

***Emona FOTEx
Lab Manual***

**Experiments in Modern
Fiber Optic Communications Systems
for the ADS Max Lab equipment**

Barry Duncan

SAMPLE MANUAL



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**Experiments in Modern Fiber Optic Communications Systems.
SAMPLE MANUAL**

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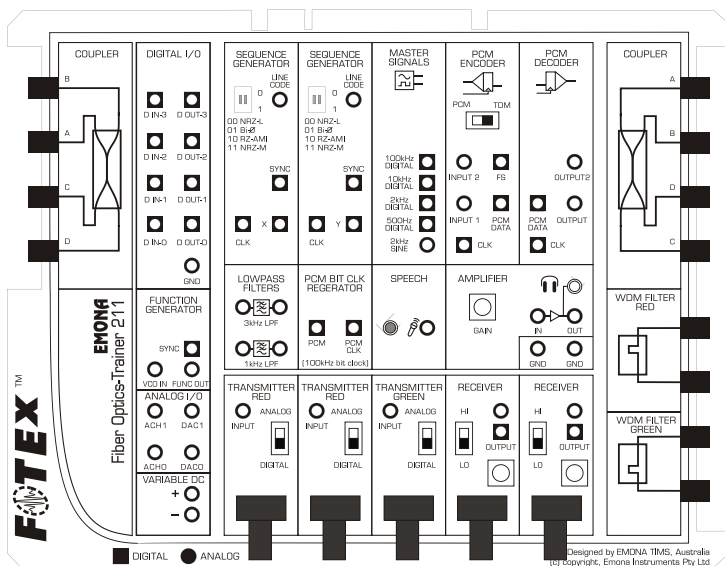
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Introduction

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 ADS MAX 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 ADS MAX platform and DIGILENT WaveForms software running on a PC. The functionality and range of the virtual instrumentation available depends on the instrumentation built into the ADS MAX platform.

Refer to the ETT-211 FOTEx USER MANUAL for further details, as well as information on the installation and use of the FOTEx/ADS MAX 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.

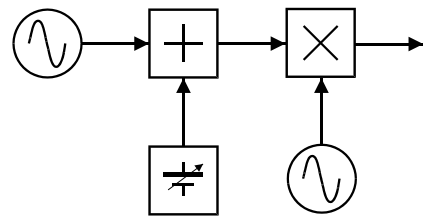
Didactic philosophy behind the ETT-211 FOTEx™ System

- Emona TIMS™ and the "Block Diagram" approach

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

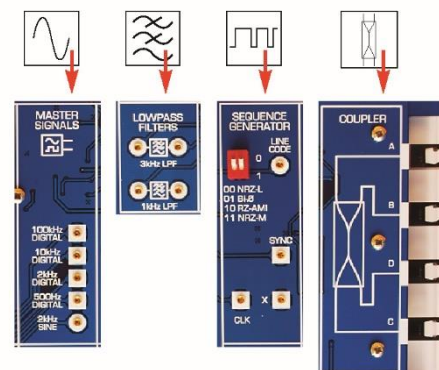
The TIMS™ and hence FOTEx™ approach to implementing telecommunications experiments through realizing BLOCK DIAGRAMS has the following benefits in the educational environment:

- 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

DIGILENT WaveForms™ and FOTEx™

The Emona FOTEx add-in module is fully integrated with the ADS MAX platform and DIGILENT WaveForms environment. All FOTEx™ analog and digital I/O can be controlled through the WaveForms software.

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 ADS MAX 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 single 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 ADS MAX 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 ADS MAX 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.

Name: _____

Class: _____

1 - An introduction to the ADS MAX Lab equipment

Experiment 1 -

An introduction to the ADS Max Lab 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 ADS MAX 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 ADS MAX sends the information via USB to a personal computer where the measurements are displayed on one screen.

On the computer, the ADS MAX 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 two ADS MAX devices and others so it's important that you're familiar with their operation.

The experiment

This experiment introduces you to the ADS MAX 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
- ADS Max plus USB cable and power pack
- Emona FOTEx experimental add-in module
- Six 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.

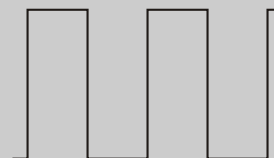


Figure 2

Procedure

Part A - Getting started

1. Ensure that the ADS MAX power switch at the back of the unit is off.
2. Carefully plug the Emona FOTEx experimental add-in module into the ADS MAX.
3. **Insert the holding screws to secure the FOTEx module to the ADS MAX.**

Note 1: This may already be done for you. If not, the screws are supplied with the ADS MAX 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 ADS MAX to the PC using the USB cable.

Note: This may already have been done for you.

5. Turn on the ADS MAX power switch at the rear of the unit then turn on its *Board Power* switch at the top left corner of the unit.
6. Turn on the PC and let it boot-up.

Part B – The ADS MAX Oscilloscope: SCOPE window

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

1. Launch the DIGILENT WaveForms software and load and run Workspace: **L1-Fx_setup1.dwf3work**

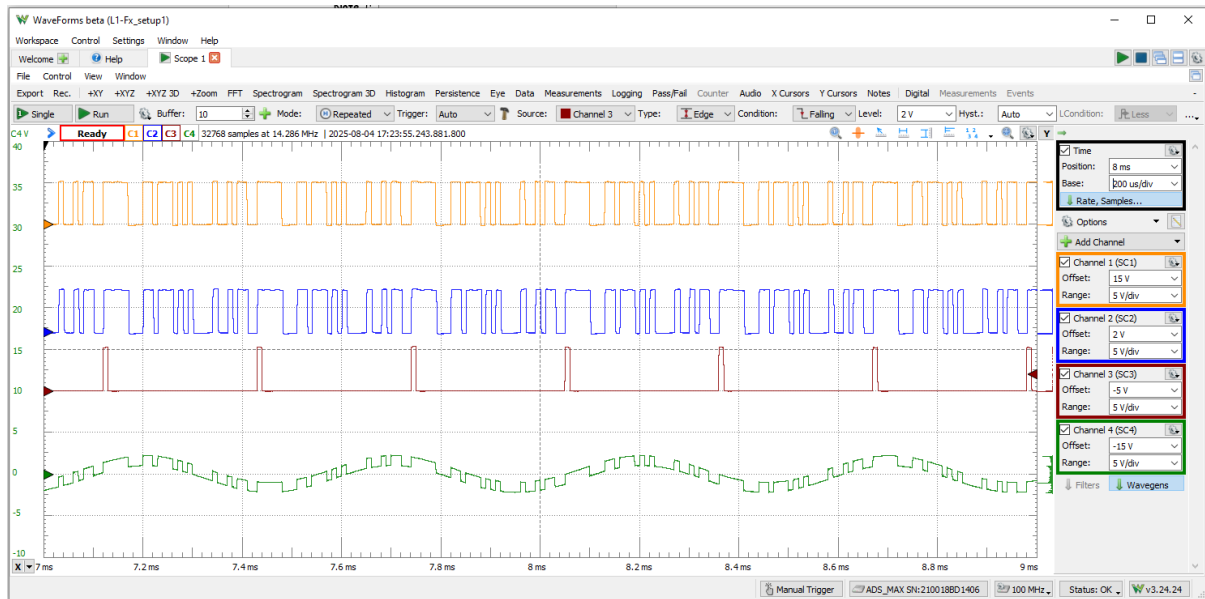


Figure 3: WaveForms SCOPE window

2. The Workspace selected above will display a SCOPE window.

The ADS MAX Oscilloscope is operated using the controls on its virtual instrument. Although operating the ADS MAX 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.

The WaveForms software for the SCOPE includes an enormous number of powerful features and options. Many are intuitive, and some require you to read the HELP information if you need to use them.

Procedure for setting up the ADS MAX Oscilloscope

3. 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 1 Source* control is ticked and thus selected.
- ii) Check that the *Probe* control for both channels is set to $1\times$, under *SETTINGS* (small gear symbol)
- iii) Set the *Coupling* control for channel to DC.
- 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 $500\mu s/div$ position.

Trigger

- i) Set the *Type* control to *Edge*.
- ii) Set the *Source* control to AUTO and Channel 1.
- iii) Check that the *Level* control is set to 0. This level can be set using the arrow on the righthand side of the scope display.
- iii) Check that the *Slope* control is set to the RISING position.

4. Activate the scope by clicking on its *RUN* button.

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

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

Note 1: As you will see, the scope's Channel 1 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.

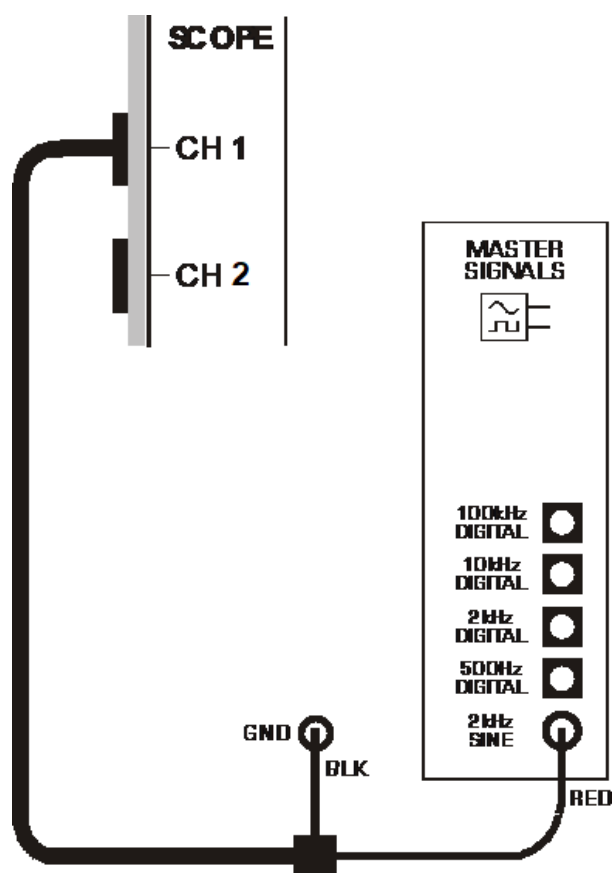


Figure 4: Scope connection patching diagram

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.

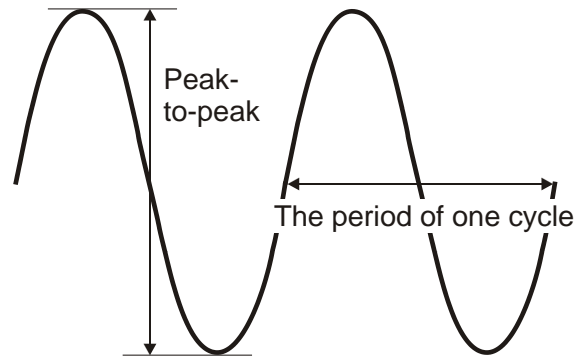


Figure 5

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:

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

Measuring the amplitude of signals and determining their frequency using conventional scopes is a little more involved than using a digital multimeter. As such, it can be easy for the novice to make mistakes. Helpfully, the ADS MAX 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.

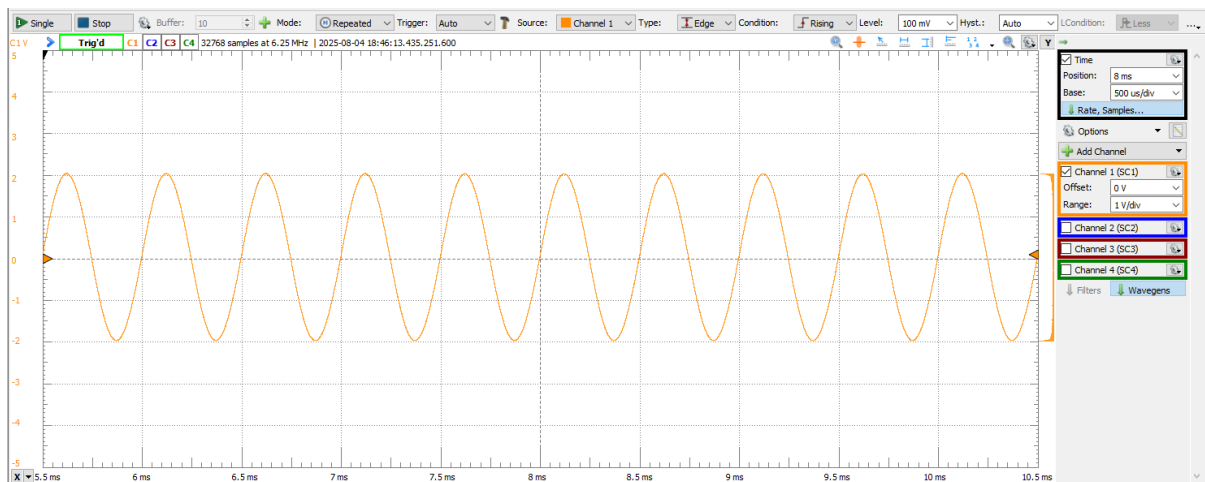


Figure 6a: Scope display

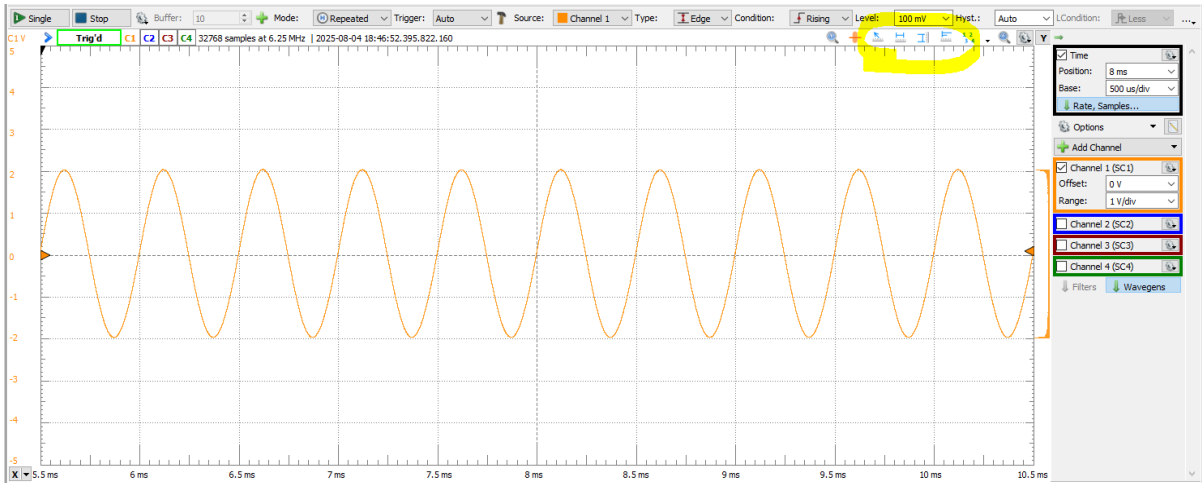


Figure 7b: Scope display with QUICK MEASURE tools highlighted

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

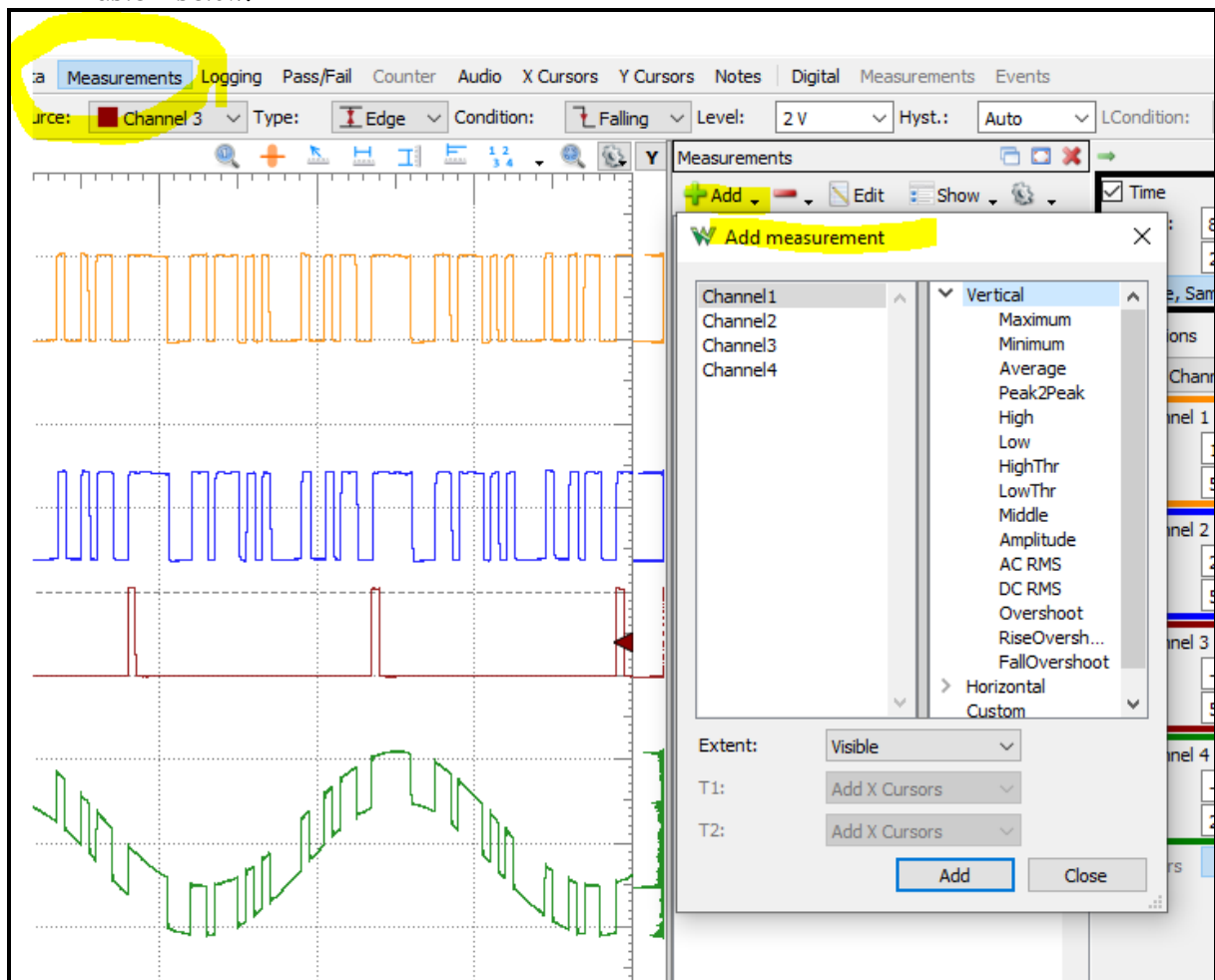


Figure 8c: Scope display with MEASUREMENTS tools highlighted

- 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 | |

Part C – The ADS MAX Function Generator

The ADS MAX Function Generator (FGEN) is an instrument that can output AC & DC signals of various shapes, sizes and frequencies to two BNC terminals on the ADS MAX. Its operation is briefly discussed next.

The Workspace you have loaded ALSO has set-up the WAVEGEN instrument, which controls the built-in FUNCTION GENERATOR outputs FG1 and FG2.

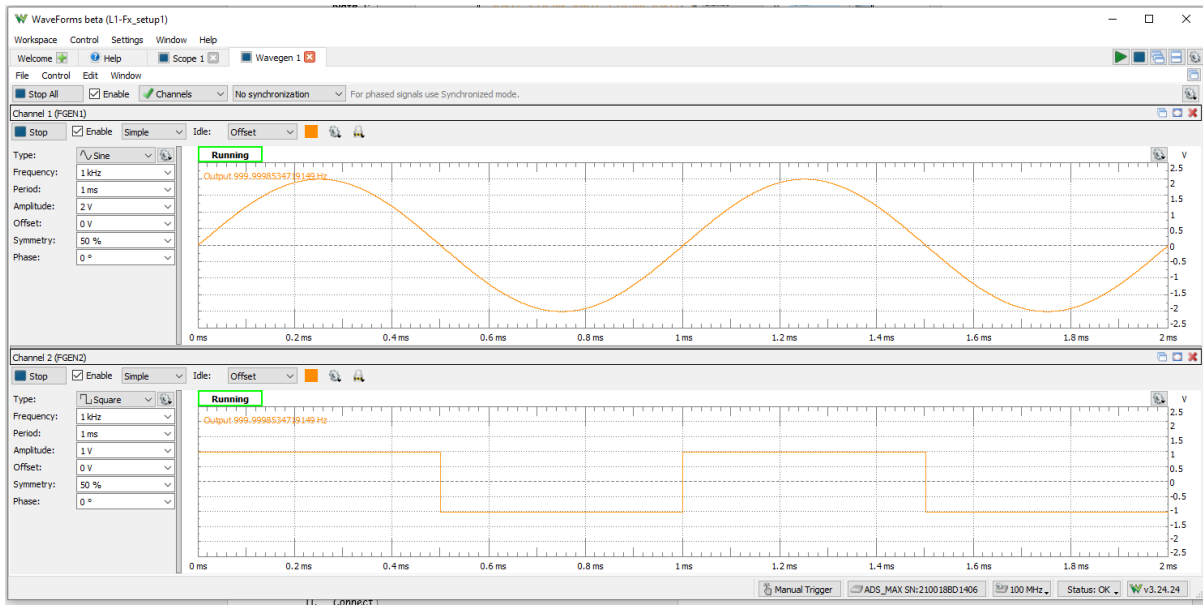


Figure 13: WAVEGEN display with both FGEN channels defined

1. Run the function generator by clicking on its RUN ALL button.
2. 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.

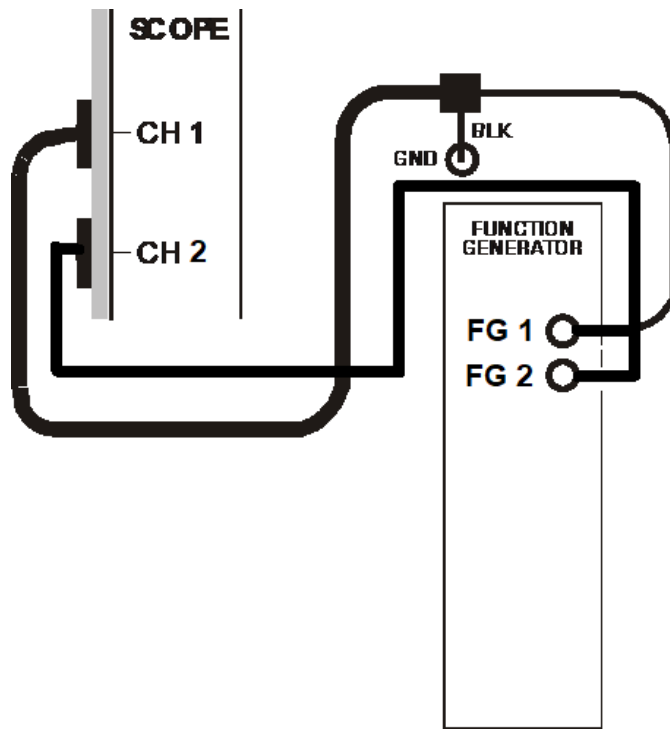


Figure 9: FUNCTION GENERATOR to SCOPE patching diagram

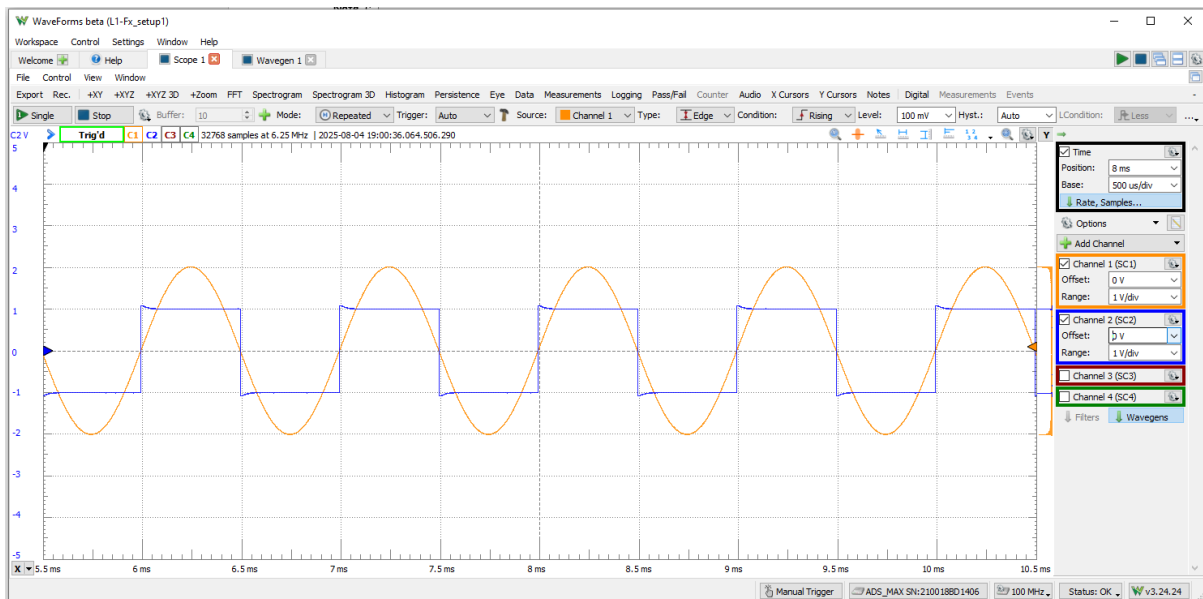


Figure 15: SCOPE display of FUNCTION GENERATOR outputs

3. Set the scope's *Timebase* control to the 500us/div position.
4. Vary the function generator's soft *Amplitude* control and observe the effect on the function generator's output as viewed in the SCOPE window.

5. Set the function generator's amplitude to exactly 2.8V by typing that number into the *AMPLITUDE* window then pressing the *Enter* key.
6. Vary the function generator's soft *Frequency* control and observe the effect on the function generator's output.
7. Set the function generator's frequency to exactly 135 Hz by typing that number into the *Hz* window below the soft *Frequency* control then pressing the *Enter* key.

Name: _____

Class: _____

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

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

Preliminary discussion

The Emona FOTEx experimental add-in module for the ADS MAX 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 ADS Max Lab equipment (or previous experience in operating the ADS MAX Lab equipment).

Equipment

- Personal computer with appropriate software installed
- ADS Max 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 ADS MAX Oscilloscope.

Procedure

1. Ensure that the ADS MAX power switch at the back of the unit is off.
2. Carefully plug the Emona FOTEx experimental add-in module into the ADS MAX.
3. **Insert the holding screws to secure the FOTEx module to the ADS MAX.**

Note 1: This may already be done for you. If not, the screws are supplied with the ADS MAX 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 ADS MAX to the PC using the USB cable.

Note: This may already have been done for you.

5. Turn on the ADS MAX power switch at the rear of the unit then turn on its *Board Power* switch at the top left corner of the unit.
6. Turn on the PC and let it boot-up.
7. Launch the DIGILENT WaveForms software and load and run Workspace:
L2-Fx_setup1.dwf3work

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.

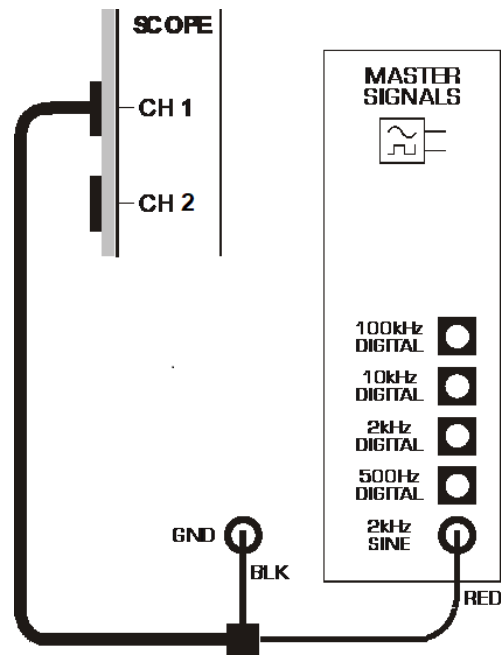


Figure 1: 2kHz sinewave to scope patching diagram

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

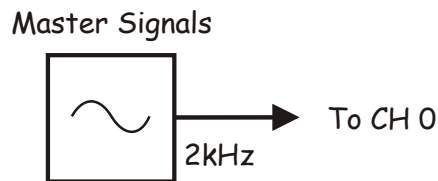


Figure 2: 2kHz sinewave to scope block diagram

2. Launch and run the ADS MAX 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.

- 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.

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

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.

- Disconnect the scope from the Master Signals module.
- Set the scope's *Timebase* control to the 2ms/div position.
- Return the scope's *Trigger Level* control to 0V.
- Connect the set-up shown in Figure 3 below.

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

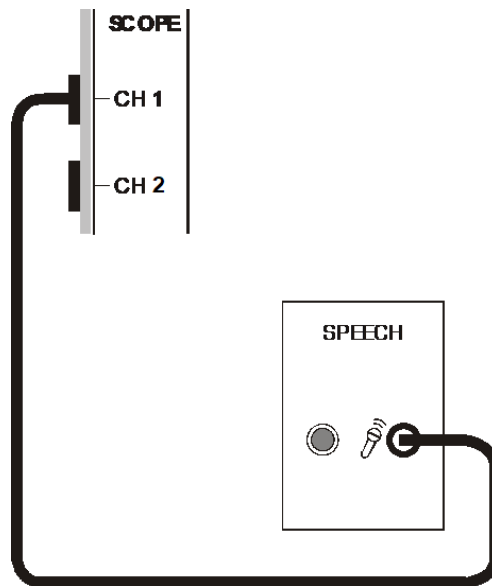


Figure 3: SPEECH module to scope patching diagram

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

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.

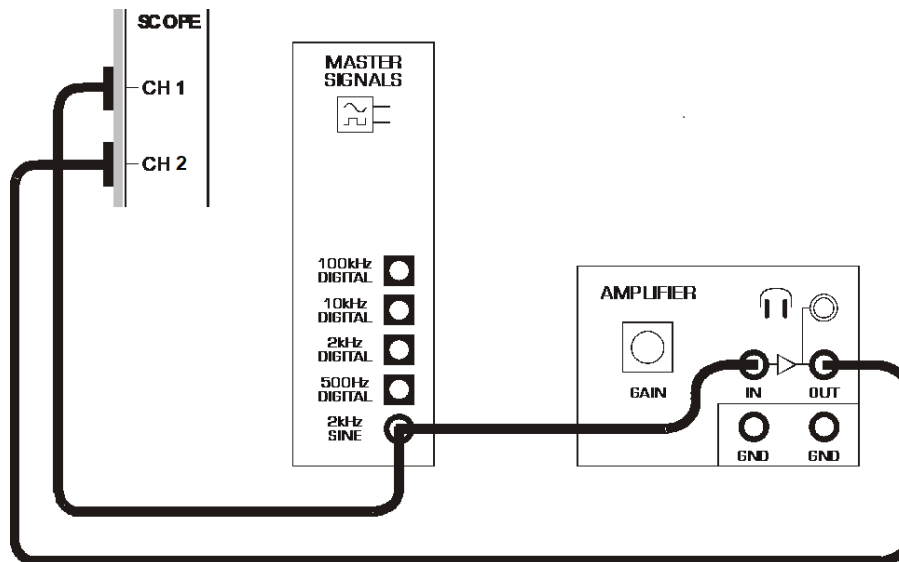


Figure 4: AMPLIFIER module usage patching diagram

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

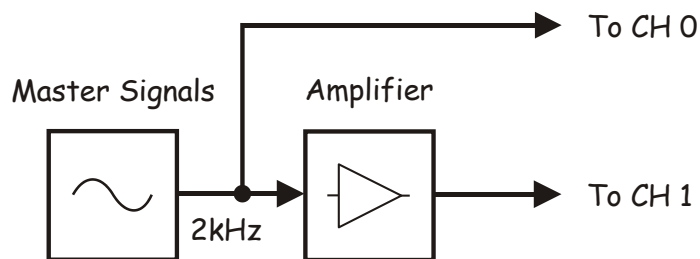


Figure 5: AMPLIFIER module usage block diagram

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.

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

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:

$$A_V = \frac{V_{out}}{V_{in}}$$

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:

$$A_{V(dB)} = 20\text{Log}\left(\frac{V_{out}}{V_{in}}\right)$$

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.

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?

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?

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.

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 ADS MAX 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 6 below.

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

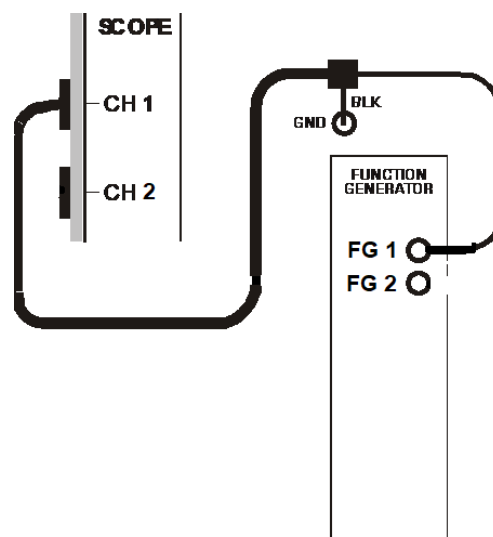


Figure 6: FUNCTION GENERATOR viewing with SCOPE

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 7 below.

Tip: Use a spare scope channel for the TRIGGER input source.

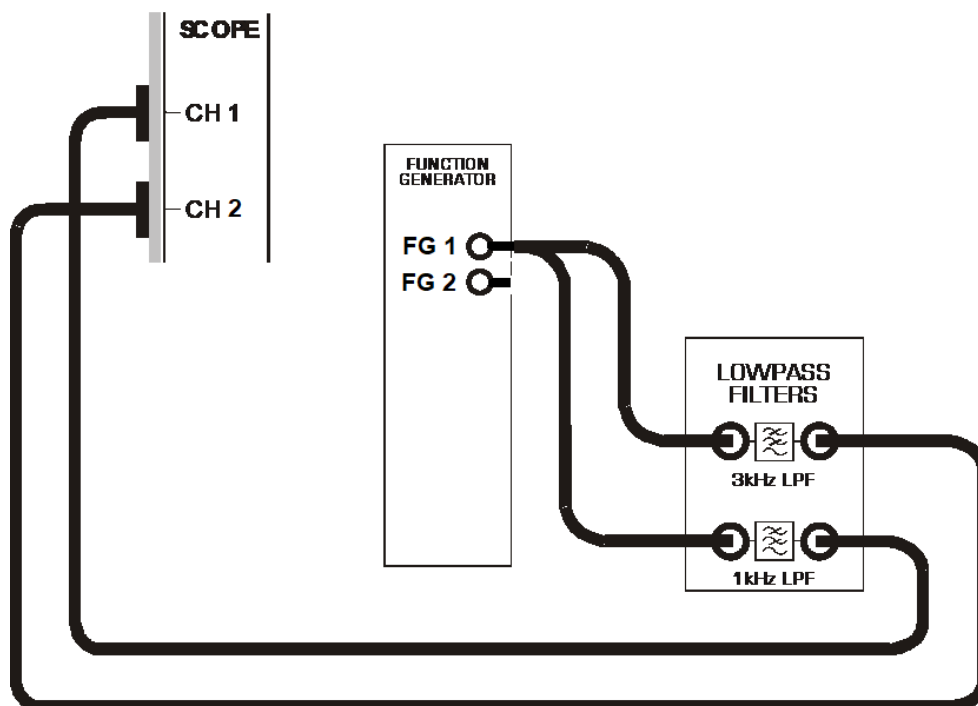


Figure 7: FUNCTION GENERATOR to LOW PASS FILTER modules

This set-up can be represented by the block diagram in Figure 8 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 1 is used to view the 1kHz LPF's output while Channel 2 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.

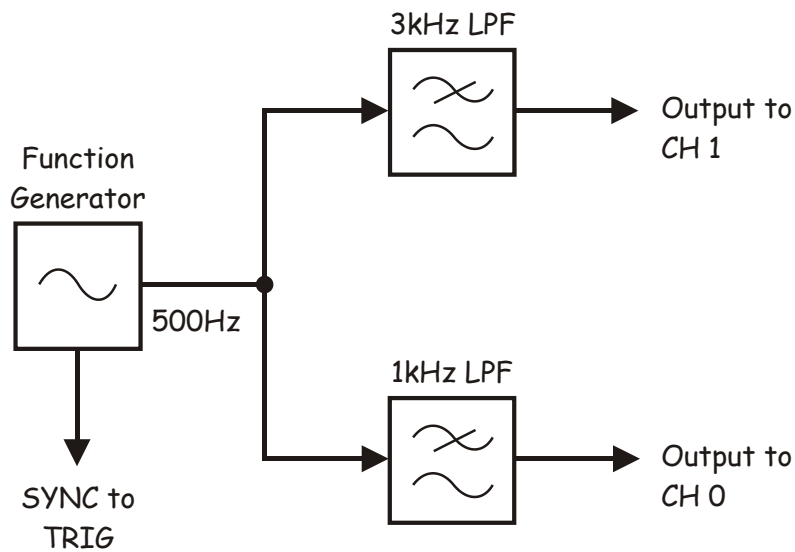


Figure 8: FUNCTION GENERATOR to LOW PASS FILTER block diagram

40. Set the scope's *Trigger Type* to *Digital*.
41. Measure the output voltage of the two filters. Record your measurements in Table 4 below.
42. Calculate the gain (in decibels) of the two filters.
43. Set the function generator's FG1 output frequency to 1kHz then repeat Steps 42 and 43.
44. 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

| | | 1kHz LPF | | 3kHz LPF | |
|-------|---------------|----------------|----------------------|----------------|----------------------|
| | Input voltage | Output voltage | Voltage gain (in dB) | Output voltage | Voltage gain (in dB) |
| 500Hz | 4Vp-p | | | | |
| 1kHz | | | | | |
| 2kHz | | | | | |
| 3kHz | | | | | |
| 4kHz | | | | | |
| 5kHz | | | | | |

Question 6

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

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.

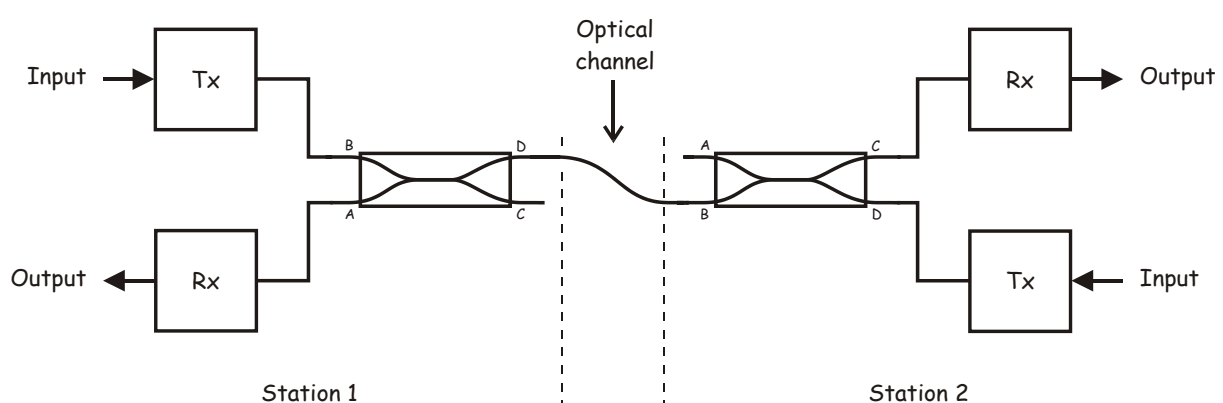


Figure 1: Coupler channel block diagram

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 ADS Max Lab 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
- ADS Max plus USB cable and power pack
- Emona FOTEx experimental add-in module
- Six 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 ADS MAX power switch at the back of the unit is off.
2. Carefully plug the Emona FOTEx experimental add-in module into the ADS MAX.
3. **Insert the holding screws to secure the FOTEx module to the ADS MAX.**

Note 1: This may already be done for you. If not, the screws are supplied with the ADS MAX 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 ADS MAX to the PC using the USB cable.

Note: This may already have been done for you.

5. Turn on the ADS MAX power switch at the rear of the unit then turn on its *Board Power* switch at the top left corner of the unit.
6. Turn on the PC and let it boot-up.
7. Launch the DIGILENT WaveForms software and load and run Workspace:
L11-Fx_setup1.dwf3work
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.

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

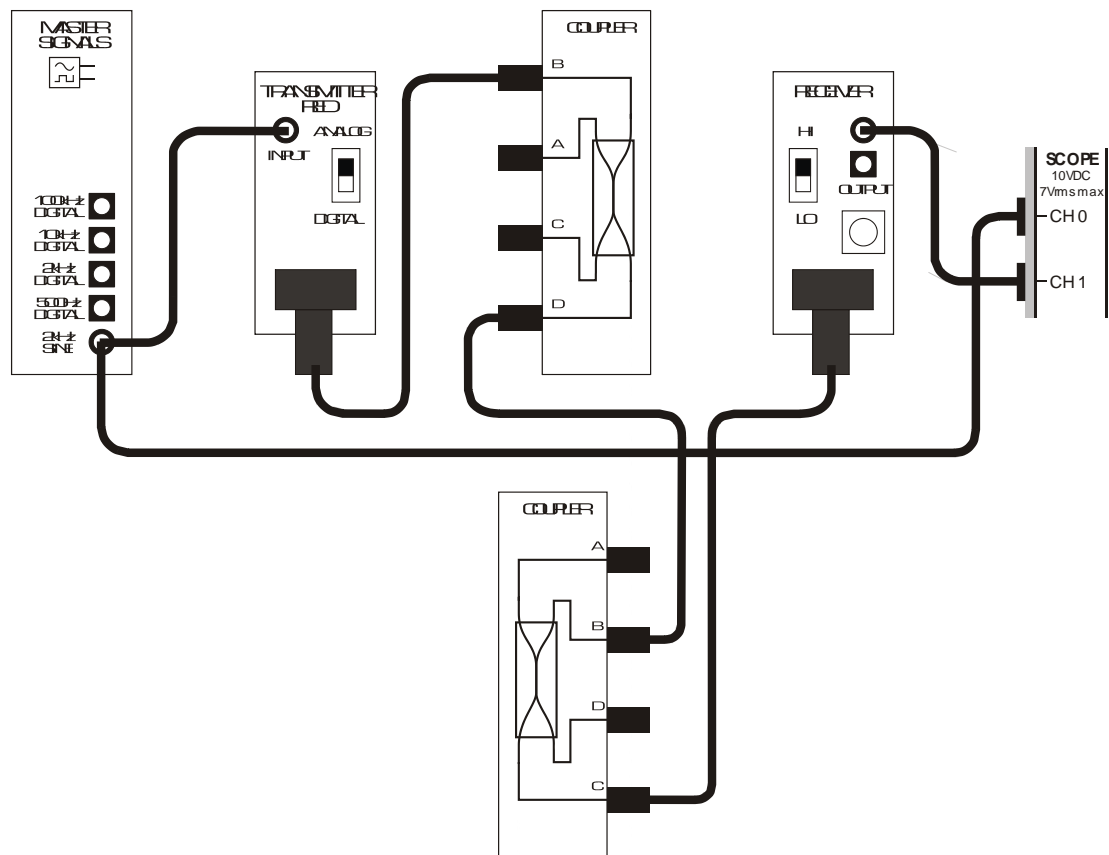


Figure 2: Coupler patching diagram

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.

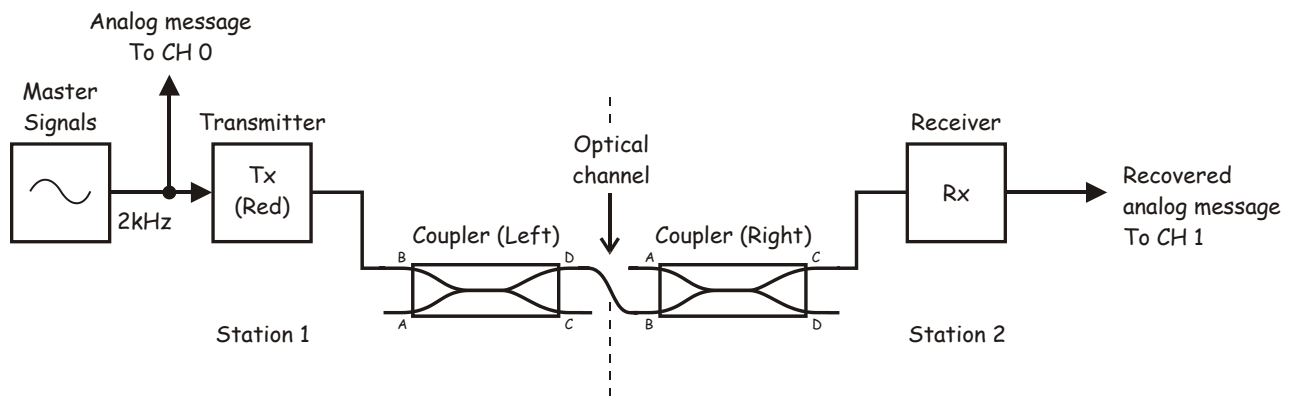


Figure 3: Coupler channel block diagram

12. Launch and run the ADS MAX Oscilloscope.
13. Set up the scope per the procedure in Experiment 1 (page 1-12) with the following change:
 - *Timebase control to 100 μ s/div instead of 500 μ s/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.

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 *50 μ s/div* position instead of the *100 μ s/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. **NOTE: use the longest fiber patchcord for the CHANNEL connection D-1 to B-2**

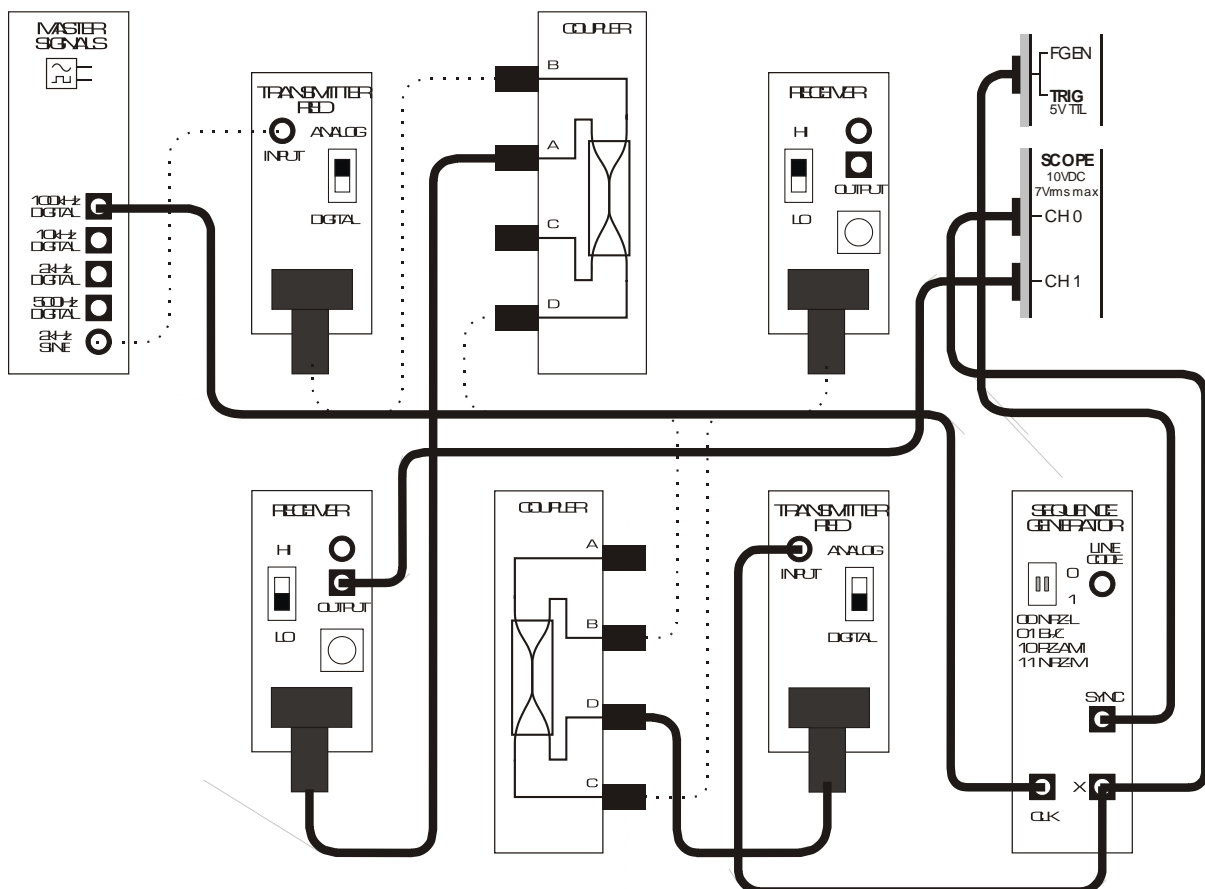


Figure 4: Bi-directional channel patching diagram

Take care not to strain the patchcords or bend excessively when installing or removing them from their tight sockets.

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.

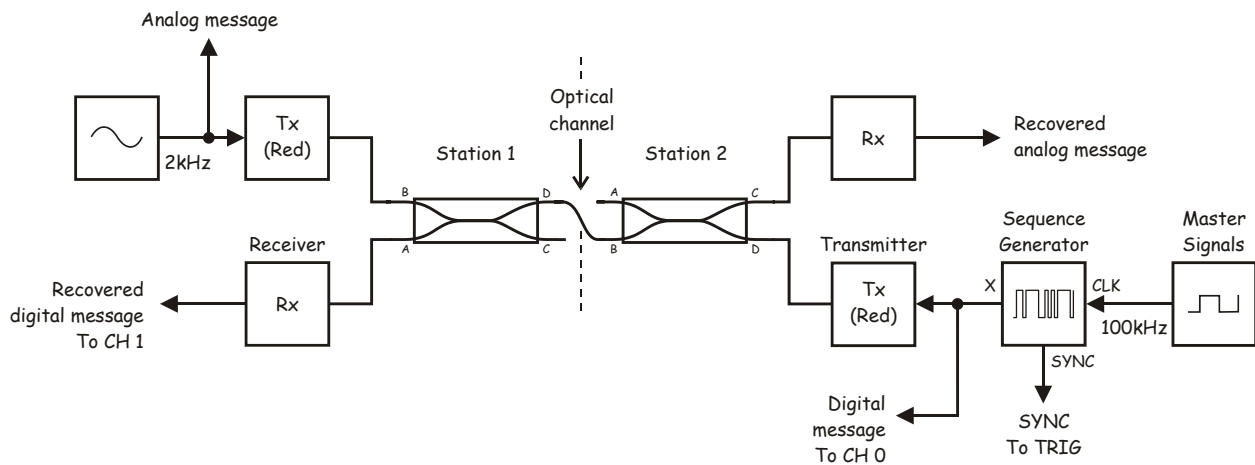


Figure 5: Bi-directional channel block diagram

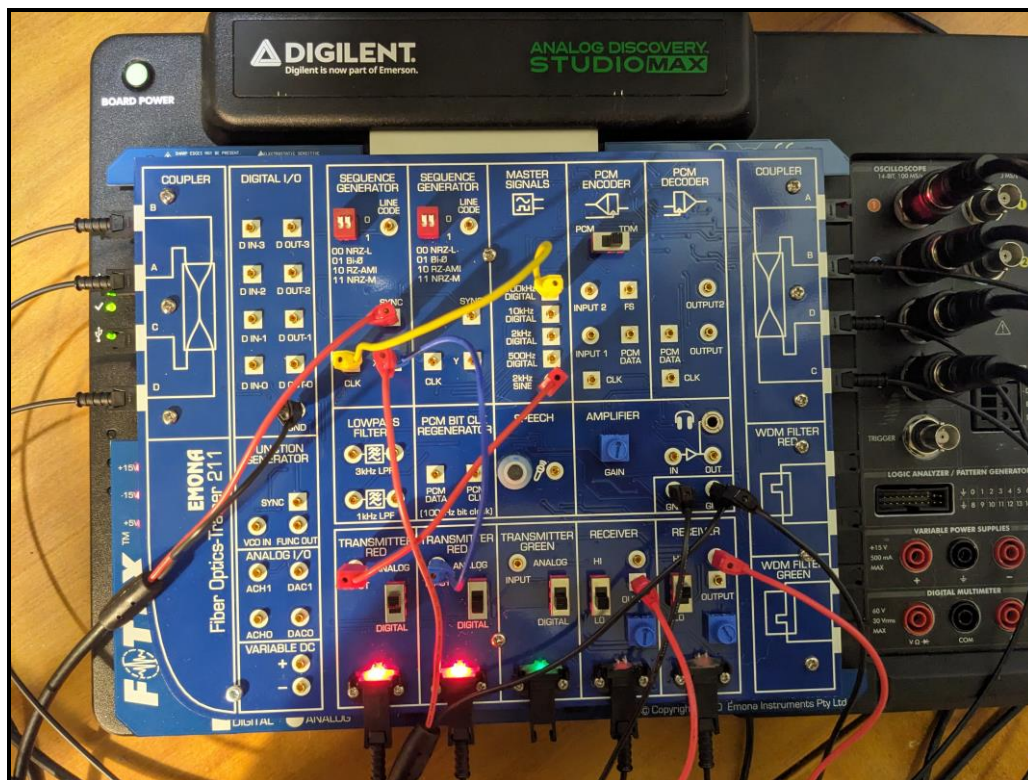


Figure 6a: Bi-directional channel patching

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?

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

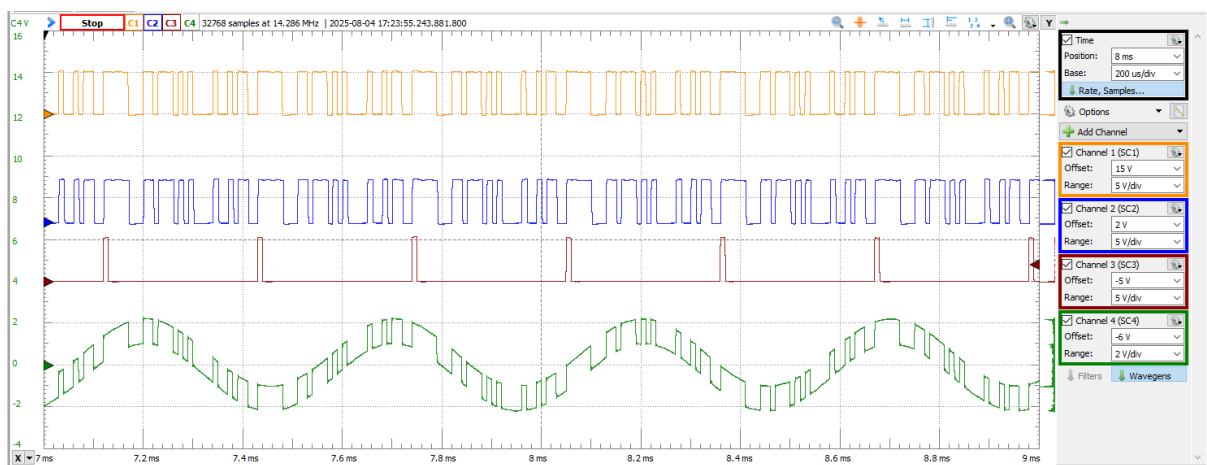


Figure 5b: Bi-directional channel signals

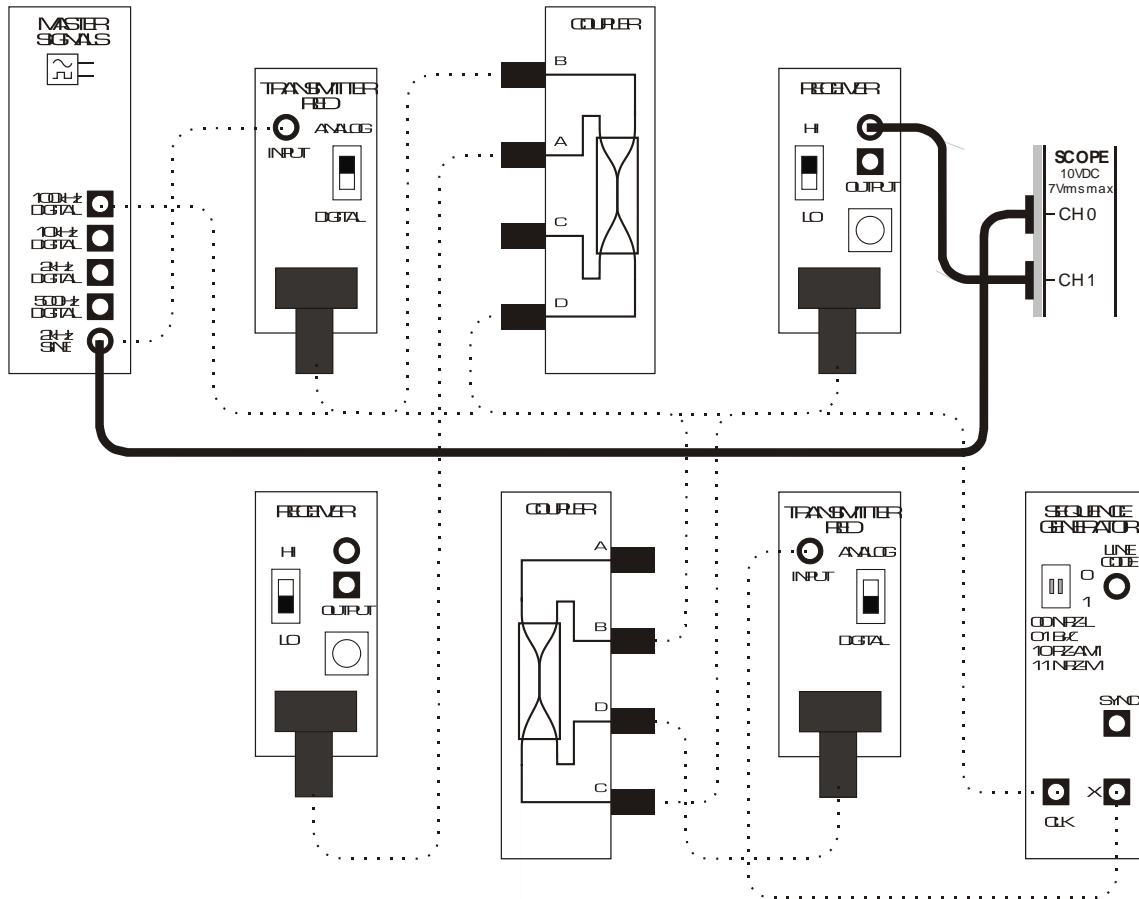


Figure 7: Bi-directional channel patching diagram

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.

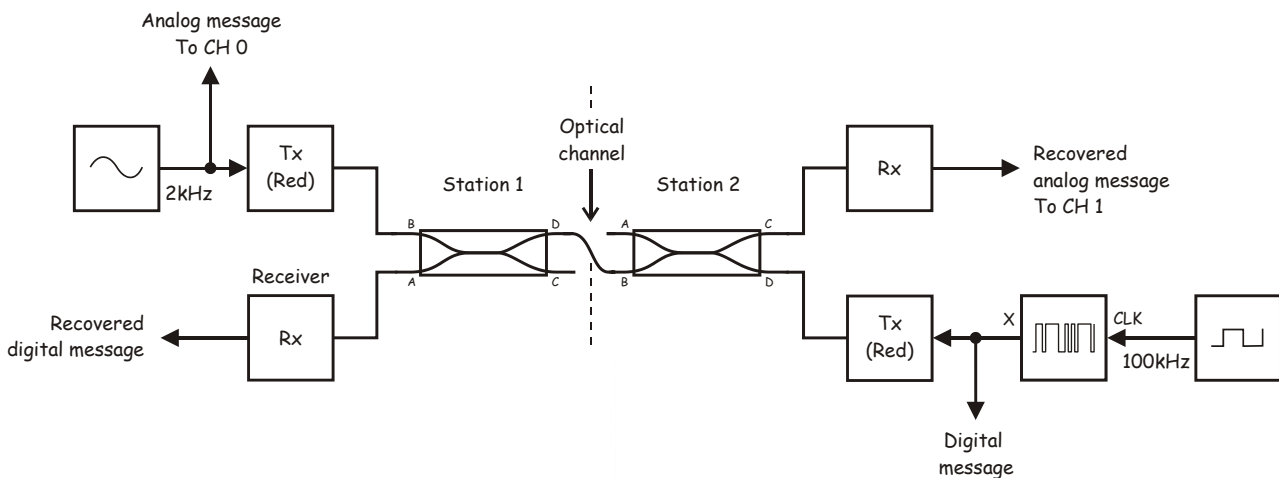


Figure 8: Bi-directional channel block diagram

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 *100 μ s/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?

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.

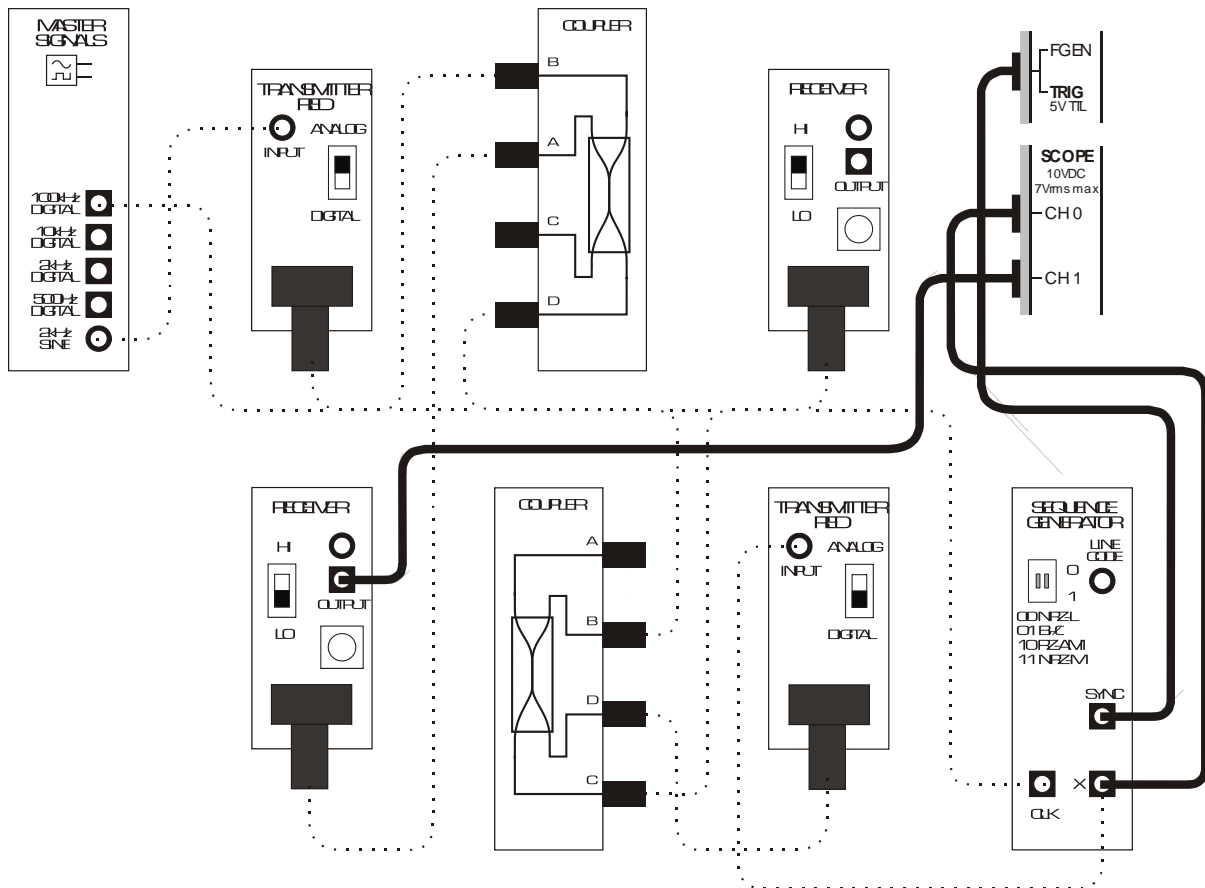


Figure 9: Bi-directional channel patching diagram, with Scope Trigger

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 *50 μ s/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 ADS Max.**

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