection can be found at the output of a(n)
   a. driver circuit.
   b. optical fiber.
   c. light source.
   d. light detector.

6. Which is not a basic part of a fiber-optic transmitting system?
   a. driver circuit
   b. light source
   c. output circuit
   d. source-to-fiber connection
7. Which is not a common term in fiber optics?
   a. light cable
   b. fiber-optic cable
   c. optical fiber
   d. light pipe

8. What cannot be sent over a fiber-optic link?
   a. electric power
   b. cable TV signals
   c. computer data
   d. telephone messages

9. Light attenuation in an optical fiber is caused by
   a. an ideal waveguide.
   b. resistance and capacitance.
   c. scattering and absorption.
   d. wavelength.

10. How can you reduce the losses in a fiber-optic system having a 10 km length of 62.5/125
    glass fiber operating at 940 nm?
    a. Use a longer fiber.
    b. Use plastic fiber.
    c. Operate at 1500 nm.
    d. None of the above.

11. Which polish will produce the largest Fresnel reflection?
    a. Ultra PC polish
    b. PC polish
    c. Super PC polish
    d. Flat polish

12. Which factors determine a fiber's acceptance angle?
    a. the refractive index of the cladding
    b. the refractive index of the core
    c. the fiber's critical angle
    d. all of the above

13. To prevent NA mismatch losses in a fiber-optic system, light should pass into fibers with an
    a. NA lower than or equal to, the previous fiber.
    b. area greater than, or equal to, the previous fiber.
    c. NA greater than, or equal to, the previous fiber.
    d. all of the above
14. Increasing a fiber's length
   a. decreases its dispersion.
   b. increases its dispersion.
   c. increases its bandwidth.
   d. decreases its attenuation.

15. Which end finish will produce the smallest Fresnel reflection?
   a. Flat polish
   b. PC polish
   c. no polish (unpolished)
   d. none of the above

16. Why is the luminous intensity of the red and green LEDs on the LED circuit block on your circuit board the same, even though the radiant intensity is different?
   a. Our eyes are most sensitive to green light.
   b. Our eyes are most sensitive to red light.
   c. The red LED is more efficient photometrically, but not radiometrically.
   d. The green LED is more efficient radiometrically, but not photometrically.

17. What is the least important characteristic of a fiber-optic light source?
   a. color
   b. intensity
   c. resistance
   d. bandwidth

18. Which is not a radiometric measure of power?
   a. W (watt)
   b. 1mW (lumens per watt)
   c. µWsr (microwatts per steradian)
   d. mWcm² (milliwatts per square centimeter)

19. When comparing two power levels in fiber optics, you can use
   a. the ratio (P2/P1) only.
   b. either the actual ratio (P2/P1) or decibels (dB).
   c. decibels (dB) only.
   d. none of the above.

20. The driver circuit can control an FOT's
   a. forward current.
   b. radiant power.
   c. switching speed.
   d. all of the above.
21. What does the rise and fall time of an output signal indicate about its driver circuit?
   a. amplitude
   b. current
   c. power
   d. bandwidth

22. Which is not a basic type of driver circuit?
   a. series
   b. parallel
   c. delta
   d. shunt

23. What are two techniques used to increase the switching speed of a digital driver circuit?
   a. constant-peaking and pre-biasing
   b. constant-biasing and constant peaking
   c. constant-biasing and pre-peaking.
   d. pre-biasing and current-peaking

\[ D_1(\text{FOT}) = 290 \text{ } \mu m \quad D_2(\text{glass}) = 62.5 \text{ } \mu m \]
\[ D_1(\text{RED}) = 400 \text{ } \mu m \quad D_2(\text{plastic}) = 980 \text{ } \mu m \]
\[ \text{LOSS}_{UI} \text{ (in dB)} = 20 \times \log(D_1D_2) \]

24. Using the plastic fiber-optic cable, what is the UI loss at the FOT source-to-fiber connection?
   a. 5.3 dB
   b. 10.6 dB
   c. no UI loss.
   d. infinite UI loss

\[ \text{LOSS}_{UI} = 21.0 \text{ dB} \quad \text{LOSS}_{NA} = 5.0 \text{ dB} \]
\[ \text{LOSS}_R = 0.3 \text{ dB} \quad \text{LOSS}_F = 1.2 \text{ dB} \]

25. What is the total coupling loss at a source-to-fiber connection that exhibits the above losses?
   a. 26.5 dB
   b. 13.5 dB
   c. 6.5 dB
   d. 53.0 dB

26. Which is not a component of a fiber-optic transmitter?
   a. driver circuit
   b. light source
   c. source-to-fiber connection
   d. optical fiber
27. How would you determine the coupling loss at a source-to-fiber connection?
   a. add the UI, NA, R, and Finish losses
   b. subtract the UI, NA, R, and Finish losses
   c. multiply the UI, NA, R, and Finish losses
   d. average the UI, NA, R, and Finish losses

28. A fiber-optic transmitter driver circuit controls FOT
   a. forward current.
   b. radiant power.
   c. switching speed.
   d. all of the above.

29. Using the light detector with an increased bandwidth
   a. decreases pulse width.
   b. decreases rise time.
   c. increases fall time.
   d. increases coupling loss.

30. Which is a measure of detector response to optical power?
   a. equivalent diameter
   b. bandwidth
   c. equivalent optical noise input power
   d. responsivity

31. What is the attenuation due to UI when a 100/140 μm glass fiber is coupled to an FOR with a 110 μm effective diameter? [LOSS_{UI} = 20 \times \log(DIA_1/DIA_2)]
   a. -2.1 dB
   b. 0 dB
   c. 0.83 dB
   d. 2.1 dB

32. A phototransistor has an input power of 2μW and a photocurrent of 20 mA. What is the transistor's responsivity?
   a. 10 mVμW
   b. 10 mAμW
   c. 0.1 mVμW
   d. 0.1 mAμW

33. What is the purpose of a receiver output circuit?
   a. convert electrical signals to optical signals
   b. convert optical signals to electrical signals
   c. provide system-compatible output
   d. provide adjustable gain
34. In a fiber-optic receiver, the light detector  
   a. is a pulse detector.  
   b. cannot have coupling losses.  
   c. **has an electrical output signal.**  
   d. has an optical output.

35. In a digital receiver output circuit, the preamplifier  
   a. **increases sensitivity.**  
   b. has a series 7400 compatible output.  
   c. increases the hysteresis voltage.  
   d. uses positive feedback.

36. Ac coupling in a digital receiver output circuit  
   a. prevents pulse detection.  
   b. **removes dc drift.**  
   c. limits high frequency response.  
   d. all of the above.

37. What is the purpose of a receiver output circuit?  
   a. provide system compatible output.  
   b. match impedance  
   c. provide compatible voltage levels  
   d. **all of the above.**

38. The optical power margin is the difference between available transmitter power after losses and the  
   a. receiver responsivity.  
   b. transmitter LED degradation.  
   c. **receiver sensitivity.**  
   d. fiber-to-detector mismatch loss.

39. To determine a system power budget, you must account for all optical power loss from  
   a. connectors.  
   b. fiber attenuation.  
   c. NA and area mismatches.  
   d. **all of the above.**

40. What does a designer use to ensure that the components of a fiber-optic system operate fast enough to meet the bandwidth requirements of an application?  
   a. Ohm's law  
   b. **rise time budget**  
   c. frequency budget  
   d. optical power budget
41. A fiber-optic system has an optical power margin of 16 dB. What is the maximum length of plastic optical fiber (attenuation = 200 dB/km) that can be added before the receiver sensitivity is reached? (NOTE: Assume that no connectors are added.)
   a. 80 m  
   b. 80 km  
   c. 12.5 km  
   d. cannot be determined

42. What equipment will indicate the distance to a faulty fiber-optic connection?
   a. fiber-optic light source  
   b. fiber-optic power meter  
   c. digital volt meter  
   d. optical time-domain reflectometer

43. Which would you use to test a fiber-optic transmitter?
   a. fiber-optic light source  
   b. fiber-optic power meter  
   c. optical time-domain reflectometer  
   d. ammeter

44. Which of the following does not affect an optical power budget?
   a. fiber bandwidth  
   b. fiber attenuation  
   c. LED degradation  
   d. receiver sensitivity

45. Fiber-optic power meters are usually calibrated in microwatts or
   a. lumens.  
   b. dBm.  
   c. volts.  
   d. steradians.

46. An OTDR can be used to
   a. measure reflections.  
   b. determine distance.  
   c. evaluate fiber loss.  
   d. all of the above.

47. Why is Manchester-encoding used for transmitting data in a digital fiber-optic communication link?
   a. to send synchronization information  
   b. to send data and timing information  
   c. to convert logic levels  
   d. to provide more power
48. Why is time-division multiplexing used for transmitting data in a digital fiber-optic communication link?
   a. to send synchronization information
   b. to convert logic levels
   c. **to send multiple signals**
   d. to provide a reference

49. The passband of a wide-band analog fiber-optic receiver is limited in order to
   a. amplify the signal.
   b. **increase the SN ratio.**
   c. improve bandwidth.
   d. amplify noise.

50. In analog fiber-optic communication links, audio amplifiers are used to boost
    a. **voice signals.**
    b. NTSC signals.
    c. color video signals.
    d. all of the above.
## APPENDIX B – FAULTS AND CIRCUIT MODIFICATIONS (CMs)

<table>
<thead>
<tr>
<th>CM</th>
<th>SCHEMATIC SWITCH NO.</th>
<th>FAULT</th>
<th>ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>–</td>
<td>21</td>
<td>1</td>
<td>opens path between J38 and J18</td>
</tr>
<tr>
<td>–</td>
<td>22</td>
<td>2</td>
<td>opens R5 (terminal 2)</td>
</tr>
<tr>
<td>–</td>
<td>23</td>
<td>3</td>
<td>opens R19</td>
</tr>
<tr>
<td>–</td>
<td>24</td>
<td>4</td>
<td>opens path between U11 pin 7 and J28</td>
</tr>
<tr>
<td>–</td>
<td>25</td>
<td>5</td>
<td>opens path to U7A pin 2</td>
</tr>
<tr>
<td>–</td>
<td>26</td>
<td>6</td>
<td>opens path from U3 pin 43</td>
</tr>
<tr>
<td>–</td>
<td>27</td>
<td>7</td>
<td>opens path between C12, C13 junction and U5 pin 3</td>
</tr>
<tr>
<td>–</td>
<td>28</td>
<td>8</td>
<td>opens RDATA path to J5</td>
</tr>
<tr>
<td>–</td>
<td>29</td>
<td>9</td>
<td>opens path between R21 wiper and R22</td>
</tr>
<tr>
<td>–</td>
<td>30</td>
<td>10</td>
<td>opens path from U3 pin 40</td>
</tr>
<tr>
<td>–</td>
<td>31</td>
<td>11</td>
<td>opens path from U3 pin 36</td>
</tr>
<tr>
<td>–</td>
<td>32</td>
<td>12</td>
<td>opens U1 pin 6 (#TX)</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
<td>–</td>
<td>CM not found</td>
</tr>
</tbody>
</table>
APPENDIX C – BOARD AND COURSEWARE TROUBLESHOOTING

Circuit Board Problems
The F.A.C.E.T. equipment is carefully designed, manufactured, and tested to assure long, reliable life. If you suspect a genuine failure in the equipment, the following steps should be followed to trace a problem.

A. ALWAYS insert the board into a base unit before attempting to use an ohmmeter for troubleshooting. The schematic diagrams imprinted on the boards are modified by the absence of base unit switch connections; therefore, ohmmeter checks will produce erroneous results with disconnected boards. Do not apply power to the base unit when you perform resistance checks.
B. Information describing fault switch functions is provided in Appendix B in this instructor guide.

Courseware Problems
The F.A.C.E.T. courseware has been written to meet carefully selected objectives. All exercises have been tested for accuracy, and information presented in discussions has been reviewed for technical content. Tolerances have been computed for all procedure and review question answers to assure that responses are not invalidated by component or instrument errors.

Nevertheless, you or your students may discover mistakes or experience difficulty in using our publications. We appreciate your comments and assure you that we will weigh them carefully in our ongoing product improvement efforts.

As we address courseware problems, we will post corrections for download from our web site, www.labvolt.com. Select the customer support tab, and then choose product line: F.A.C.E.T. Select a course, select from a list of symptoms that have been addressed, and follow the instructions.
We will do our best to help you resolve problems if you call the number below. However, for best results, and to avoid confusion, we prefer that you write with a description of the problem.

If you write, please include the following information:

- Your name, title, mailing address, and telephone number (please include the best time to reach you).
- Publication title and number.
- Page number(s), and step and/or figure number(s) of affected material.
- Complete description of the problem encountered and any additional information that may help us solve the problem.

Send your courseware comments to:

techsupport@labvolt.com

Lab-Volt Systems
P.O. Box 686
Farmingdale, NJ 07727
ATTN: Technical Support

If you prefer to telephone regarding hardware or courseware problems, call us between 9:00 AM and 4:30 PM (Eastern time) at: (800) 522-4436 or (888)-LAB-VOLT.