Emona FOTEx Lab Manual

Experiments in Modern Fiber Optic Communications Systems For NI™ ELVIS I & II

Barry Duncan

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Experiments in Modern Fiber Optic Communications Systems.

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Contents

*** experiments included in this Sample Manual**

WARNING

As a matter of good practice:

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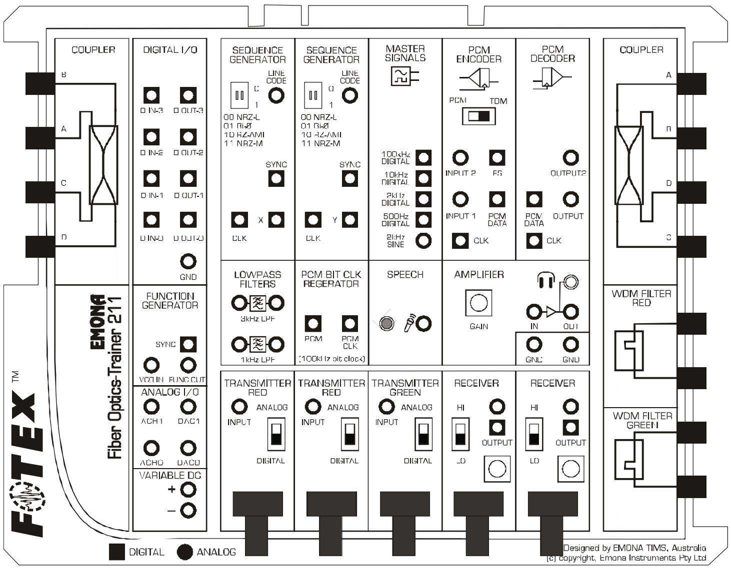
Do NOT look directly into an optical fiber which is connected to the RED or GREEN light sources.

FOTEx uses optical LEDs: laser sources are NOT used

Introduction

The ETT-211 FOTEx ™ Lab Manual Overview
The ETT-211 Lab Manual provides a complete lab program in the key concepts of the transmission and manipulation of optical signals in a modern fiber optic communications system. The initial chapters introduce students to the NI ELVIS unit and FOTEx add-in module. Subsequent chapters provide students with a background in the important digital communications topics of digitization, encoding and multiplexing.

Each experiment is carefully paced, interspersed with thought provoking questions which consolidate the concepts being investigated. Emphasis has been placed on ensuring that each FOTEx experiment presents an interesting, hands-on learning experience for the student. The student is challenged to build, measure and consider: there are no "instant" or "cookbook-style" experiments. FOTEx is actually a true engineering modeling system where students see that the block diagrams so common in their textbooks represent real functioning systems.



The Emona FOTEx Add-in Module has a collection of blocks (called modules) that are patched together to implement a dozen digital and fiber optics communications systems experiments.

Equipment Required
Experiments make use of the Emona FOTEx fiber optics trainer kit together with the NI ELVIS I or II platform and NI LabVIEW running on a PC. The functionality and range of the virtual instrumentation available depends on the NI DAQ that is coupled with NI ELVIS I platform. ELVIS II has all necessary interfacing circuitry built into it.

Refer to the ETT-211 FOTEx USER MANUAL for further details, as well as information on the installation and use of the FOTEx/NI ELVIS experiment system.

Student Academic Level
Experiments in this volume have been prepared for students with only a basic knowledge of mathematics and a limited background in physics and electricity.

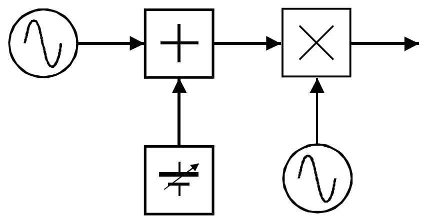
Students with a higher level of competence in mathematics will also gain a deeper understanding of fiber optics communications theory by using the FOTEx system. Due to the engineering "modeling" nature of the FOTEx trainer, they will be able to investigate more complex issues, carry out additional measurements and then contrast their findings to their theoretical understanding and mathematical analysis.

Didactic philosophy behind the ETT-211 FOTEx™ System – <u>Emona TIMS™ and the "Block Diagram" approach</u>

The Emona FOTEx fiber optics communications trainer draws on a well established experimental methodology that brings to life the "universal language" of telecommunications, the BLOCK DIAGRAM. Originally developed in the 1970's by Tim Hooper, a senior lecturer in telecommunications at The University of New South Wales, Australia, and further developed by Emona Instruments, Emona TIMS™, or "Telecommunications Instructional Modeling System", is used by thousands of students around the world, **to implement practically any form of modulation or coding**.

Block Diagrams

Block diagrams are used to explain the principle of operation of electronic systems (like a radio transmitter for example) without worrying about how the circuit works. Each block represents a part of the circuit that performs a separate task and is named according to what it does. Examples of common blocks in communications equipment include the *adder*, *multiplier, oscillator*, and so on.



A typical telecom's BLOCK DIAGRAM

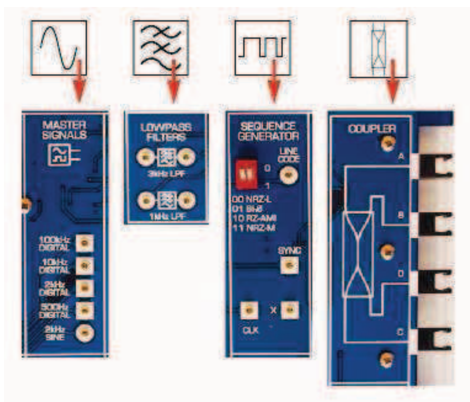
The TIMS™ and hence FOTEx™ approach to implementing telecommunications experiments through realizing BLOCK DIAGRAMS has the following benefits in the educational environment:

- Students gain practical experience with true mathematical modeling hardware, designed specifically for implementing telecommunications theory.
- Students actually build each experiment stage-by-stage, in an engineering manner, by following the BLOCK DIAGRAM.
- Students are free to try "what-if" scenarios to validate their understanding of the theory being investigated, by viewing real, real-time electrical signals.
- FOTEx is designed to allow students to make mistakes, hence students will learn from their hands-on experiences as they investigate their findings.

One-to-One Relationship

The figure on the right illustrates the one-to-one relationship between each block of the BLOCK DIAGRAM and the independent functional circuit blocks of the FOTEx trainer board.

The functional blocks of the FOTEx board are used and re-used in experiments, just as blocks of the block diagram reappear in many different implementations.



Examples of FOTEx ™ functional blocks

NI LabVIEW™ and FOTEx™
The Emona FOTEx add-in module is fully integrated with the NI ELVIS platform and NI LabVIEW environment. All FOTEx™ analog and digital I/O can be controlled though NI LabVIEW VIs.

Guidelines for Using the Lab Manual

The experiments in this volume have been prepared for students with only a basic knowledge of mathematics. However, due to the engineering "modeling" nature of the FOTEx add-in module, students with a higher level of competence in mathematics will equally gain a deeper understanding of fiber optics communications theory by carrying out these experiments.

The 12 chapters cover a broad range of concepts, from introduction to using NI ELVIS and FOTEx, the basics of digital baseband communications, simple fiber optic transmission of an electrical signal through to wavelength division multiplex and bidirectional communications along a sigle fiber. In each experiment, the core technology is revealed to the student, at its most fundamental level.

Chapters can be covered in any order, however, it is recommended that all students complete the first seven chapters before proceeding to the later chapters.

- Chapter 1 introduces the NI ELVIS test equipment.
- Chapter 2 introduces the Emona FOTEx experimental add-in module.
- Chapter 3 to 6 introduces basic digital communications concepts, and
- Chapter 7 to 12 focus on various fiber optic concepts.

In order to make the student's learning experience more memorable, the student is usually able to both view signals on the NI ELVIS oscilloscope and then listen to their own voice undergoing the optical transmission method being investigated.

Making Mistakes and Mis-wiring
An important factor which makes the learning experience more valuable for the student is that the student is allowed to make wiring mistakes. FOTEx inputs and outputs can be connected in any combination, without causing damage. As the student builds the experiment, they need to make constant observations, adjustments and corrections. If signals are not as expected then the student needs to make a decision as to whether the correction required is an adjustment or an incorrectly placed patching wire.

Structure of the Experiments and Topics
Each experiment in the FOTEx Lab Manual provides a basic introduction to the topic under investigation, followed by a series of carefully graded hands-on activities. At the conclusion of each sub section the student is asked to answer questions to confirm their understanding of the work before proceeding.

Finally, since the ETT-211 Trainer is a true modeling system, the instructor has the freedom to modify existing experiments or even create completely new experiments to convey new and course specific concepts to students.

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Name: ______________________________

Class: ______________________________

1 - An introduction to the NI ELVIS II test equipment

Experiment 1 – An introduction to the NI ELVIS II test equipment

Preliminary discussion

The *digital multimeter* and *oscilloscope* are probably the two most used pieces of test equipment in the electronics industry. The bulk of measurements needed to test and/or repair electronics systems can be performed with just these two devices.

At the same time, there would be very few electronics laboratories or workshops that don't also have a *DC Power Supply* and *Function Generator*. As well as generating DC test voltages, the power supply can be used to power the equipment under test. The function generator is used to provide a variety of AC test signals.

Importantly, the NI ELVIS II has these four essential pieces of laboratory equipment in one unit (and others). However, instead of each having its own digital readout or display (like the equipment pictured), the NI ELVIS II sends the information via USB to a personal computer where the measurements are displayed on one screen.

On the computer, the NI ELVIS II devices are called "virtual instruments". However, don't let the term mislead you. The digital multimeter and scope are real measuring devices, not software simulations. Similarly, the DC power supply and function generator output real voltages.

The experiments in this manual make use of all four NI ELVIS II devices and others so it's important that you're familiar with their operation.

The experiment

This experiment introduces you to the NI ELVIS II digital multimeter, variable DC power supplies (there are two of them), oscilloscope and function generator. Importantly, the oscilloscope can be a tricky device to use if you don't do so often. So, this experiment also gives you a procedure that'll set it up ready to display a stable 2kHz 4Vp-p signal every time. Importantly, it's recommended that you use this procedure as a starting point for the other experiments in this manual.

It should take you about 50 minutes to complete this experiment.

Equipment

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona FOTEx experimental add-in module
- Two BNC to 2mm banana-plug leads
- Assorted 2mm banana-plug patch leads

Some things you need to know for the experiment

This box contains definitions for some electrical terms used in this experiment. Although you've probably seen them before, it's worth taking a minute to read them to check your understanding.

The **amplitude** of a signal is its physical size and is measured in *volts* (V). It is usually measured either from the middle of the waveform to the top (called the *peak* voltage) or from the bottom to the top (called the *peak-to-peak* voltage).

The **period** of a signal is the time taken to complete one cycle and is measured in *seconds* (s). When the period is small, it is expressed in milli seconds (ms) and even micro seconds (μs).

The **frequency** of a signal is the number of cycles every second and is measured in *hertz* (Hz). When there are many cycles per second, the frequency is expressed in kilo hertz (kHz) and even mega hertz (MHz).

A **sinewave** is a repetitive signal with the shape shown in Figure 1.

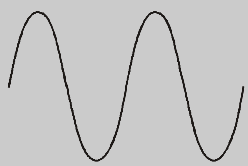

Figure 1

A **squarewave** is a repetitive signal with the shape shown in Figure 2.

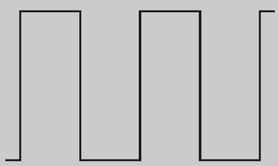

Figure 2

Procedure

Part A – Getting started

1. Ensure that the NI ELVIS II power switch at the back of the unit is off.

2. Carefully plug the Emona FOTEx experimental add-in module into the NI ELVIS II.

3. Insert the holding screws to secure the FOTEx module to the NI ELVIS II.

   Note 1: This may already be done for you. If not, the screws are supplied with the NI ELVIS II and are inserted through holes in the top left and right corners of the FOTEx.

   Note 2: This must be done with the power off to avoid damaging the FOTEx.

4. Set the *Control Mode* switch on the FOTEx module (top right corner) to *Manual.*

5. Connect the NI ELVIS II to the PC using the USB cable.

   Note: This may already have been done for you.

6. Turn on the NI ELVIS II power switch at the rear of the unit then turn on its *Prototyping Board Power* switch at the top right corner near the power indicator.

7. Turn on the PC and let it boot-up.

8. Launch the NI ELVISmx software per the instructor's directions.

   Note: If the NI ELVISmx software has launched successfully, the window called "ELVISmx Instrument Launcher" will be visible (see Figure 3).

Figure 3

Part B – The NI ELVIS II Digital Multimeter

The NI ELVIS II Digital Multimeter (DMM) is an instrument that can measure the following electrical properties: DC & AC voltages, DC & AC currents, resistance, capacitance and inductance. Its operation is briefly introduced next.

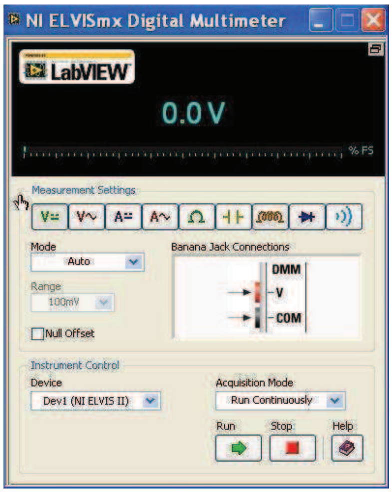

Figure 4

9. Use the mouse to click on the "DMM" button on the NI ELVISmx Instrument Launcher.

   Note: If the digital multimeter virtual instrument has launched successfully, the instrument's window will be visible (see Figure 4).

The digital multimeter's mode of operation is selected using "soft" controls on the virtual instrument instead of physical buttons on the NI ELVIS II. That is, you tell the meter what to measure by pressing the appropriate buttons under the heading *Measurement and Settings* near the mouse-pointer in Figure 4.

10. Move the mouse-pointer over these controls but don't click on any of them yet.

    Note: As you do this, you'll notice that a pop-up appears to tell you by name what measurement mode the controls activate.

11. Click back and forth between one of the *Voltage* controls (marked *V*) and one of the *Current* controls (marked *A*).

    Note 1: As you do, notice that the buttons on the virtual instrument are animated. The selected control fades as though it has been physically pressed in.

    Note 2: Notice also that the *Banana Jack Connections* window updates to tell you which of the DMM's banana jacks to use on the left side of the NI ELIVS II for that particular measurement.

Importantly, simply launching the DMM virtual instrument doesn't activate the instrument's hardware. To do so, you must press the soft *Run* control (the button with the green arrow) and this must be done every time you launch the DMM virtual instrument.

12. Click on the DMM's *Run* control.

13. Click on each of the *Measurement and Settings* controls in turn while watching the DMM's readout.

    Note: As you do, notice that the readout updates to tell you the unit of measurement (eg *V* for volts, *A* for amps, etc). The readout also indicates the relative size of the measurement (for example, *m* for milli, *M* for mega, etc). See the instructor for more information if you're not familiar with the metric system of multiples and sub-multiples.

Question 1
Given you've not been asked to connect the digital multimeter's inputs to anything yet, why does the DMM read very small values of voltage instead of zero?

If you examine the DMM virtual instrument closely you'll notice that there are other controls that can be adjusted including the *Mode*, *Null Offset* and *Acquisition Mode*. These controls default to appropriate settings for regular use so we'll not discuss them further here. Where adjustment of these controls is necessary, they'll be explained at the appropriate place in the experiments.

Ask the instructor to check your work before continuing.

Part C – The NI ELVIS II Variable Power Supplies

The NI ELVIS II Variable Power Supplies (VPS) is an instrument that can simultaneously output two DC voltages (one positive and one negative) to terminals on the Emona FOTEx. Its operation is briefly discussed next.

14. Use the mouse to click on the "VPS" button on the NI ELVISmx Instrument Launcher.

    Note: If the Variable Power Supplies virtual instrument has launched successfully, the instrument's window will be visible (see Figure 5).

A couple of the Variable Power Supplies settings can be adjusted by "hard" controls on the NI ELVIS II (on the right-hand sand of the unit). However, all of the VPS's settings can be adjusted using its soft controls on its virtual instrument. This is the preferred method of operation throughout this manual.

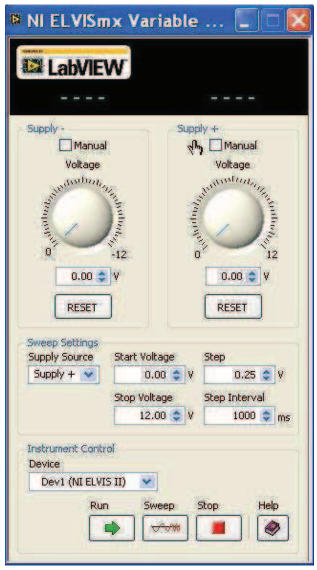

Figure 5

15. Click on the  DMM's control to put it into DC voltage measuring mode.

16. Connect the set-up shown in Figure 6 below.

    Tip: Use the 4mm banana plug to 2mm banana plug patch leads.

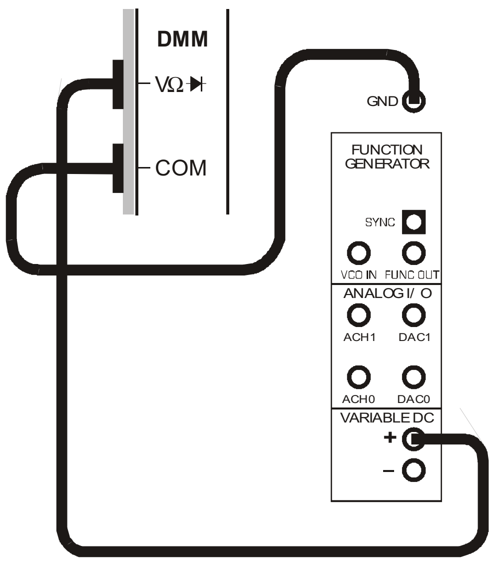

Figure 6

17. Activate the Variable Power Supplies' VI by clicking on its *Run* control.

18. Vary the Variable Power Supplies' positive output voltage by using the mouse to "grab and turn" the *Voltage* control shown in Figure 7.

    Note: Notice that, as you do this, a meter above the control changes.

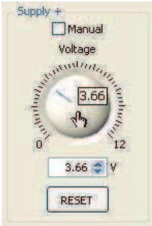

Figure 7

19. Compare the meter's value with output voltage indicated by the DMM. The two readings should be close but they'll probably not be exactly the same.

20. Set the Variable Power Supplies positive output voltage to exactly 7.59V by typing that number into the *V* window as shown in Figure 8 then press the *Enter* key.

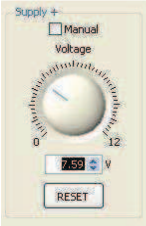

Figure 8

21. Compare the value you typed-in with the output voltage indicated by the DMM.

22. Preset the *RESET* button below the *V* window and observe the effect.

23. Connect the DMM to the Variable Power Supplies' negative *Variable DC* output.

24. Repeat Steps 18 to 23 to affect the Variable Power Supplies' negative output.

Ask the instructor to check your work before continuing.

Part D – The NI ELVIS II Oscilloscope

The NI ELVIS II Oscilloscope (or just "scope") is a fully functional dual channel oscilloscope that allows engineers and technicians to measure AC waveforms and view their shape. Its operation is briefly discussed next.

25. Close the virtual instruments for the digital multimeter and Variable Power Supplies.

26. Use the mouse to click on the "Scope" button on the NI ELVISmx Instrument Launcher.

    Note: If the scope virtual instrument has launched successfully, the instrument's window will be visible (see Figure 9).

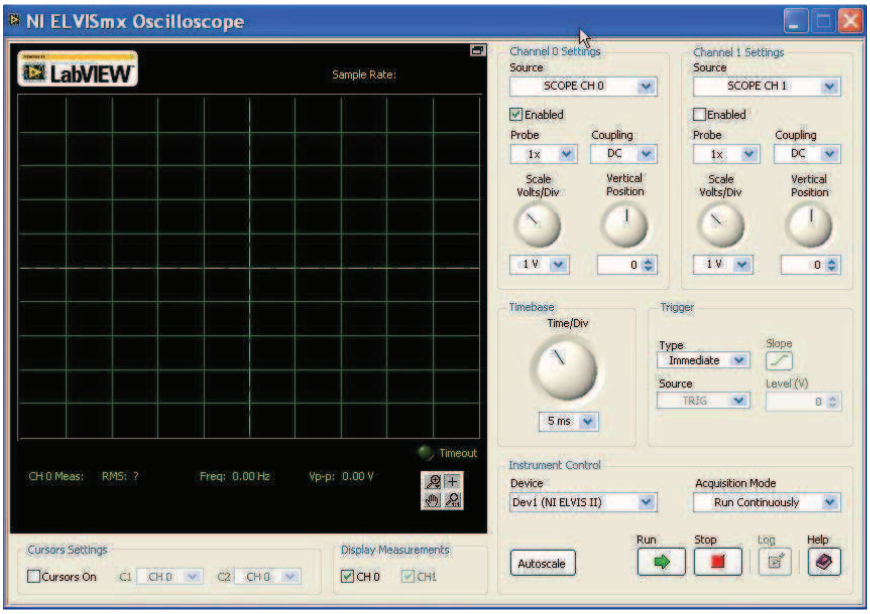

Figure 9

The NI ELVIS II Oscilloscope is operated using the controls on its virtual instrument. Although operating the NI ELVIS II Oscilloscope is much easier than operating other types of scopes, it can still be a little tricky to use when you're new to this piece of test equipment. The procedure on the next page is one that you can use to set it up ready to reliably view waveforms and take measurements when undertaking FOTEx experiments.

Procedure for setting up the NI ELVIS II Oscilloscope

27. Follow the procedure below. Call the instructor for assistance if you can't find a particular control.

    Note: Much of this procedure simply involves checking that control settings are in the default positions used at the time of writing this manual.

    General

    i) Check that the *Cursors On* box doesn't have a tick in it.

    Vertical

    i) Check that the Channel 0 *Source* control is set to *SCOPE CH 0* and the Channel 1 *Source* control is set to *SCOPE CH 1*.

    ii) Check that the *Probe* control for both channels is set to *1×*.

    iii) Set the *Coupling* control for both channels to *AC*.

    iv) Check that the *Scale Volts/Div* control for both channels is set to *1V/div*.

    v) Check that the *Vertical Position* control for both channels is in the middle of their travel.

    Timebase

    i) Set the *Time/Div* (or *Timebase*) control to the *500µs/div* position.

    Trigger

    i) Set the *Type* control to *Edge*.

    ii) Set the *Source* control to *CH 0 Source*.

    iii) Check that the *Level* control is set to *0*.

    iii) Check that the *Slope* control is set to the  position.

28. Activate the scope's VI by clicking on its *Run* control.

Ask the instructor to check your work before continuing.

The next part of this experiment lets you familiarize yourself with NI ELVIS II Oscilloscope by observing and measuring a FOTEx signal.

29. Connect the set-up shown in Figure 10 below.

    Note 1: As you will see, the scope's Channel 0 trace is green so use the BNC-to-banana-plug lead with the green bead on it. You'll find this practice very helpful when using the scope's two channels at once.

    Note 2: Notice that the connection to the Master Signals' *2kHz SINE* output must be made with the red banana plug. The black banana plug should be connected to any one of the ground (*GND*) sockets on the Emona FOTEx.

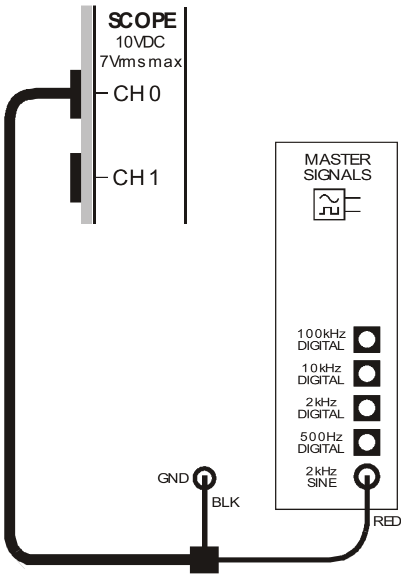

Figure 10

When measuring the amplitude of an AC waveform using a scope, it's common to measure its *peak-to-peak* voltage. That is, the difference between its lowest point and its highest point. This is shown in Figure 11. Importantly, knowing the waveform's peak-to-peak voltage allows us to calculate its *RMS* voltage where required.

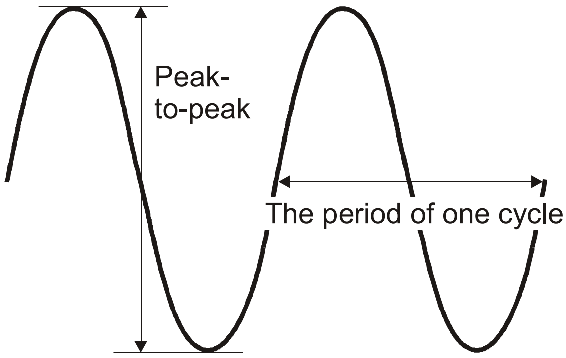

Figure 11

The other dimension of an AC waveform that's important to measure is its period. The period is the time it takes to complete one cycle and this is also shown in Figure 11. While knowing the waveform's period may be useful in its own right, it also allows us to calculate the signal's frequency using the equation:

$$f = \frac{1}{Period}$$

Measuring the amplitude of signals and determining their frequency using conventional scopes is a little more involved that using a digital multimeter. As such, it can be easy for the novice to make mistakes. Helpfully, the NI ELVIS II Oscilloscope includes meters that measure voltage and frequency for you and readout the information on the display. The location of this information on the virtual instrument is below the graticule as shown in Figure 12 below.

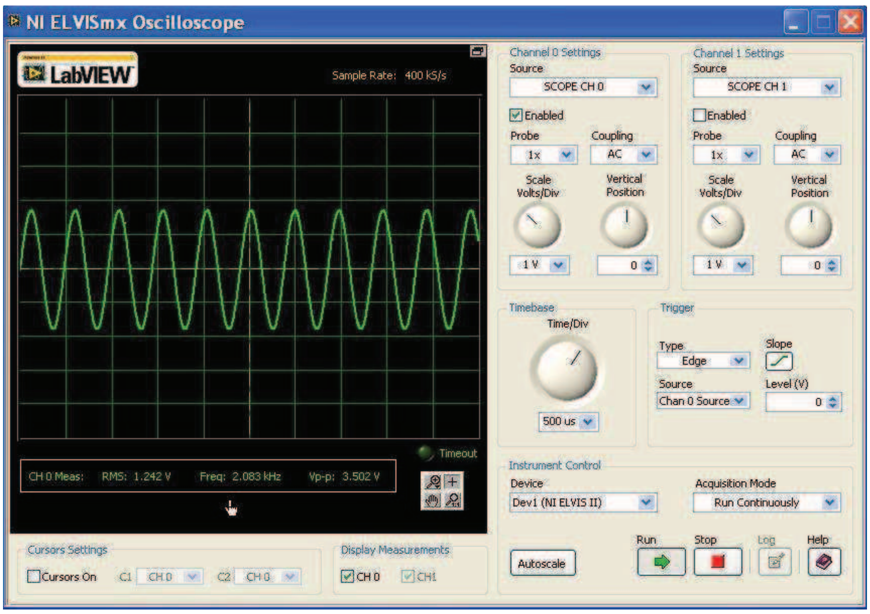

Figure 12

30. Record the scope's measured value of voltage (RMS and peak-to-peak) and frequency in Table 1 below.

31. Use the signal's frequency to work backwards to calculate and record its period.

    Tip: You'll have to transpose the equation on the previous page to make period (*P*) the subject.

Table 1

RMS voltage	
Frequency	
Pk-Pk voltage	
Period	

Ask the instructor to check your work before continuing.

Part E – The NI ELVIS II Function Generator

The NI ELVIS II Function Generator (FGEN) is an instrument that can output AC signals of various shapes, sizes and frequencies to terminals on the Emona FOTEx. Its operation is briefly discussed next.

32. Use the mouse to click on the "FGEN" button on the NI ELVISmx Instrument Launcher.

    Note 1: Don't close the NI ELVISmx Scope virtual instrument because you'll be using it to verify the operation of the function generator.

    Note 2: If the function generator virtual instrument has launched successfully, the instrument's window will be visible (see Figure 13).

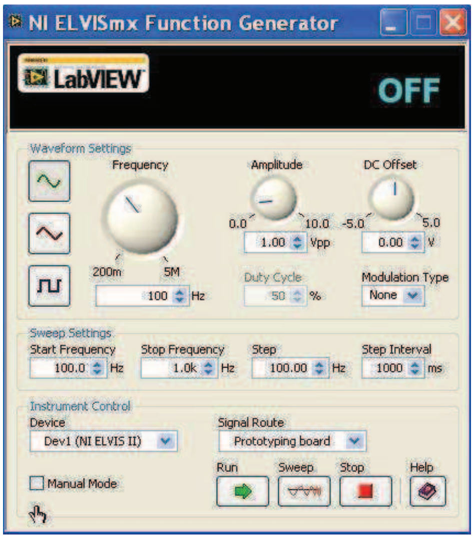

Figure 13

33. Activate the function generator's VI by clicking on its *Run* control.

34. To observe the function generator's output, connect the set-up shown in Figure 14 below.

    Note: Again, the connection to the function generator's output must be made using the lead's red banana plug.

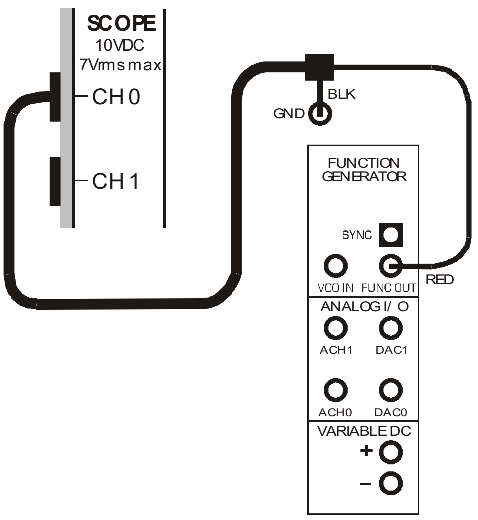

Figure 14

35. Set the scope's *Timebase* control to the *2ms/div* position.

    Note: Once this step has been performed, you should see two complete cycles of a sinewave.

36. Vary the function generator's soft *Amplitude* control left and right and observe the effect on the function generator's output.

37. Set the function generator's amplitude to exactly 2.8V by typing that number into the *Vpp* window below the soft *Amplitude* control then pressing the *Enter* key.

38. Vary the function generator's soft *Frequency* control left and right and observe the effect on the function generator's output.

39. Set the function generator's frequency to exactly 135Hz by typing that number into the *Hz* window below the soft *Frequency* control then pressing the *Enter* key.

Ask the instructor to check your work before finishing.

Name: ______________________________

Class: ______________________________

2 - An introduction to the FOTEx experimental add-in module

Experiment 2 – An introduction to the FOTEx experimental add-in module

Preliminary discussion

The Emona FOTEx experimental add-in module for the NI ELVIS II is used to help people learn about key telecommunications principles generally and optical fiber telecoms specifically. As you will see, the Emona FOTEx lets you implement widely used telecommunication digital data techniques in both copper and optical environments as well as letting you investigate real world optical fiber performance issues.

Before you explore these interesting techniques and issues, there are a number of FOTEx modules that are used to help implement the experiments. It's helpful to know a little about these modules before using them.

The experiment

This experiment introduces you to several of the FOTEx's (non-optical) modules that are required by most of the experiments in this manual.

It should take you about 1 hour to complete this experiment.

Pre-requisites:

Experiments 1: An introduction to the NI ELVIS II test equipment (or previous experience in operating the NI ELVIS II test equipment).

Equipment

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona FOTEx experimental add-in module
- Two BNC to 2mm banana-plug leads
- Assorted 2mm banana-plug patch leads
- One set of headphones (stereo)

Part A - The Master Signals, Speech and Amplifier modules

The Master Signals module

The Master Signals module is an AC signal generator or *oscillator*. The module has five outputs providing the following:

- 2kHz sinewave (analog)
- 500Hz squarewave (digital)
- 2kHz squarewave (digital)
- 10kHz squarewave (digital)
- 100kHz squarewave (digital)

Each signal is available on a socket on the module's faceplate that is labeled accordingly. Importantly, all signals are synchronized. The next part of the experiment gets you to investigate these signals using the NI ELVIS II Oscilloscope.

Procedure

1. Ensure that the NI ELVIS II power switch at the back of the unit is off.

2. Carefully plug the Emona FOTEx experimental add-in module into the NI ELVIS II.

3. Insert the holding screws to secure the FOTEx module to the NI ELVIS II.

   Note 1: This may already be done for you. If not, the screws are supplied with the NI ELVIS II and are inserted through holes in the top left and right corners of the FOTEx.

   Note 2: This must be done with the power off to avoid damaging the FOTEx.

4. Connect the NI ELVIS II to the PC using the USB cable.

   Note: This may already have been done for you.

5. Turn on the NI ELVIS II power switch at the rear of the unit then turn on its *Prototyping Board Power* switch at the top right corner near the power indicator.

6. Turn on the PC and let it boot-up.

7. Launch the NI ELVISmx software per the instructor's directions.

   Note: If the NI ELVISmx software has launched successfully, the window called "ELVISmx Instrument Launcher" will be visible.

Ask the instructor to check your work before continuing.

1. Connect the set-up shown in Figure 1 below.

   Tip: Use the BNC-to-banana-plug lead with the green bead on it because this matches the color of the Channel 0 trace.

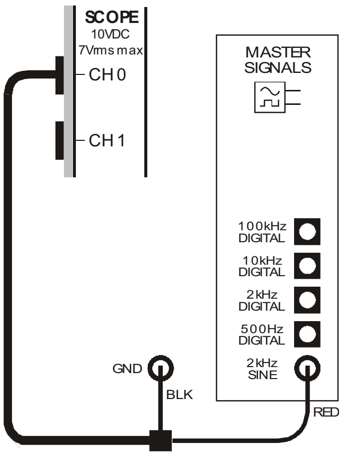

Figure 1

This set-up can be represented by the block diagram in Figure 2 below.

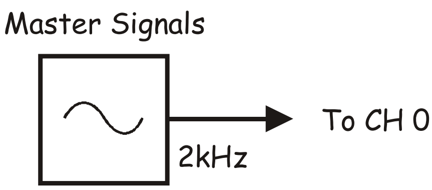

Figure 2

2. Launch and run the NI ELVIS II Oscilloscope and set it up per the procedure in Experiment 1 (page 1-12) with the following change:

   - *Input coupling* control to *DC* instead of *AC*

3. Adjust the scope's *Timebase* control to view only two or so cycles of the Master Signals module's *2kHz SINE* output.

4. Use the scope's measuring function to find the amplitude (the peak-to-peak voltage) of the Master Signals module's *2kHz SINE* output. Record this in Table 1 below.

5. Measure and record the frequency of the Master Signals module's *2kHz SINE* output.

6. Determine whether the signal is unipolar or bipolar.

   Note: To do this, look closely at the scope's 0V reference across the middle of the screen. If the signal's peaks swing above **and** below this line, the signal is bipolar. If the peaks don't do this, the signal is unipolar.

7. Set the scope's *Trigger Level* control to *2.5V* instead of *0V.*

8. Repeat Steps 5 to 7 for the Master Signals module's other four outputs.

   Note: You'll need to adjust the scope's *Timebase* control to an appropriate setting for each output.

Table 1	Amplitude	Frequency	Uni- or bipolar?
2kHz SINE			
500Hz DIGITAL			
2kHz DIGITAL			
10kHz DIGITAL			
100kHz DIGITAL			

Ask the instructor to check your work before continuing.

Part B - The Speech module

One of the main functions of telecommunications is to allow people to talk to each other. As such, it's important when modeling optical fiber telecommunications to use speech signals. The Emona FOTEx allows you to generate speech signals using the Speech module and the next part of the experiment gets you to do so.

9. Disconnect the scope from the Master Signals module.

10. Set the scope's *Timebase* control to the *2ms/div* position.

11. Return the scope's *Trigger Level* control to *0V*.

12. Connect the set-up shown in Figure 3 below.

    Note: Insert the oscilloscope lead's black plug into a ground (*GND*) socket.

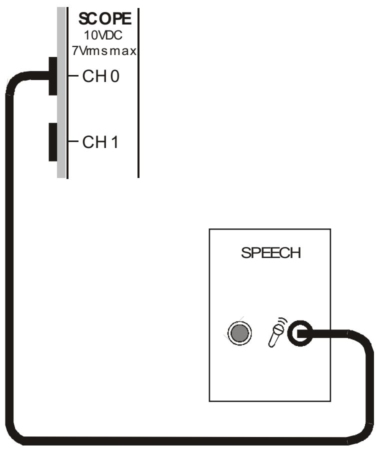

Figure 3

13. Talk and hum into the microphone while watching the scope's display. Be sure to say "one" and "two" several times.

Ask the instructor to check your work before continuing.

Part C - The Amplifier module

Amplifiers are used extensively in telecommunications equipment. They're often used to make signals bigger. They're also used as an interface between devices and circuits that can't normally be connected. The Amplifier module on the Emona FOTEx can do both. The next part of the experiment gets you to investigate the Amplifier module's performance and use it to listen to signals on the headphones.

14. Disconnect the scope from the Speech module.

15. Locate the Amplifier module and set its *Gain* control to about a third of its travel.

16. Connect the set-up shown in Figure 4 below.

    Tip: Use the BNC-to-banana-plug lead with the blue bead on it for the Channel 1 input because this matches the color of the Channel 1 trace.

    Note: Insert the black plugs of the oscilloscope leads into a ground (*GND*) socket.

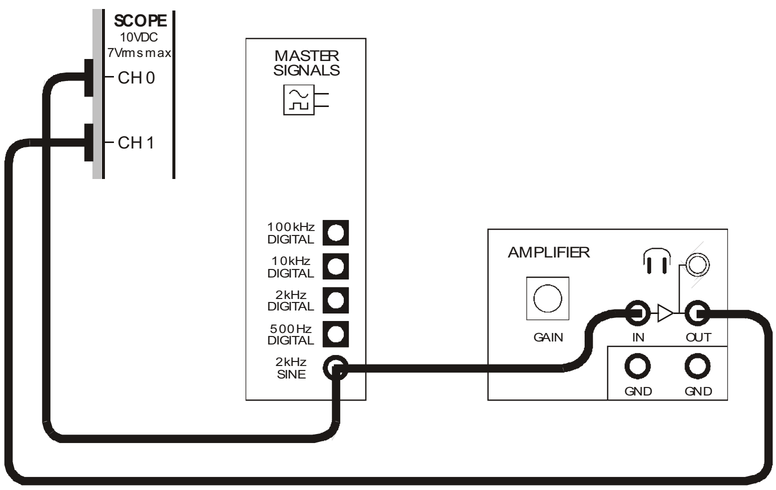

Figure 4

The set-up in Figure 4 can be represented by the block diagram in Figure 5 below.

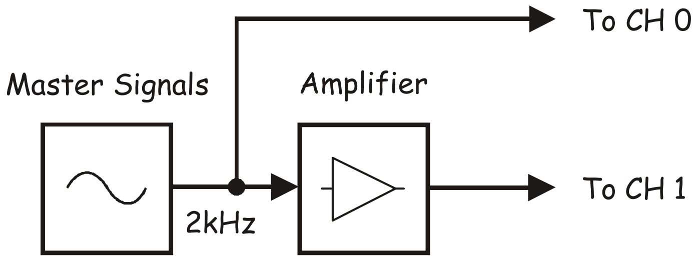

Figure 5

17. Adjust the scope's *Timebase* control to view two or so cycles of the Amplifier module's input.

18. Activate the scope's Channel 1 input by checking (that is, putting a tick in) the Channel 1 *Enabled* box as shown in Figure 6 below.

    Note: You may need to adjust the scope's Channel 1 *Scale* control to see the entire signal.

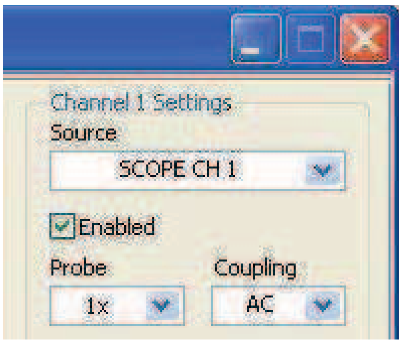

Figure 6

19. Measure the amplitude (the peak-to-peak voltage) of the Amplifier module's input. Record your measurement in Table 2 below.

20. Measure and record the amplitude of the Amplifier module's output.

Table 2

Input voltage	Output voltage

The measure of how much bigger an amplifier's output voltage is compared to its input voltage is called *voltage gain* (A_V). An amplifier's voltage gain can be expressed as a simple ratio calculated using the equation:

$$A_V = \frac{Vout}{Vin}$$

Importantly, if the amplifier's output signal is upside-down (or *inverted*) compared to its input then a negative sign is put in front of the gain figure to highlight this fact.

Question 1
Calculate the Amplifier module's gain (on its present gain setting).

____

____

An amplifier's voltage gain can also be expressed in decibels and is calculated using the equation:

$$A_{V(dB)} = 20Log\left(\frac{Vout}{Vin}\right)$$

Importantly, the minus sign is not used to denote inversion for gains expressed in decibels. This is because the negative sign in front of a decibel denotes attenuation. (You'll see this for yourself later.)

Question 2
Calculate the Amplifier module's gain in decibels.

Ask the instructor to check your work before continuing.

The Amplifier module's gain is variable. Usefully, it can be set so that the output voltage is smaller than the input voltage. This is not amplification at all. Instead it's a loss or *attenuation*. The next part of the experiment shows how attenuation affects the gain figure.

21. Set the scope's Channel 1 *Scale* control to the *100mV/div* position.

22. Turn the Amplifier module's *Gain* control fully counter-clockwise then turn it clockwise just a little until you can just see a sinewave.

23. Measure and record the amplitude of the Amplifier module's new output.

24. Calculate the amplifier's new gain as both a ratio and in decibels.

Table 3

Input voltage	Output voltage	Voltage gain (ratio)	Voltage gain (in decibels)
See Table 2			

Question 3
In terms of the gain figure as a ratio, what's the difference between gain and loss (attenuation)?

Question 4
In terms of the gain figure as a decibel, what's the difference between gain and attenuation?

Ask the instructor to check your work before continuing.

Amplifiers work by taking the DC power supply voltage and using it to make a copy of the amplifier's input signal. Obviously then, the DC power supply limits the size of the amplifier's output. If the amplifier is forced to try to output a signal that is bigger than the DC power supply voltages, the tops and bottoms of the signal are chopped off. This type of signal distortion is called *clipping*.

Clipping usually occurs when the amplifier's input signal is too big for the amplifier's gain. When this happens, the amplifier is said to be *overdriven*. It can also occur if the amplifier's gain is too big for the input signal. To demonstrate clipping:

25. Turn the Amplifier module's *Gain* control fully clockwise.

26. Resize the Amplifier module's output signal on the display by adjusting Channel 1's *Scale* control to an appropriate setting.

Question 5
What do you think the output signal would look like if the amplifier's gain was sufficiently large?

Ask the instructor to check your work before continuing.

27. **Turn the Amplifier module's *Gain* control fully counter-clockwise.**

Headphones are typically low impedance devices – usually around 50Ω. Most electronic circuits are not designed to have such low impedances connected to their output. For this reason, headphones should not be directly connected to the output of most of the modules on the Emona FOTEx.

However, the Amplifier module has been specifically designed to handle low impedances. So, it can act as a buffer between the modules' outputs and the headphones to let you listen to signals. The next part of the experiment shows how this is done.

28. Ensure that the Amplifier module's *Gain* control is turned fully counter-clockwise.

29. Without wearing the headphones, plug them into the Amplifier module's headphone socket.

30. Put the headphones on.

31. Turn the Amplifier module's *Gain* control clockwise and listen to the signal.

32. Disconnect the plugs from the Master Signals module's *2kHz SINE* output and connect them to the Speech module's output.

33. Speak into the microphone and listen to the signal.

Ask the instructor to check
your work before continuing.

Part D - The 1kHz and 3kHz low-pass filters

Filters are also used extensively in telecommunications equipment. As their name implies they pass and reject sinewaves discriminating between them by frequency. That is, filters are designed to let sinewaves at certain frequencies pass from input to output relatively unaffected while attenuating sinewaves at other frequencies.

The Emona FOTEx has two dedicated low-pass filters (LPFs) which pass relatively low frequency sinewaves down to DC while rejecting relatively high frequency sinewaves. The threshold point where rejection is said to begin is called the *cut-off frequency* and is determined by design. One of the FOTEx LPFs has a 1kHz cut-off frequency and the other has a 3kHz cut-off frequency. The next part of the experiment lets you compare the two filters' frequency performance.

34. Dismantle the current set-up.

35. Launch and run the NI ELVIS II Function Generator VI.

36. Adjust the function generator for an output with the following specifications:

- Waveshape: Sine
- Frequency: 500Hz
- Amplitude: 4Vpp
- DC Offset: 0V
- Modulation Type: None

37. Connect the set-up in Figure 7 below.

Note: Insert the black plugs of the oscilloscope leads into a ground (*GND*) socket.

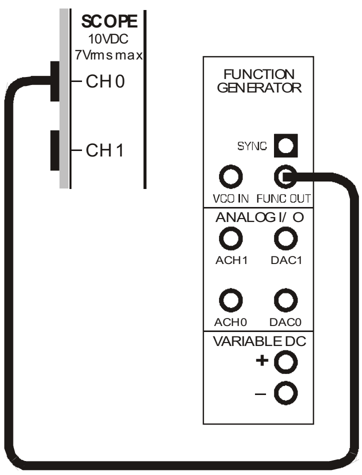

Figure 7

38. Use the scope to check that the function generator's output is to specification.

    Note: You'll probably need to adjust several of the scope's controls to appropriate settings. If you're not sure what to do, simply set-up the scope per the procedure on page 1-12.

39. Modify the set-up as shown in Figure 8 below.

    Tip: Use the BNC-to-banana-plug lead with the red bead on it for the scope's *TRIG* input.

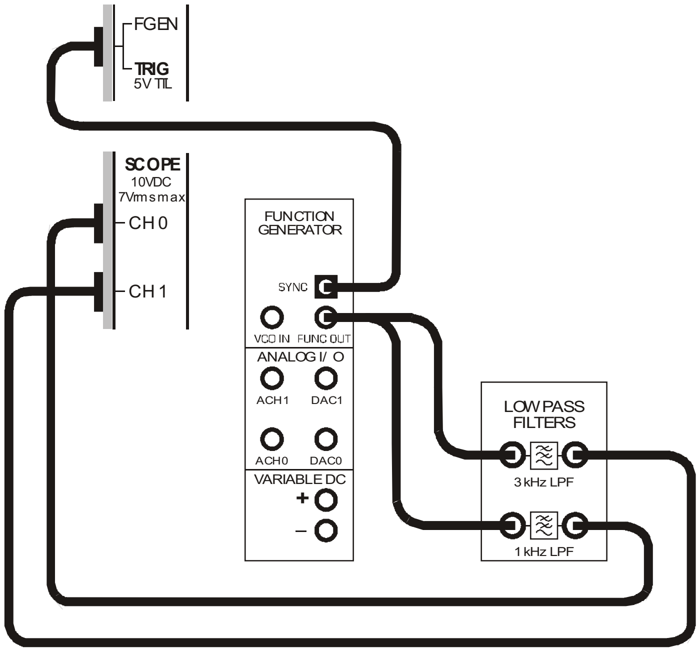

Figure 8

This set-up can be represented by the block diagram in Figure 9 on the next page. As you can see, the function generator's output is connected to the input of both filters. The scope's Channel 0 is used to view the 1kHz LPF's output while Channel 1 is used to view the 3kHz LPF's output. As the signals will ultimately become quite small, the scope will be unable to use them for reliable triggering. So the function generator's *SYNC* output is used to trigger the scope and ensure a stable display.

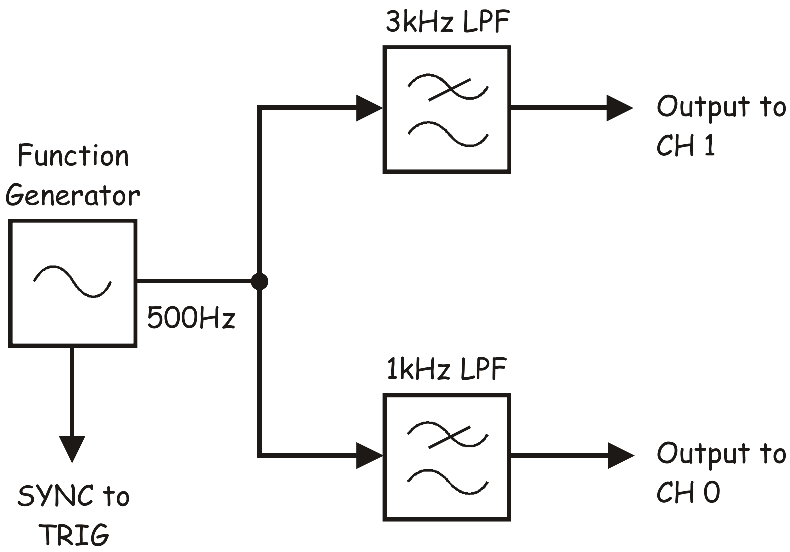

Figure 9

40. Check that the function generator's *Signal Route* option (near the bottom right-hand corner of the VI is set to *Prototyping Board*.

    Important note: There is the potential for a hardware conflict when using the scope's external triggering input (*TRIG*) at the same time as the function generator. This is because the connector for the *TRIG* input doubles as an output for the function generator when its *Signal Route* option is set to *FGEN BNC*. To avoid hardware conflicts always set the *Signal Route* to *Prototyping Board*.

41. Set the scope's *Trigger Type* to *Digital*.

Ask the instructor to check your work before continuing.

42. Measure the output voltage of the two filters. Record your measurements in Table 4 below.

43. Calculate the gain (in decibels) of the two filters.

Ask the instructor to check your work before continuing.

44. Set the function generator's output frequency to 1kHz then repeat Steps 42 and 43.

45. Repeat for the remaining frequencies in Table 4.

Note: For each frequency, adjust the scope's *Scale* controls as necessary to ensure that the signals are not too small to measure.

Table 4

<table>
<tr><th></th><th></th><th colspan="2">1kHz LPF</th><th colspan="2">3kHz LPF</th></tr>
<tr><th></th><th>Input voltage</th><th>Output voltage</th><th>Voltage gain (in dB)</th><th>Output voltage</th><th>Voltage gain (in dB)</th></tr>
<tr><td>500Hz</td><td rowspan="6">4Vp-p</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1kHz</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2kHz</td><td></td><td></td><td></td><td></td></tr>
<tr><td>3kHz</td><td></td><td></td><td></td><td></td></tr>
<tr><td>4kHz</td><td></td><td></td><td></td><td></td></tr>
<tr><td>5kHz</td><td></td><td></td><td></td><td></td></tr>
</table>

Question 6
What happens to the filters' output signals as the input frequency is increased beyond their cut-off frequencies?

Ask the instructor to check your work before finishing.

Name: ____________________

Class: ____________________

3 - PCM encoding

Experiment 3 – PCM encoding

Preliminary discussion
As you know, digital transmission systems are steadily replacing analog systems in commercial communications applications. This is especially true in telecommunications. That being the case, an understanding of digital transmission systems is crucial for technical people in the telecommunications industry.

Pulse Code Modulation (PCM) is a widely used digital transmission system for converting analog message signals (such as speech) to a serial stream of 0s and 1s. The conversion process is called *encoding*. At its simplest, encoding involves:

- Sampling the analog signal's voltage at regular intervals using a sample-and-hold scheme
- Comparing each sample to a set of reference voltages called *quantization levels*
- Deciding which quantization level the sampled voltage is closest to
- Generating the binary number for that quantization level
- Outputting the binary number one bit at a time (that is, in serial form)
- Taking the next sample and repeating the process

An important PCM performance issue relates to the difference between the sample voltage and the quantization levels that it is compared to. To explain, most sampled voltages will not be the same as any of the quantization levels. As mentioned above, the PCM Encoder assigns to the sample the quantization level that is closest to it. However, in the process, the original sample's value is lost and the difference is known as *quantization error*. Importantly, the error is reproduced when the PCM data is decoded by the receiver because there is no way for the receiver to know what the original sample voltage was. The size of the error is affected by the number of quantization levels. The more quantization levels there are (over a given range) the closer they are together. This means that the difference between the quantization levels and the samples is smaller and so the error is lower.

Another issue that is crucial to the performance of the PCM system is the encoder's clock frequency. The clock tells the PCM encoder when to sample the input. Sampling must occur at no-less than twice the message frequency to avoid problem called *aliasing* (or, if the message contains more than one sinewave, at least twice its highest frequency). As the effect of aliasing is experienced at the output of the PCM system, further discussion on this issue is left to the PCM decoding experiment.

A little information about the PCM Encoder module on the Emona FOTEx
The PCM Encoder module uses a PCM encoding and decoding chip (called a *codec*) to convert analog voltages between -2.5V and +2.5V to a 7-bit binary number. With seven bits, it's possible to produce 128 different numbers between 0000000 and 1111111 inclusive. This in turn means that there are 128 quantization levels (one for each number).

Each binary number is available on the PCM Encoder module's output in serial form in 8-bit *frames*. The binary number's most significant bit is sent first and so is found on bit-7 of the frame. The number's next most significant bit is sent next and so on to the least significant bit (which is found on bit-1 of the frame). Bit-0 of the frame is a frame synchronization bit used by the PCM Decoder module to find the beginning of each frame. It simply alternates between 0 and 1 on successive frames. How this is used by the PCM Decoding module for frame synchronization is explain in the PCM Decoding experiment.

The PCM Encoder module also outputs a separate *Frame Synchronization* signal (*FS*) that goes high at the same time as the frame's synchronization bit is outputted. The *FS* output is not needed by the PCM Decoder module and has been provided on the FOTEx purely for scope triggering.

Figure 1 below shows an example of three frames of a PCM Encoder module's output data together with its clock input and its *FS* output. Bits 7 to 1 are shown as both a 0 and a 1 because they could be either depending on the size of the analog input.

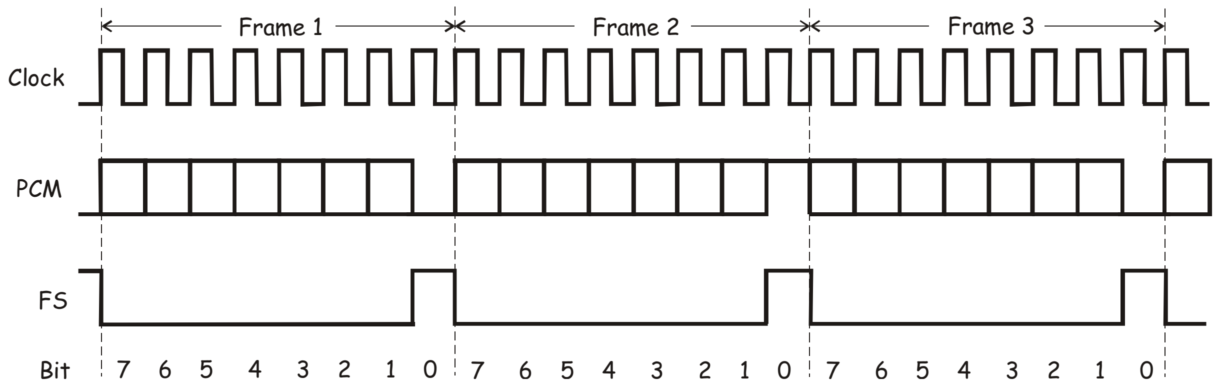

Figure 1

The experiment
For this experiment you'll use the PCM Encoder module on the Emona FOTEx to convert the following to PCM: a fixed DC voltage, a variable DC voltage and a continuously changing signal. In the process, you'll verify the operation of PCM encoding.

It should take you about 50 minutes to complete this experiment.

Pre-requisites:
Experiment 1: An introduction to the NI ELVIS II test equipment
Experiment 2: An introduction to the Emona FOTEx

Equipment

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona FOTEx experimental add-in module
- Two BNC to 2mm banana-plug leads
- Assorted 2mm banana-plug patch leads

Procedure

Part A – An introduction to PCM encoding using a static DC voltage

1. Ensure that the NI ELVIS II power switch at the back of the unit is off.

2. Carefully plug the Emona FOTEx experimental add-in module into the NI ELVIS II.

3. Insert the holding screws to secure the FOTEx module to the NI ELVIS II.

   Note 1: This may already be done for you. If not, the screws are supplied with the NI ELVIS II and are inserted through holes in the top left and right corners of the FOTEx.

   Note 2: This must be done with the power off to avoid damaging the FOTEx.

4. Connect the NI ELVIS II to the PC using the USB cable.

   Note: This may already have been done for you.

5. Turn on the NI ELVIS II power switch at the rear of the unit then turn on its *Prototyping Board Power* switch at the top right corner near the power indicator.

6. Turn on the PC and let it boot-up.

7. Launch the NI ELVISmx software.

8. Set the PCM Encoder module's *Mode* switch to the *PCM* position.

9. Connect the set-up shown in Figure 2 below.

Note 1: Insert the black plugs of the oscilloscope leads into a ground (*GND*) socket.

Note 2: The PCM Encoder module's *INPUT 1* can be connected to any available ground socket.

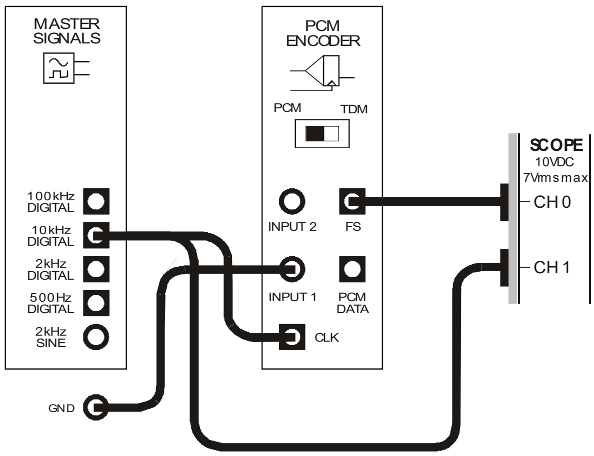

Figure 2

This set-up can be represented by the block diagram in Figure 3 below. The PCM Encoder module is clocked by the Master Signals module's *10kHz DIGITAL* output and its analog input is connected to 0V DC.

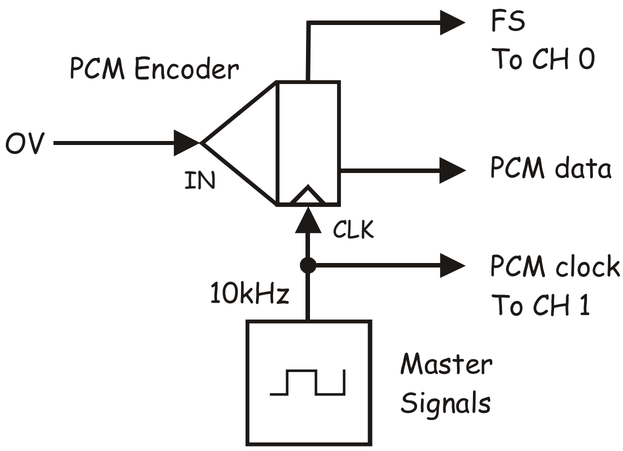

Figure 3

10. Launch and run the NI ELVIS II Oscilloscope VI.

11. Set up the scope per the procedure in Experiment 1 (page 1-12) with the following changes:

- *Scale* control for both channels to the *2V/div* position instead of the *1V/div* position
- *Coupling* control for both channels to the *DC* position instead of the *AC* position
- *Trigger Level* control to *2V* instead of *0V*
- *Timebase* control to the *200μs/div* position instead of the *500μs/div* position

12. Set the scope's *Slope* control to the  position.

Setting the *Slope* control to the "-" position makes the scope start its sweep across the screen when the *FS* signal goes from high to low instead of low to high. You can really notice the difference between the two settings if you flip the scope's *Slope* control back and forth. If you do this, make sure that the *Slope* control finishes on the "-" position.

13. Set the scope's *Timebase* control to the *100μs/div* position.

Note 1: The *FS* signal's pulse should be one division wide as shown in Figure 4. If it's not, adjust the function generator's output frequency until it is.

Note 2: Setting the function generator this way makes each bit in the serial data stream one division wide on the graticule's horizontal axis.

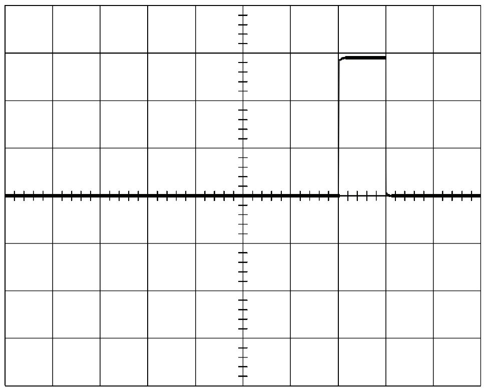

Figure 4

14. Activate the scope's Channel 1 input (by checking the Channel 1 *Enabled* box) to observe the PCM Encoder module's *CLK* input as well as its *FS* output.

Tip: To see the two waveforms clearly, you may need to adjust the scope so that the two signals are not overlayed. Do this by setting the Channel 0 *Vertical Position* control to 2V and the Channel 1 *Vertical Position* control to -5V

15. Draw the two waveforms to scale in the space provided below leaving enough room for a third digital signal.

Tip: Draw the clock signal in the upper third of the graph paper and the *FS* signal in the middle third.

Ask the instructor to check your work before continuing.

16. Connect the scope's Channel 1 input to the PCM Encoder module's output as shown in Figure 5 below.

    Remember: Dotted lines show leads already in place.

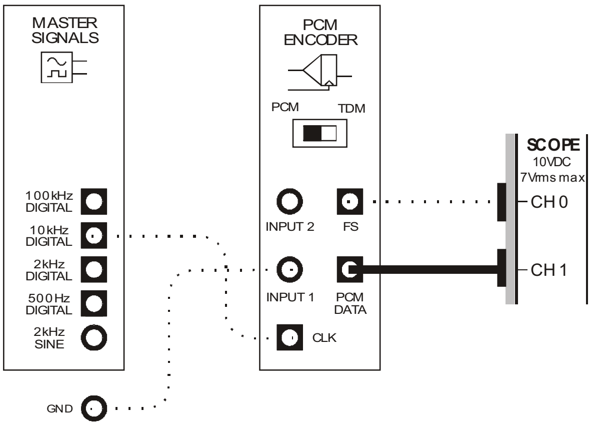

Figure 5

The change to the scope's connection can be represented by the block diagram in Figure 6 below. Channel 1 should now display 10 bits of the PCM Encoder module's data output. Reading from the left of the display, the first 8 bits belong to one frame and the last two bits belong to the next frame.

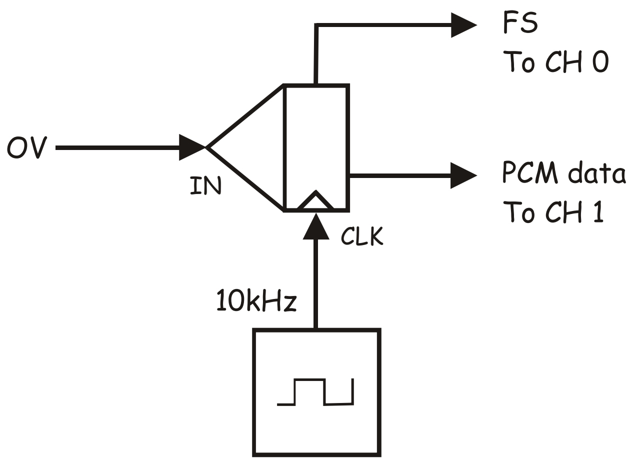

Figure 6

17. Draw this waveform to scale in the space that you left on the graph paper.

Question 1
Indicate on your drawing the start and end of the frame. **Tip:** If you're not sure where these points are, reread the preliminary discussion.

Question 2
Indicate on your drawing the start and end of each bit.

Question 3
Indicate on your drawing which bit in the PCM data is the frame synchronization bit. **Tip:** This bit occasionally toggles between logic-0 and logic-1.

Question 4
Indicate on your drawing which bit in the PCM data is the binary number's most significant bit (MSB) and its least significant bit (LSB).

Question 5
What is the 7-bit binary number that the PCM Encoder module is outputting?

Question 6
Why does the PCM Encoder module output this code for 0V DC and not 0000000?

Ask the instructor to check your work before continuing.

Part B – PCM encoding of a variable DC voltage

So far, you have used the PCM Encoder module to convert a fixed DC voltage (0V) to PCM. The next part of the experiment lets you see what happens when you vary the DC voltage.

18. Launch and run the Emona VarDC VI.

    Note: The Emona VarDC VI is an instrument that uses the NI ELVIS II hardware to output an adjustable bi-polar DC voltage to the DAC0 output on the FOTEx.

19. Check with the instructor that the Emona VarDC VI's default device number is appropriate for the PC set-up that you're using.

20. Set the VarDC's output to 0V.

21. Unplug the patch lead connected to the ground socket.

22. Modify the set-up as shown in Figure 7 below.

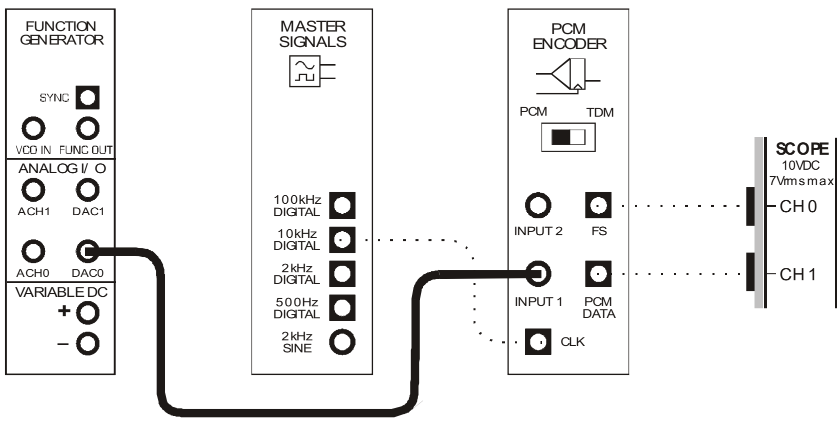

Figure 7

This set-up can be represented by the block diagram in Figure 8 on the next page. The Emona VarDC VI is used for the DC voltage on the PCM Encoder module's input.

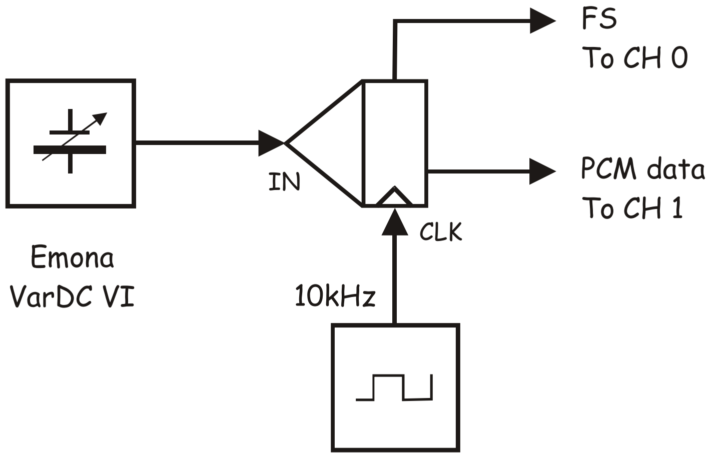

Figure 8

23. Determine the 7-bit number on the PCM Encoder module's output.

Tip 1: Remember, the first eight horizontal divisions of the scope's graticule correspond with one frame of the PCM Encoder module's output.

Tip 2: Remember that bit-0 is a frame synchronization bit.

Note: You should find that the PCM Encoder module's output is reasonably close to the code you determined earlier when the module's input was connected directly to ground.

Number: ______________________________

Ask the instructor to check your work before continuing.

24. Increase the VarDC VI's output voltage in small increments in the **negative** direction and note what happens to the binary number on the PCM Encoder module's output.

Question 7
What happens to the binary number as the input voltage increases in the negative direction?

25. Determine the first instance of the changing negative voltage that produces the number 0000000 on the PCM Encoder module's output.

26. Record this voltage in Table 1 below.

Table 1

PCM Encoder's output number	PCM Encoder's input voltage
0000000	

Ask the instructor to check your work before continuing.

27. Return the VarDC VI's output to 0V.

28. Increase the VarDC VI's output voltage in small increments in the **positive** direction and note what happens to the binary number on the PCM Encoder module's output.

Question 8
What happens to the binary number as the input voltage increases in the positive direction?

29. Determine the lowest positive voltage that produces the number 1111111 on the PCM Encoder module's output.

30. Record this voltage in Table 2 below.

Table 2

PCM Encoder's output number	PCM Encoder's input voltage
1111111	

Question 9
Based on the information in Tables 1 & 2, what is the maximum allowable peak-to-peak voltage for an AC signal on the PCM Encoder module's *INPUT*?

Question 10
Calculate the difference between the PCM Encoder module's quantization levels by subtracting the values in Tables 1 & 2 and dividing the number by 128 (the number of possible numbers).

Ask the instructor to check your work before continuing.

Part C – PCM encoding of continuously changing voltages

Now let's see what happens when the PCM encoder is used to convert continuously changing signals like a sinewave.

31. Close the VarDC's VI.

32. Disconnect the plugs to the DAC0 output.

33. Modify the set-up as shown in Figure 9 below.

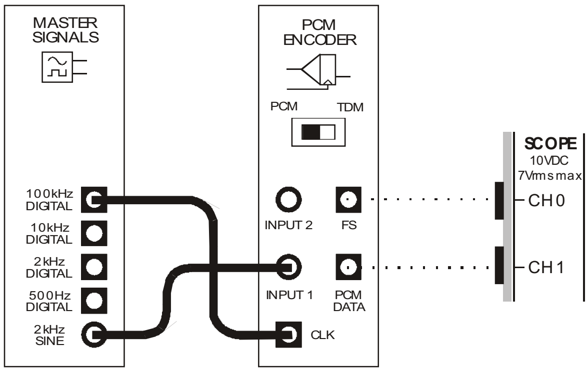

Figure 9

The changes to the set-up shown in Figure 9 can be represented by the block diagram in Figure 10 on the next page. The VarDC has been replaced by the Master Signals module's *2kHz SINE* output to model a continuously changing message.

Notice also that the bit-clock frequency has been increased to 100kHz. This has been done to avoid the problem of *aliasing* mentioned in the preliminary discussion. Without going into too much detail at this stage, aliasing occurs when the sample rate is less than twice the message frequency. A 10kHz clock gives a sample rate of 1250 samples per second (1.25kSa/s) which is well below the 4kSa/s minimum required for a 2kHz message. Using 100kHz clock gives a sample rate of 12kSa/s which comfortably exceeds the minimum sampling requirement.

Why is the sample rate so much lower than the bit-clock frequency? Recall that the PCM Encoder module's output is serial data. Being an 8-bit word, the PCM Encoder module requires eight clock pulses to output each frame. That being the case, there's no point in the PCM Encoder module sampling the analog input at a rate greater than one-eighth of the clock. What would it do with the extra information?

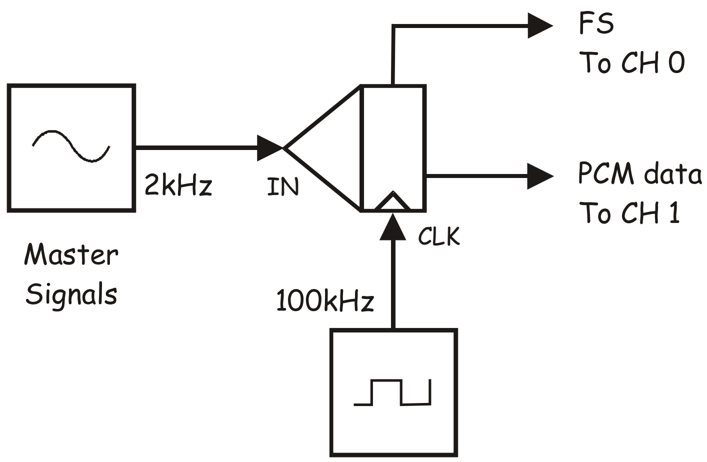

Figure 10

34. Watch the PCM Encoder module's output on the scope's display.

Question 11
Why does the code on PCM Encoder module's output change continuously?

Ask the instructor to check your work before finishing.

Name: ______________________________

Class: ______________________________

11 - Fiber optic bi-directional communication

Experiment 11 – Fiber optic bi-directional communication

Preliminary discussion

An interesting feature of optical fibers is that light traveling in one direction is largely unaffected by light traveling in the opposite direction along the same fiber. This makes sense when you think about it. If you were to shine two torches at each other, their beams wouldn't interfere with one another.

The ability of light to travel in both directions along optical fibers without interfering allows us to use them for bi-directional communications. That said, the loading and unloading of the signals at each end is more involved because both ends of the fiber must be connected to both a transmitter and a receiver. In telecommunications, this is usually managed by a device called a *circulator*. However, circulators for plastic fiber systems are expensive (defeating the purpose of using plastic in the first place). A cheaper alternative involves using two optical couplers but the trade-offs include increased losses and cross-talk.

Recall that an optical coupler is a 4-port device with the ports usually denoted alphabetically from A to D. Recall also that a signal injected in to one port is literally split and becomes available on the two ports at the opposite end of the coupler (though one port's output is significantly stronger than the other). For example, a signal injected in to port A is split between port D (the strong path) and port C (the weak path). Importantly, the optical coupler is a bi-directional device. So, a signal injected in to ports C or D is split between ports A and B and this is true even if a signal is connected to ports A and/or B at the same time. It's this property that allows us to use optical couplers to implement bi-directional fiber optic communications.

Figure 1 below shows the basic implementation of bi-directional fiber optic communications between two stations using optical couplers.

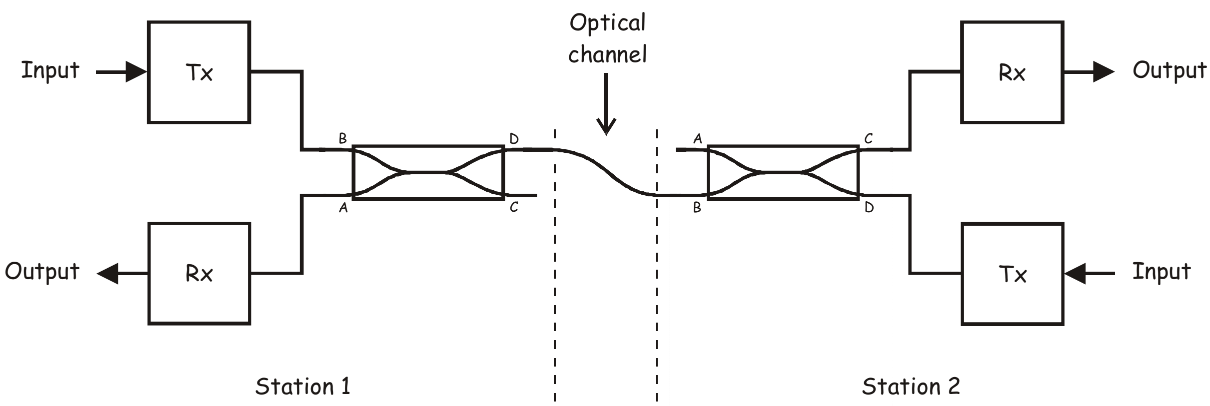

Figure 1

As you can see, the transmitter (Tx) of Station 1 is connected to the channel via the weak path of its optical coupler (that is, from port B to D). This transmitted signal is connected to the receiver (Rx) at Station 2 via the strong path of its optical coupler (that is, from port B to C). At the same time, the transmitter of Station 2 is connected to the channel via the weak path of its optical coupler (that is, from port D to B) and this signal is directed to the Station 1 receiver via its optical coupler's its strong path (that is, from port D to A).

The fact that the two signals travel through a weak path of one of the optical couplers is responsible for the higher losses involved in this method of loading and unloading the signals (compared with using a circulator).

Also, recall from your investigations into the operation of the Coupler modules in Experiment 10, that the input signal to an optical coupler is actually split three ways not just two. A small amount of light is reflected to the port on the same end as the input. For example, a signal injected in to port A results in a very small signal on the output of port B. This is responsible for the cross-talk mentioned earlier and may need to be managed.

The experiment
For this experiment you'll use the Emona FOTEx to set up a uni-directional communication system over a fiber optic channel. Once you've established that the set-up is working, you'll modify it to implement a full fiber optic bi-directional communications system and investigate its operation.

It should take you about 40 minutes to complete this experiment.

Pre-requisites:
Experiment 1: An introduction to the NI ELVIS II test equipment
Experiment 2: An introduction to the Emona FOTEx
Experiment 8: Fiber optic transmission
Experiment 10: Optical signal filtering, splitting and combining

Precaution:
Use this experiment to develop the habit of not looking directly into the end of an optical fiber.

Equipment

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona FOTEx experimental add-in module
- Two BNC to 2mm banana-plug leads
- Assorted 2mm banana-plug patch leads
- Assorted optical patch leads

Procedure

Part A – Setting up a uni-directional fiber optic communications system
Before experimenting with bi-directional fiber optic communications, it's useful to set up a uni-directional link first.

1. Ensure that the NI ELVIS II power switch at the back of the unit is off.

2. Carefully plug the Emona FOTEx experimental add-in module into the NI ELVIS II.

3. Insert the holding screws to secure the FOTEx module to the NI ELVIS II.

   Note: This must be done with the power off to avoid damaging the FOTEx.

4. Connect the NI ELVIS II to the PC using the USB cable.

   Note: This may already have been done for you.

5. Turn on the NI ELVIS II power switch at the rear of the unit then turn on its *Prototyping Board Power* switch at the top right corner near the power indicator.

6. Turn on the PC and let it boot-up.

7. Launch the NI ELVISmx software.

8. Select one of the **red** LED Transmitter modules and set its *Mode* control to *ANALOG*.

9. Select one the Receiver modules and set its *Gain Range* control to *HI*.

10. Turn the same Receiver module’s *Variable Gain* control fully clockwise.

11. Connect the set-up shown in Figure 2 below using the Transmitter and Receiver modules you adjusted for Steps 8 to 10.

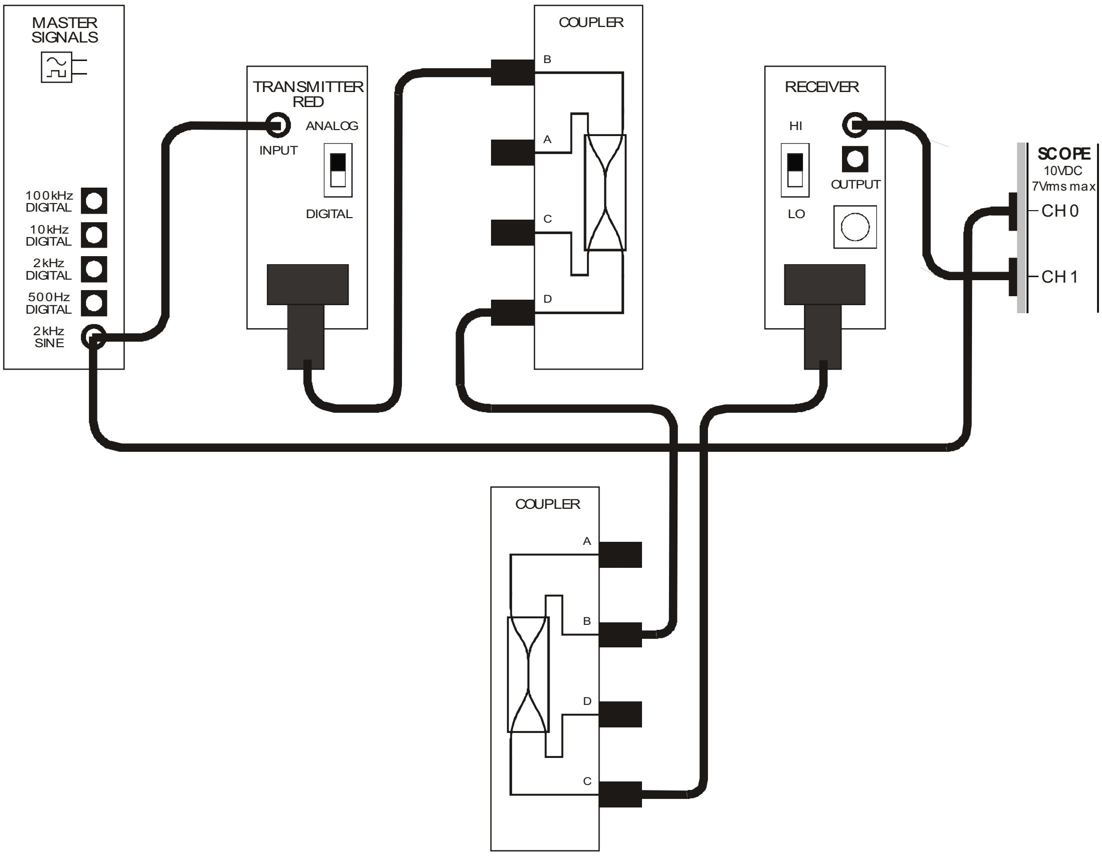

Figure 2

This set-up can be represented by the block diagram in Figure 3 on the next page. Station 1 is the transmitter in a uni-directional communications system and Station 2 is the receiver. An analog message is modeled by the Master Signals module's *2kHz SINE* output. The channel between the stations is modeled by the optical patch lead between the left and right couplers. The optical patch leads between the couplers and the Transmitter and Receiver modules are internal station connections and do not model the channel.

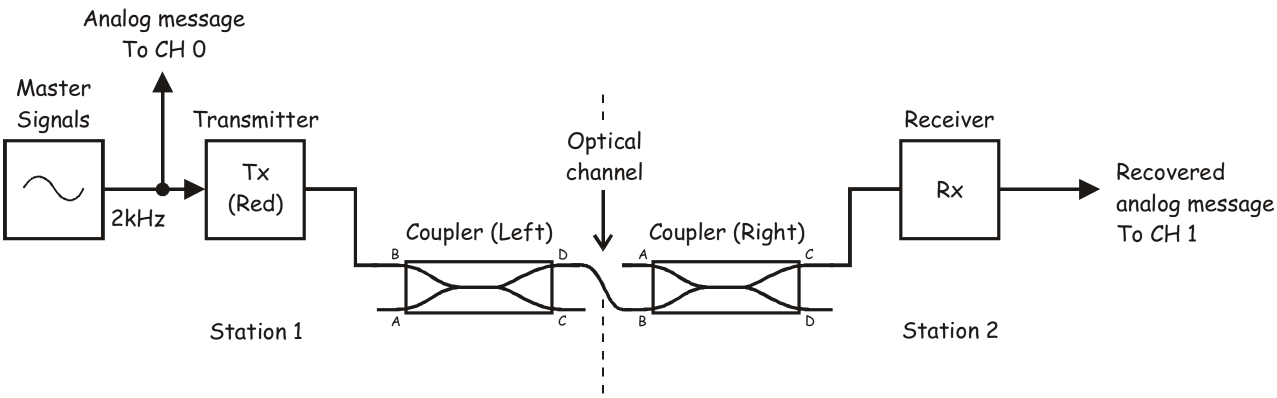

Figure 3

12. Launch and run the NI ELVIS II Oscilloscope VI.

13. Set up the scope per the procedure in Experiment 1 (page 1-12) with the following change:

    - *Timebase* control to *100μs/div* instead of *500μs/div*

14. Activate the scope's Channel 1 input to observe the recovered version of the analog message on the output of Station 2.

    Note: If the set-up has been wired correctly, you should observe a copy of the message at about the same amplitude.

Ask the instructor to check
your work before continuing.

Part B – Converting the set-up to a fiber optic bi-directional communications system

An additional Transmitter and Receiver module can be used to readily convert the current set-up to a bi-directional link. The next part of the experiment gets you to do so.

15. Set the *Mode* control of the other red Transmitter module to *DIGITAL*.

16. Set the *Gain Range* control of the other Receiver module to *LO*.

17. Turn the same Receiver module's *Variable Gain* control to about the middle of its travel.

18. Make the following changes to the scope's set-up:

   - *Input Coupling* controls for both channels to the *DC* position instead of the *AC* position
   - Channel 1 *Vertical Position* control to *-5V* instead of *0V*
   - *Timebase* control to the *50µs/div* position instead of the *100µs/div* position
   - *Trigger Type* control to the *Digital* position instead of the *Edge* position

19. Modify the set-up as shown in Figure 4 below.

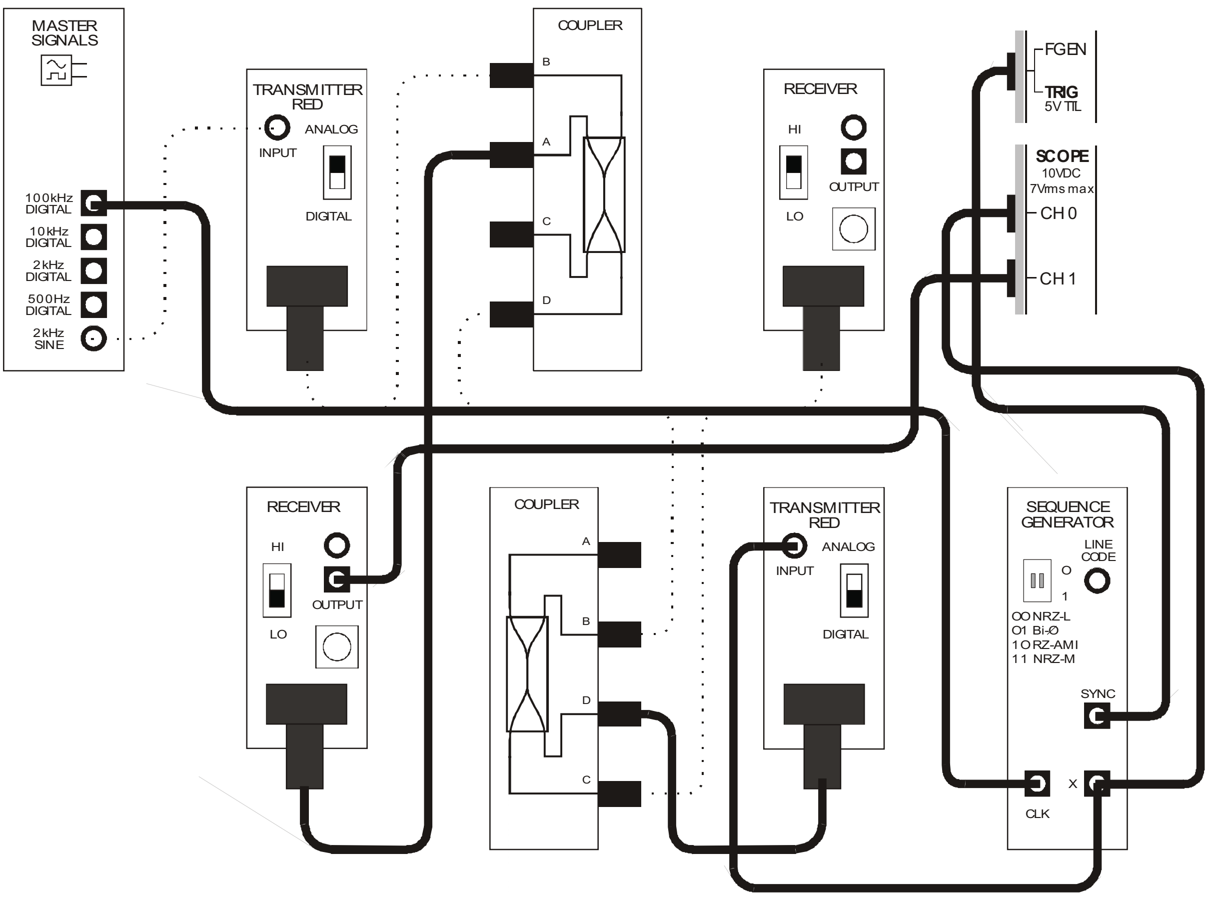

Figure 4

The set-up in Figure 4 can be represented by the block diagram in Figure 5 below. Both stations can now transmit and receive information. For contrast, the Station 2 message is a digital data signal modeled by the Sequence Generator module with a 100kHz bit-clock. The channel (modeled by the optical patch lead between the left and right couplers) now carries information in both directions.

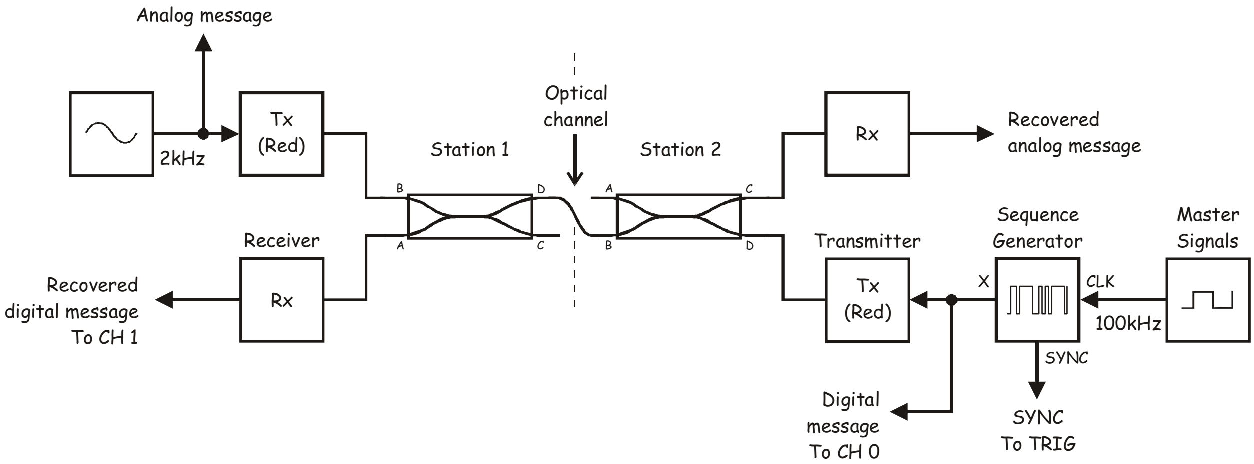

Figure 5

20. Observe digital data message and the recovered version of it on the output of Station 1.

Note: If the set-up has been wired correctly and the scope is adjusted correctly, you should observe two digital data signals with the same amplitude.

Question 1
In which direction does the analog message travel?

☐ From Station 1 to Station 2

☐ From Station 2 to Station 1

Question 2
In which direction does the digital message travel?

☐ From Station 1 to Station 2

☐ From Station 2 to Station 1

Question 3
How many of the optical patch leads are used to model the channel?

Ask the instructor to check your work before continuing.

21. Modify the scope's connections to the set-up as shown in Figure 6 below.

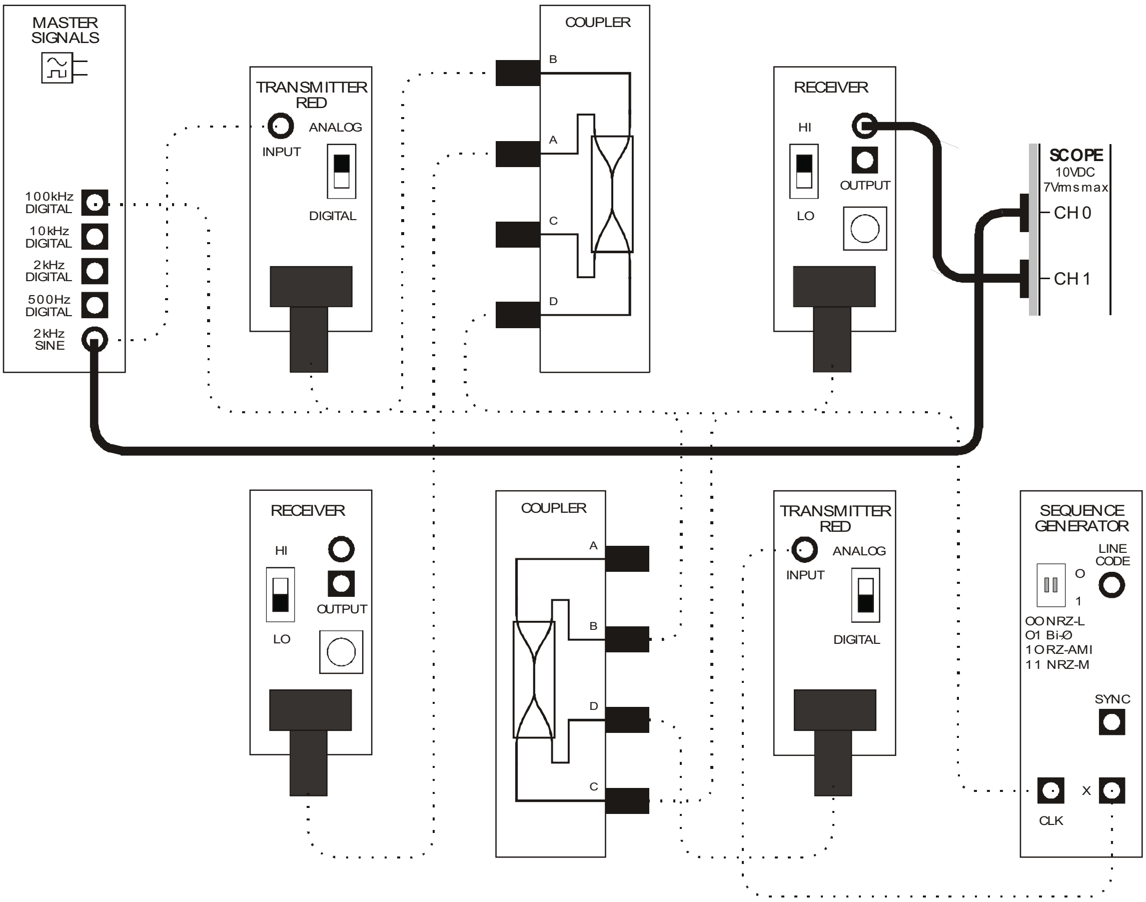

Figure 6

The changes to the scope's connections in Figure 6 can be represented by the block diagram in Figure 7 below. The change has been made to observe the analog message and the recovered version of it.

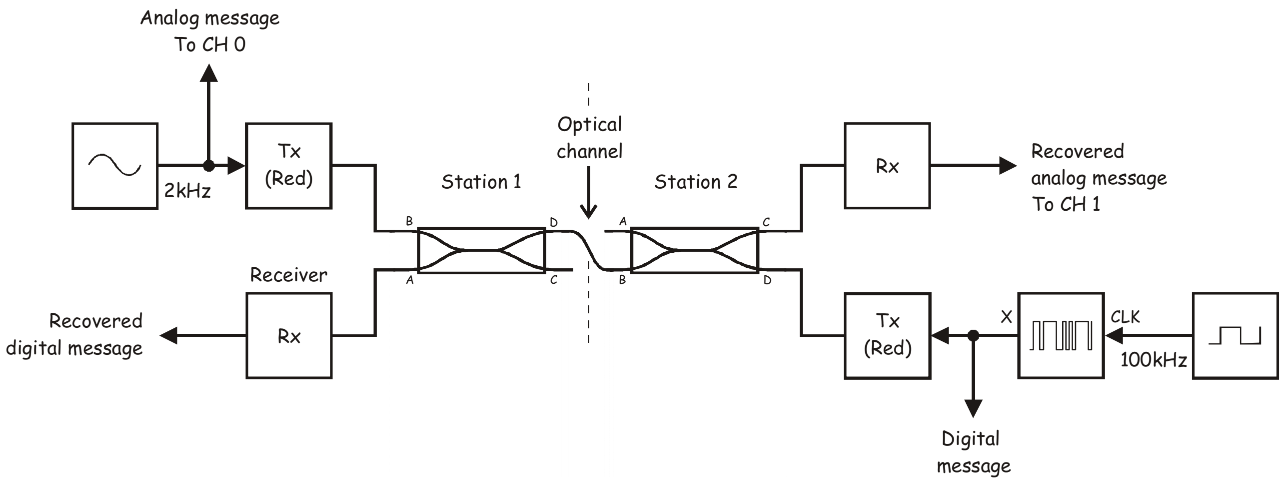

Figure 7

22. Make the following changes to the scope's set-up:

- *Input Coupling* controls for both channels back to the *AC* position
- Channel 1 *Vertical Position* control back to *0V*
- *Timebase* control back to the *100μs/div* position
- *Trigger Type* control back to the *Edge* position

23. Observe the analog message and the recovered version of it.

Note: You should see that the recovered version of the analog message is now distorted.

Question 4
It's clear that some of the digital message is super-imposed on the recovered version of the analog message? What's the name for this problem?

____

Question 5
Which one of the Coupler modules is causing this problem and why?

____

____

____

Question 6
How can the analog message be cleaned up?

Question 7
Under what conditions would this solution be unsuitable for this set-up?

Question 8
Why didn't the recovered version of the digital message (on the output of Station 1) experience this problem?

Ask the instructor to check
your work before continuing.

Question 9
Which optical patch lead or leads in the set-up are carrying information in both directions?

____

____

The next part of the experiment lets you verify your answer to Question 9.

24. Disconnect one end of any one of the optical patch leads and observe the effect on the recovered message.

25. Reconnect the optical patch lead.

26. Repeat Steps 24 and 25 for the rest of the optical patch leads. Make a note of all the patch leads that, when disconnected, cause the recovered analog message to be lost.

27. Modify the scope's connections to the set-up as shown in Figure 8 below.

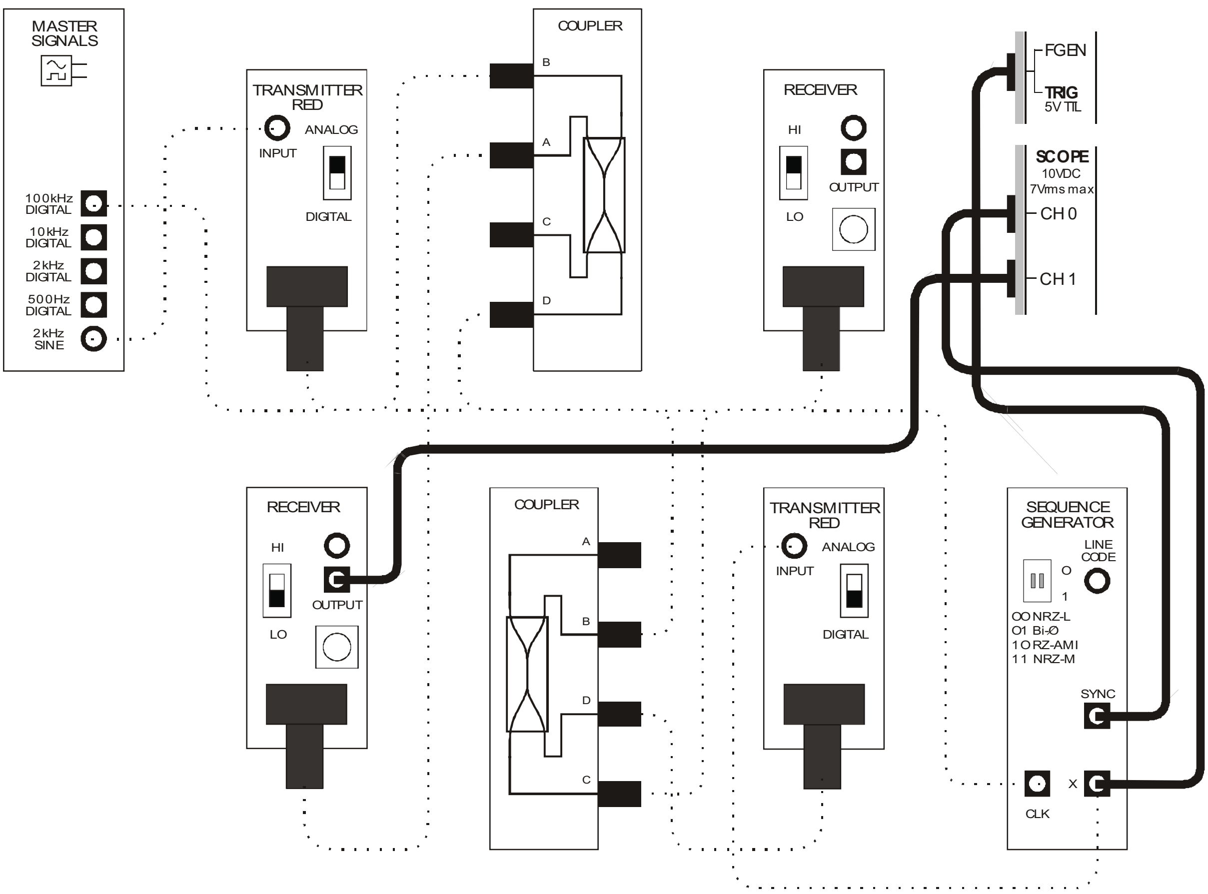

Figure 8

The changes to the scope's connections return the set-up to the block diagram in Figure 5.

28. Make the following changes to the scope's set-up:

- *Input Coupling* controls for both channels back to the *DC* position
- Channel 1 *Vertical Position* control back to *-5V*
- *Timebase* control back to the *50µs/div* position
- *Trigger Type* control back to the *Digital* position

29. Repeat Steps 24 to 26.

Note: As you do, note which optical patch lead or leads from Steps 24 to 26 also cause the recovered digital message to be lost.

Question 10
Explain how your observations prove your answer to Question 9.

Think about the physical nature of this optical medium and consider how it differs from electrical signals traveling in a channel made of an electrical conductor. With the bi-directional electrical signal, the opposing currents (made up of electron flow) subtract from one another and the individuality of the signals is lost. In the case of the optical medium, the photons of light are independent elements and do not interact significantly with other elements in the channel.

Importantly, this is true even when both optical signals are operating in the same frequency band as long as they're traveling in opposite directions. However, if they are operating at the same frequency band but traveling in the same direction, it's impossible to separate them at the receiver. This issue is explored in Experiment 11 on wave division multiplexing (WDM).

Ask the instructor to check your work before finishing.

Emona FOTEx™ Fiber Optics Communications Trainer Lab Manual - Experiments in Modern Fiber Optic Communicaitons Systems For NI™ ELVIS I & II.

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