

Lab Manual:  
Communications Principles  
  
Using the EMONA Communications board for NI ELVIS III



Lab 1: Introduction to the   
EMONA Communications board

List of Updates

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## Lab 1: Introduction to the EMONA Communications board

In this lab you will become familiar with the relationship between the block diagram and the circuit modules on the board which relate to the block diagram. This will enable you to build a system from the block diagram in order to be able to study the performance of that theory.

## Learning Objectives

After completing this lab, you should have the ability to complete the following actions.

1. Use the NI ELVIS III Oscilloscope and Function Generator
2. Describe the basic functionality of individual circuit modules on the board.
3. Patch together these modules to model block diagrams and build systems.

## Prerequisites

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 telecommunications theory by using this system. Due to the engineering “modeling” nature of the board, 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.

This lab manual was designed for students who have completed the following courses and have a working knowledge of the following hardware, software, and tools.

## Required Tools and Technology

|  |  |
| --- | --- |
| Platform: NI ELVIS III Instruments used in this lab:   * Oscilloscope-Time * Oscilloscope-FFT * Function Generator | * Install Instruments: [http://www.ni.com/documentation/en/ni-elvis-iii/latest/getting-started/installing-the-soft-front-panel/](http://www-preview.ni.com/documentation/en/ni-elvis-iii/1.0/getting-started/installing-the-soft-front-panel/) * Access instruments <https://measurementslive.ni.com> * View User Manual <http://www.ni.com/en-us/support/model.ni-elvis-iii.html> * View tutorials <https://www.youtube.com/playlist?list=PLvcPIuVaUMIWm8ziaSxv0gwtshBA2dh_M> |
| Hardware: Emona Communications Board Components used in this lab:   * Four BNC to 2mm banana-plug leads * Assorted 2mm banana-plug patch leads * Set of headphones or earbuds | * View User Manual <http://www.ni.com/en-us/support/model.emona-communications-board-for-ni-elvis-iii.html> |
| Software: NI ELVIS III Function Generator File used in this lab (available in lab folder):   * ECB\_120k-noise.csv | * Access instrument <https://measurementslive.ni.com> |

## 

## Expected Deliverables

In this lab, you will collect the following deliverables:

* Calculations
* Data from measurements
* Observations

Your instructor may expect you complete a lab report. Refer to your instructor for specific requirements or templates.

## Section 1: Getting to know the NI ELVIS III platform

The function generator 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.

Figure 1: A collection of traditional benchtop instruments

At the same time, there would be very few electronics laboratories or workshops that don’t also have a *DC Power Supply* and Digital Multimeter.

Importantly, NI ELVIS III 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), NI ELVIS III sends the information to a personal computer where the measurements are displayed on one screen.

On the computer, the NI ELVIS III 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 III devices and others so it’s important that you’re familiar with their operation.

This experiment introduces you to the NI ELVIS III oscilloscope and function generator. The oscilloscope can be a tricky device to use if you don’t do so often. As such, this experiment also gives you a procedure that will set it up to display a stable 2kHz 4Vp-p signal every time. It’s recommended that you use this procedure as a starting point for the other experiments in this manual.

**Powering up the ELVIS III EMONA Communications Board**

|  |  |
| --- | --- |
| 1. | Ensure that the NI ELVIS III Application Board power button at the top left corner of the unit is OFF (not illuminated). |

|  |  |
| --- | --- |
| 2. | Carefully plug the Emona Communications board (ECB) into the NI ELVIS III ensuring that it is fully engaged both front and back. |

|  |  |
| --- | --- |
| 3. | Ensure that you have connected the NI ELVIS III to the PC using the USB cable and that the PC is turned on. |

|  |  |
| --- | --- |
| 4. | Turn on the Application *Board Power* button by pressing it once and confirm that it is illuminated. The LEDs on the ECB should also be illuminated. If they are not, then switch the unit off immediately and check for connection or insertion errors. |

|  |  |
| --- | --- |
| 5. | Open the Instrument Launcher software in your browser and select the required instruments. |

## 1.1 Using the ELVIS III oscilloscope

The NI ELVIS III Oscilloscope (or just “scope” in brief) 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 though it is expected that students will be familiar with this instrument. In this section we highlight the main features which will be used throughout these labs.

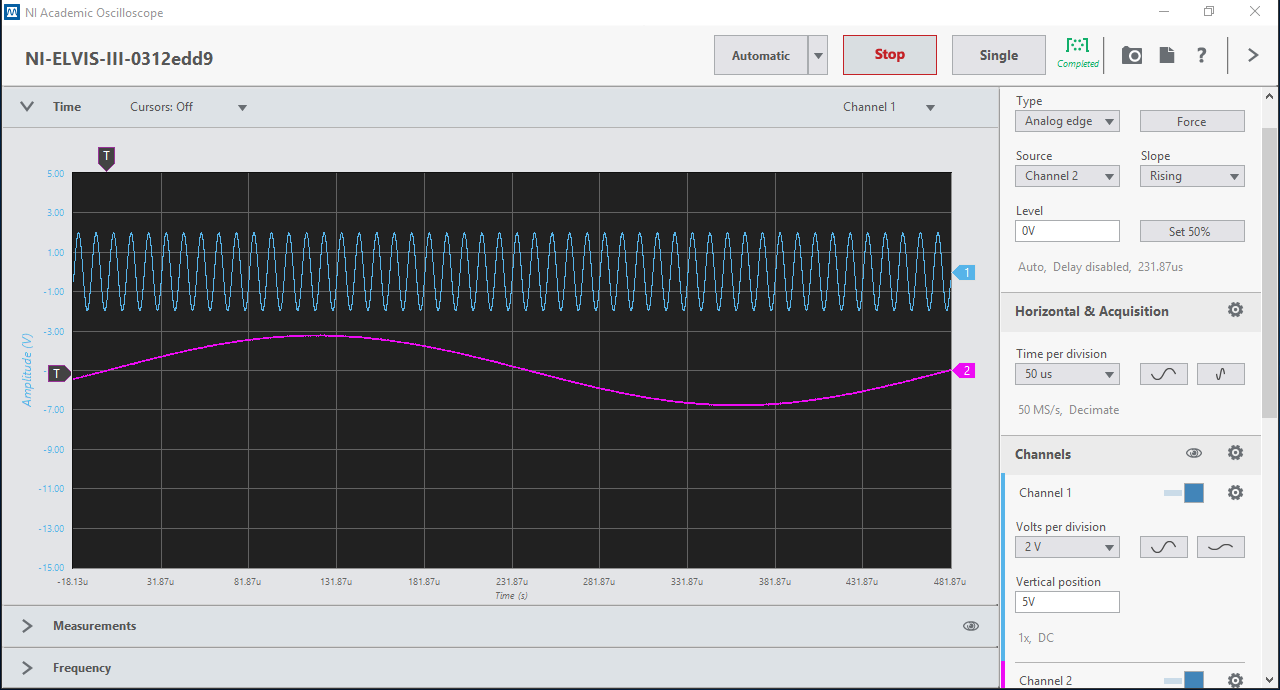


Figure 2: ELVIS III Oscilloscope instrument panel

The NI ELVIS III Oscilloscope is operated using the controls on its virtual instrument. Most of the controls are menu-based, so you need to consider where to look for options and settings.

Figure 2 is configured as follows and is displaying two of the fundamental signals from the ECB, i.e.: the 2.08kHz message and the 100kHz carrier.

Table 1 Scope Configuration

|  |  |
| --- | --- |
| Channel Voltage Range | 2 V/div |
| Horizontal Timebase (Time per Division) | 50us/div |
| Trigger | Analog Edge, Channel 2, Rising |
| Probe Attenuation | 1x |

Voltage and Timebase settings are fairly intuitive and obvious. Of most importance, and often overlooked is the Triggering of an oscilloscope.

1. Connect Channel 1 of the scope to the 100kHz SINE output on the MASTER SIGNALS module of the ECB.

2. Connect Channel 2 of the scope to the 2.08kHz SINE output on the MASTER SIGNALS module of the ECB.

## 1.2 Triggering the oscilloscope

In order to obtain a stable signal onscreen, you need to select a point at which to “trigger” the scope and capture the signal at.

In the example above we have selected Channel 2 as the source of the trigger. This is the purple signal, a 2.08kHz sinewave.

**TIP:** Trigger on the slowest signal you are viewing.

1. To prove this for yourself, try triggering on Channel 1, the 100kHz signal, and view the difference in stability.

|  |  |  |
| --- | --- | --- |
| 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 3. Importantly, knowing the waveform’s peak-to-peak voltage allows us to calculate its *RMS* voltage where required.  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 |  | Fig%201-8  Figure 3: Waveform dimensions |
|  |  |
|  |  |
| cycle and this is also shown in Figure 3. 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: 1.3 Saving instrument displays for Lab reporting The NI ELVIS III oscilloscope has a built-in “save display” function on the top menu bar. This feature will save both the displays as well as all relevant settings. This is convenient for including in Lab reports and is used extensively in the following experiments.  An example capture is shown in Figure 4.  For smaller or more detailed screen captures, simply use the “Snipping Tool” included in your operating system.  C:\Users\carlo\Documents\TIMS modules-design\DATEx-IQ\manuals\images\save-display-example.png  Figure 4: Example Oscilloscope display "save" output file 1.4 Viewing Frequency Spectrum with FFT mode The NI ELVIS III oscilloscope has a built-in FFT mode for viewing the frequency spectrum of connected signals. The FFT is calculated from the samples points of the displayed scope signals and it is useful to view both time and frequency domains at the same time.  The use of the FFT mode is intuitive and various settings are available from the drop-down menu.  Most importantly, users must select the source of the signal to display as an FFT, as the FFT mode currently only supports one channel.    Figure 5: FFT mode enabled and displaying the 100kHz carrier signal | | |

## 

## 1.5 Using the NI ELVIS III Function Generator

The NI ELVIS III Function Generator (FGEN) is an instrument that can output AC signals of various shapes and frequencies to BNC terminals on the ELVIS III.

Using this instrument is also intuitive. There are two independent channels and a number of defined signal shapes from which to choose. Amplitude, frequency and DC offset on settable via the onscreen controls.

Of significant interest to users of the EMONA Communications Board is the ability to output Custom waveforms. This option allows users to “replay” signals which have either been generated externally in LabVIEW or captured by the Oscilloscope’s “Export to Multisim/LabVIEW” feature.

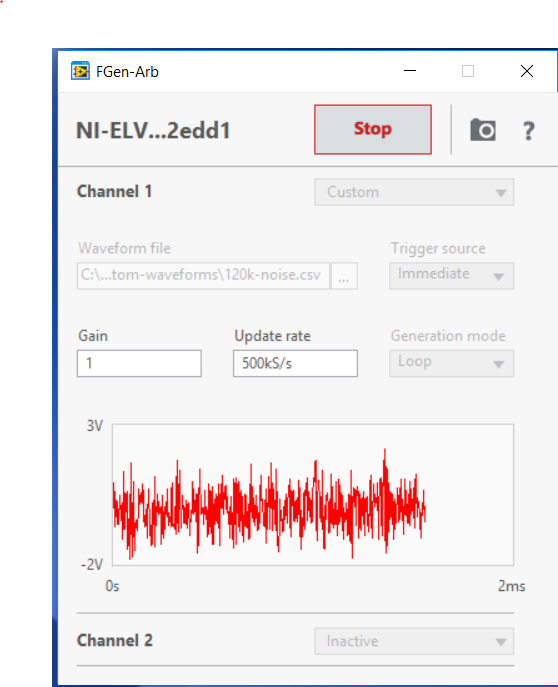


Figure 6: Custom waveform output from Function Generator

As an example, select the Custom waveform option and load the supplied file “ECB\_120k-noise.csv”.

## 

## Section 2: Getting to know the EMONA Communications Board

The Emona Commucniations Board (ECB) for the NI ELVIS III is used to help learn about communications and telecommunications principles. It lets you bring to life the block diagrams that fill communications textbooks. A “block diagram” is a simplified representation of a more complex circuit. An example is shown in Figure 7.

|  |
| --- |
| Fig%202-P-1  Figure 7: A sample communications block diagram |
|  |

Textbooks use Block diagrams to explain the principle of operation of electronic systems (such as a radio transmitter) without having to describe the detail of 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*, *filter*, *phase shifter* and so on.

The ECB has a collection of blocks (called *modules*) that you can put together to implement dozens of communications and telecommunications block diagrams.

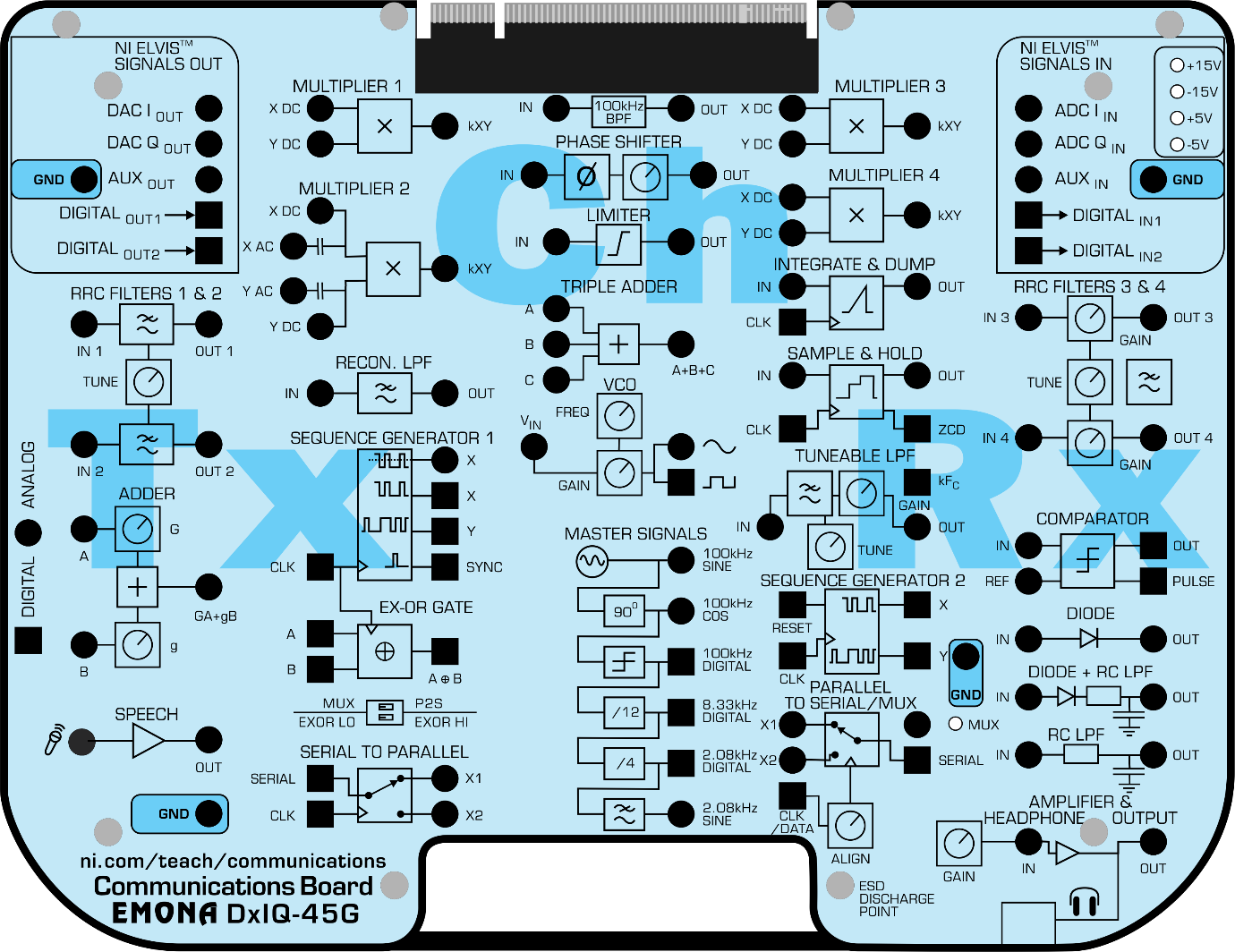


Figure 8: EMONA Communications Board overlay

REFER TO THE USER MANUAL FOR FURTHER INFORMATION ABOUT EACH MODULE OF THE EMONA COMMUNICATIONS BOARD.

## 2.1 Using the MASTER SIGNALS module

The Master Signals module is an AC signal generator or *oscillator*. The module has six outputs that provide the following analog and digital signals:

|  |  |
| --- | --- |
| **Analog** | **Digital** |
| 1. A 2.08kHz sinewave | 1. A 2.08kHz square wave |
| 1. A 100kHz sinewave | 1. An 8.33kHz square wave |
| 1. A 100kHz cosine wave | 1. A 100kHz square wave |

Each signal is available through a socket on the module’s faceplate that’s labelled accordingly. Importantly, all signals are synchronized.

|  |  |
| --- | --- |
| 1. | Connect the set-up shown in Figure 9. |

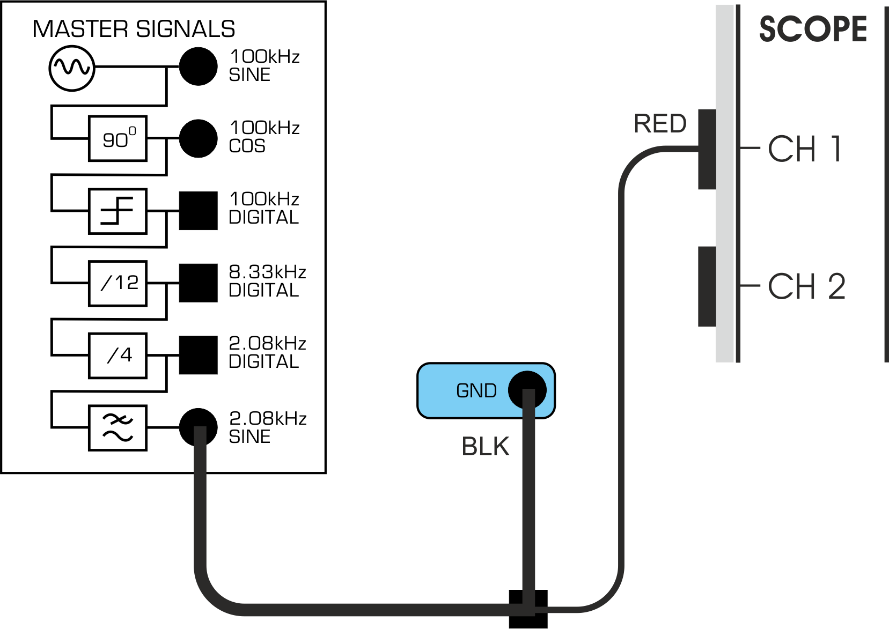


Figure 9: Viewing the 2.08kHz SINE signal

This set-up can be represented by the block diagram in Figure 10.

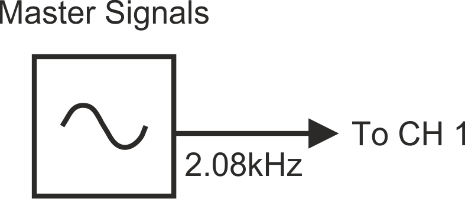


Figure 10: 2.08kHz sinewave block diagram

|  |  |
| --- | --- |
| 2. | Launch and run the NI ELVIS III Oscilloscope and set it up ensuring that the *Trigger Source* control is set to *Channel 1*. |

|  |  |
| --- | --- |
| 3. | Adjust the scope’s *Timebase* control to view only two or so cycles of the Master Signals module’s *2.08kHz SINE* output. |

|  |  |
| --- | --- |
| 4. | Use the scope’s Measurements function to find the peak-to-peak amplitude of the Master Signals module’s *2.08kHz SINE* output. Record this in Table 1. |

|  |  |
| --- | --- |
| 5. | Measure and record the frequency of the Master Signals module’s *2.08kHz SINE* output. |

|  |  |
| --- | --- |
| 6. | Repeat Steps 3 to 5 for the Master Signals module’s 100kHz SINE and 100kHz COSINE outputs. |

|  |  |  |
| --- | --- | --- |
| Table 1 | **Peak-to-peak Output voltage** | **Frequency** |
| **2.08kHz SINE** | 3.611V | 2.082kHz |
| **100kHz COSINE** | 3.945V | 100.061kHz |
| **100kHz SINE** | 3.974V | 100.068kHz |

You probably just found that there doesn’t appear to be much difference between the Master Signals module’s SINE and COSINE outputs. They’re both 100kHz sinewaves. However, the two signals are out of phase with each other.

It’s critical to the operation of many communications and telecommunications systems that there be two sinewaves with identical frequencies but out of phase with each other (usually by a specific amount). The Master Signals module’s two 100kHz outputs satisfy this requirement and are 90° out of phase. The next part of the experiment lets you see this.

|  |  |
| --- | --- |
| 7. | Connect the set-up shown in Figure 11.  **Note:** Insert the black plugs of the oscilloscope leads into a ground (*GND*) socket. |

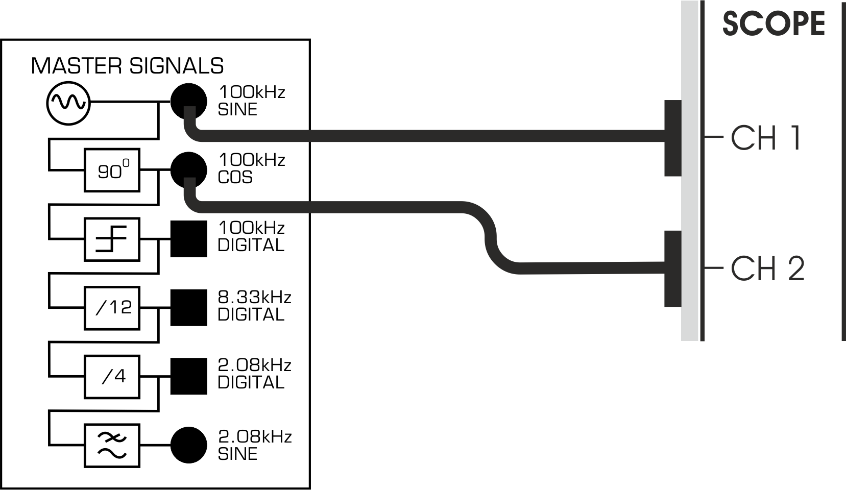


Figure 11: Viewing the two 100kHz carriers

|  |  |
| --- | --- |
| 8. | Activate the scope’s Channel 2 input by checking the Channel 2 *Enabled* box  **Note:** When you do, you should see a second signal appear on the display that’s a different color to the Channel 1 signal. |

2-1 By visual inspection of the scope’s display, which of the two signals is leading the other? Explain your answer.

The COSINE output leads the SINE output (by 90°) because it reaches its peak to

|  |
| --- |
| the left of the SINE output on the display. |

|  |
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## 2.2 Using the ADDER module

Several communications and telecommunications systems require that signals be added together. The Adder module has been designed for this purpose.

|  |  |
| --- | --- |
| 1. | Locate the Adder module and turn its *g* control (for *Input B*) fully anti-clockwise. |

|  |  |
| --- | --- |
| 2. | Set the Adder module’s *G* control (for *Input A*) to about the middle of its travel. |

|  |  |
| --- | --- |
| 3. | Connect the set-up shown in Figure 12.  **Note:** Although not shown on the figure, insert the black plugs of the oscilloscope leads into a ground (*GND*) socket. |

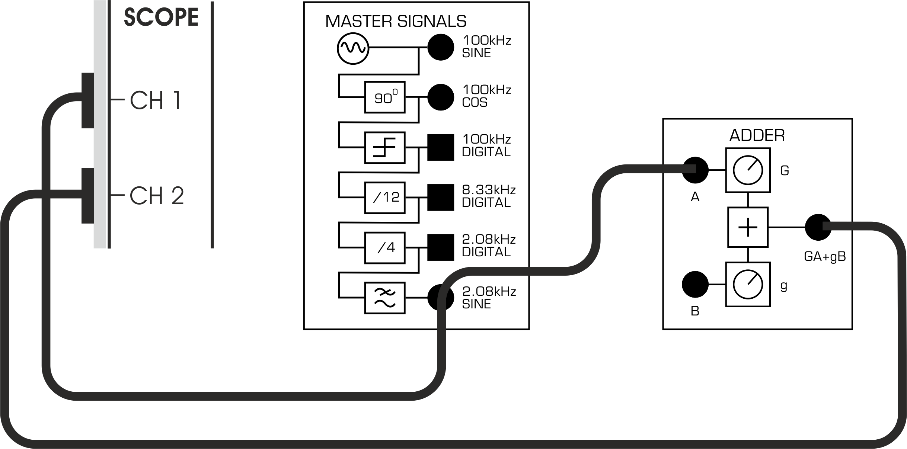


Figure 12: Patching the ADDER module

This set-up page can be represented by the block diagram in Figure 13 below.

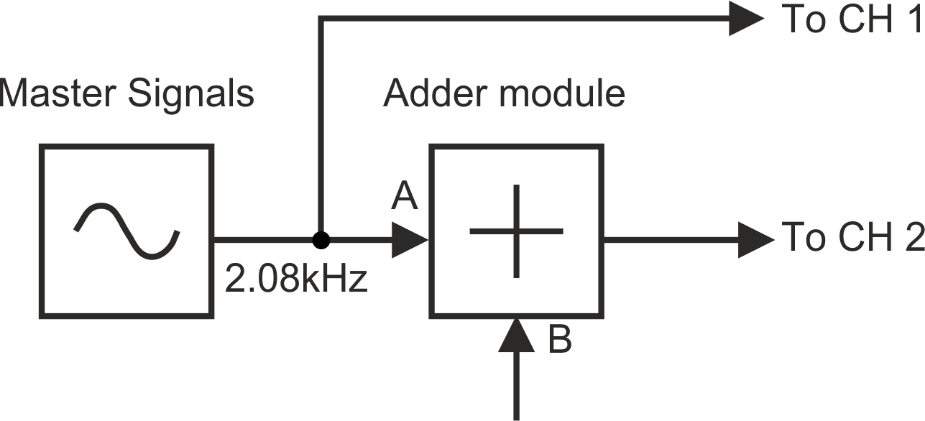


Figure 13: Block diagram for ADDER module use

|  |  |
| --- | --- |
| 4. | Adjust the scope’s *Timebase* control to view two or so cycles of the Master Signals module’s *2.08kHz SINE* output. |

|  |  |
| --- | --- |
| 5. | Activate the scope’s Channel 2 input by checking the Channel 2 *Enabled* box to view the Adder module’s output **as well as** the Master Signals module’s *2.08kHz SINE* output. |

|  |  |
| --- | --- |
| 6. | Vary the Adder module’s *G* control left and right and observe the effect. |

2-2 What aspect of the Adder module’s performance does the *G* control vary?

The gain of Input A. So, “G” is for gain.

|  |
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|  |  |
| --- | --- |
| 7. | Use the scope’s Measurements function to measure the peak-to-peak voltage on the Adder module’s *Input A*. Record your measurement as the input voltage in Table 2. |
| 8. | Turn the Adder module’s *G* control fully clockwise. |
| 9. | Use the scope’s Measurements function to measure the Adder module’s peak-to-peak output voltage and record your measurement as the maximum output voltage on Table 2. |
| 10. | Calculate and record the maximum voltage gain of the Adder module’s *Input A*. |
| 11. | Turn the Adder module’s *G* control fully anti-clockwise. |
| 12. | Measure the Adder module’s output voltage and record your measurement as the minimum output voltage on Table 2. |
| 13. | Calculate and record the minimum voltage gain of the Adder module’s *Input A*. |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table 2 | | **Input voltage** | **Output voltage** | **Gain** |
| **Input A** | **Maximum** | 3.485V | 6.907V | 1.98 |
| **Minimum** | 13.201mV | 0.0038 |

2-3 What is the range of gains for the Adder module’s A input?

Approximately 0 to 2

|  |
| --- |
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|  |  |
| --- | --- |
| 14. | Leave the Adder module’s *G* control fully anti-clockwise. |
| 15. | Disconnect the Master Signals module’s *2.08kHz SINE* output from the Adder module’s *Input A* and connect it to the Adder’s *Input B*. |
| 16. | Use the scope’s Measurements function to measure the peak-to-peak voltage on the Adder module’s *Input B*. Record your measurement as the input voltage in Table 3. |
| 17. | Turn the Adder module’s *g* control fully clockwise. |
| 18. | Measure the Adder module’s output voltage. Record your measurement as the maximum output voltage in Table 3. |
| 19. | Calculate and record the maximum voltage gain of the Adder module’s *Input B*. |
| 20. | Turn the Adder module’s *g* control fully anti-clockwise. |
| 21. | Measure the Adder module’s output voltage and record your measurement as the minimum output voltage on Table 3. |
| 22. | Calculate and record the minimum voltage gain of the Adder module’s *Input B*. |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table 3 | | **Input voltage** | **Output voltage** | **Gain** |
| **Input B** | **Maximum** | 3.472V | 6.904V | 1.99 |
| **Minimum** | 15.058mV | 0.0043 |

2-4 Compare the results in Tables 2 and 3. What can you say about the Adder module’s two inputs in terms of their gain?

They are the same.

|  |
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| --- | --- |
| 23. | Turn both of the Adder module’s *Gain* controls fully clockwise. |
| 24. | Connect the Master Signals module’s *2.08kHz SINE* output to both of the Adder module’s inputs. |
| 25. | Resize the Adder module’s output signal on the scope’s display by adjusting Channel 2’s *Scale* control to an appropriate setting. |
| 26. | Measure the Adder module’s new output voltage. Record your measurement as part of the following question. |

2-5 What is the relationship between the amplitude of the signals on the Adder module’s inputs and output?

|  |
| --- |
|  |
|  |

## 2.3 Using the PHASE SHIFTER module

Several communications and telecommunications systems require that the signal to be transmitted (speech, music and/or video) is phase shifted. Crucial to being able to implement these systems in later experiments is the ability to phase shift any signal by almost any amount. The Phase Shifter module has been designed for this purpose.

|  |  |
| --- | --- |
| 1. | Set the Phase Shifter module’s *Phase Adjust* control to about the middle of its travel. |
| 2. | Connect the set-up shown in Figure 14. |
|  | **Note:** Insert the black plugs of the oscilloscope leads into a ground (*GND*) socket. |

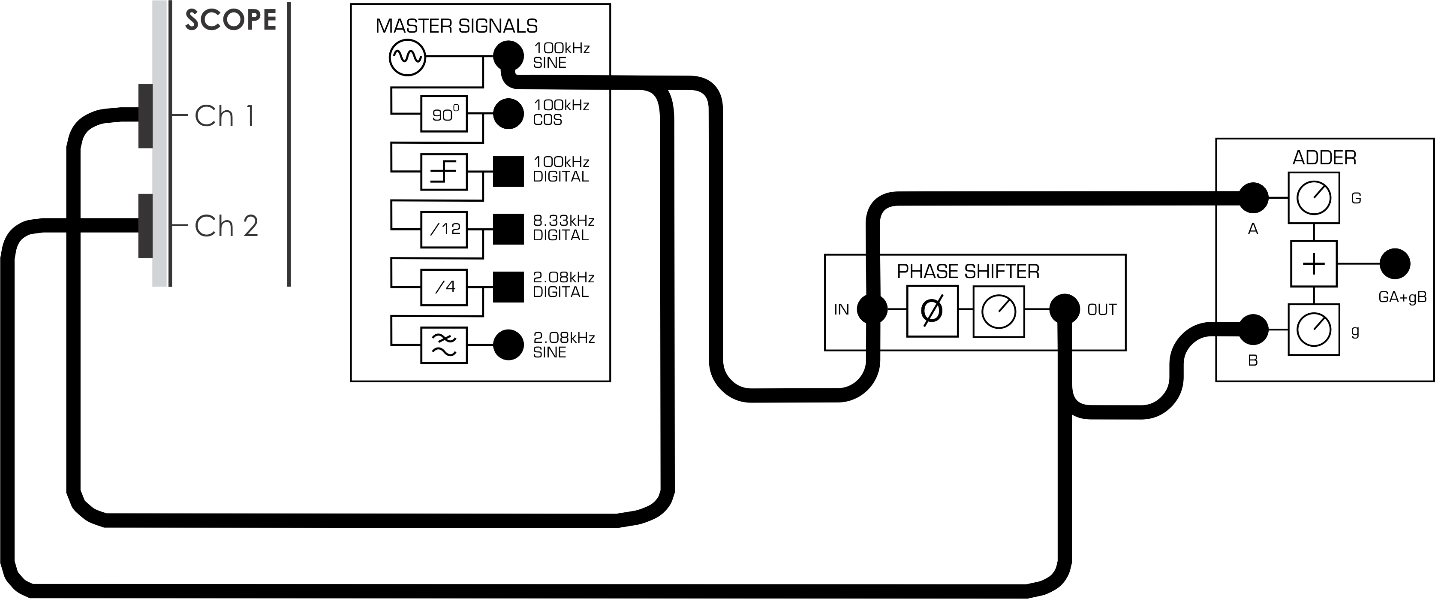


Figure 14: Patching for the PHASE SHIFTER

This set-up can be represented by the block diagram in Figure 15.

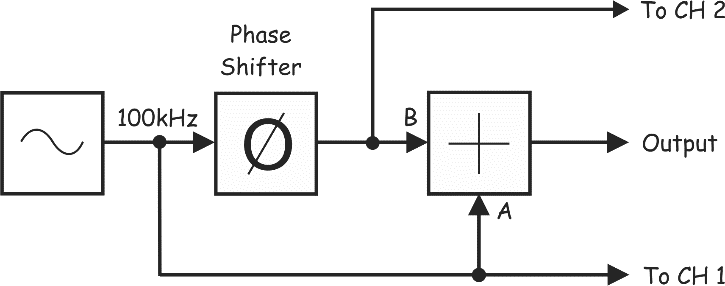


Figure 15: Block diagram for PHASE SHIFTER

|  |  |
| --- | --- |
| 3. | Adjust the scope’s *Scale* control for both channels for signals that are a suitable size on the display. |
| 4. | Vary the Phase Shifter module’s *Phase Adjust* control left and right and observe the effect on the two signals. |

2-6 The Phase Shifter module’s output signal can be phase shifted by different amounts, but does it lead or lag the input signal?

It lags the input, starting from 0 degrees.

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## 2.4 Using the VCO module

A VCO is an oscillator with an adjustable output frequency that is controlled by an external voltage source. It’s a useful circuit for communications and telecommunications systems as you’ll see.

This set-up can be represented by the block diagram in Figure 16.

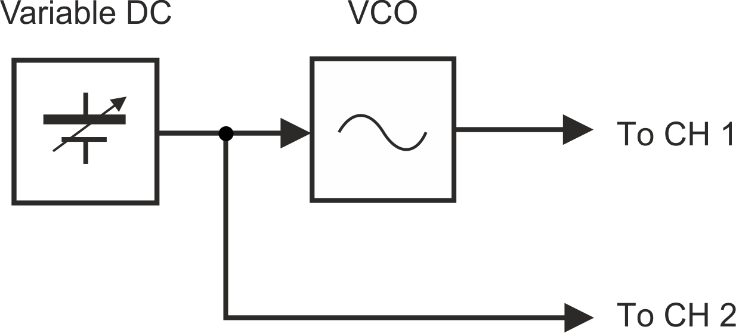


Figure 16: Block diagram for VCO operation

Using a DC voltage as input will cause the output frequency to be a stable fixed value.

Using a varying voltage such as from a 2.08kHz sinewave source will cause the frequency to vary at 2.08kHz.

1. Connect the 2.08kHz SINE signal to the Vin input to the VCO module. Set the GAIN to minimum (fully anti-clockwise). This will effectively reduce the input voltage to 0V.
2. View the VCO module output signal on the scope and vary the FREQ control until the frequency is set to approximately 100kHz.
3. Slowly increase the GAIN of the input whilst viewing the output signal. You should also view the 2.08kHz input signal on the other channel.  
     
   **HINT:** Remember to trigger the scope on the 2.08kHz signal.  
     
   As you increase the gain of the signal you will notice the frequency of the VCO output will vary in proportion to the input signal level.
4. Set the GAIN of the VCO module to maximum.
5. Measure the frequencies of the VCO module output at the most negative and most positive peaks of the VCO module input. Do this by measuring the period of the VCO module output at these points. Use a combination of scope cursors, and Trigger level to zoom in on the minimum and maximum signal levels. Make sure that the scope is stopped (not running) when you make the measurements.

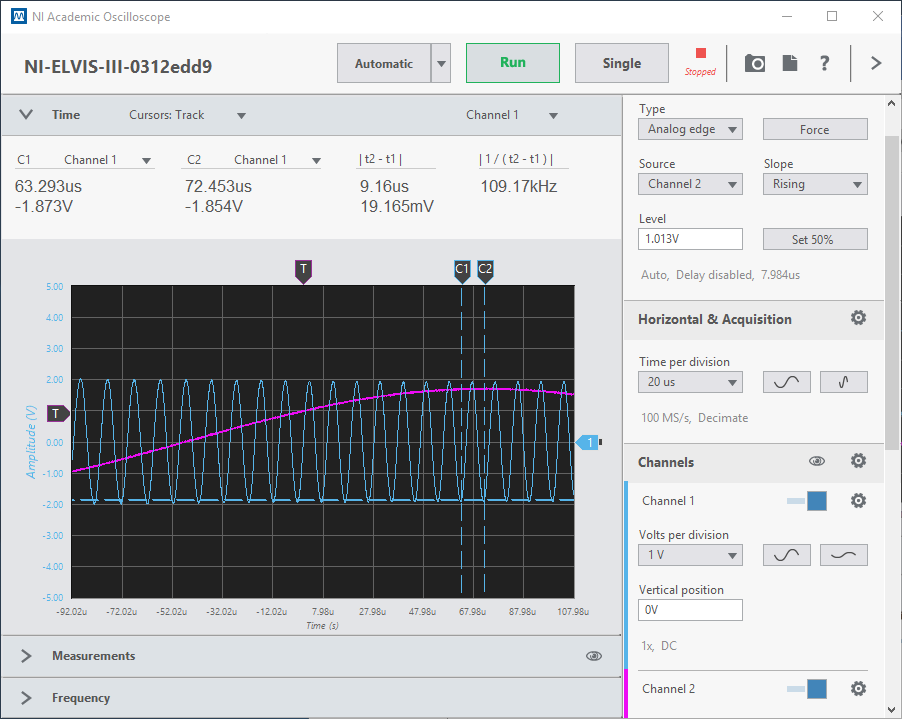


Figure 17: Example of period measurement using cursors and trigger level at a VCO module input maximum

2.7 What are the minimum and maximum frequencies at the VCO module output?

The approximate measured minimum frequency is 88kHz and the maximum

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| frequency is 111kHz. |
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2.8 What is the voltage difference between minimum and maximum for the VCO module input?

The measured voltage difference between the minimum and the

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| maximum peaks is 3.6V. |
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The VCO’s sensitivity, or frequency deviation is a measure of how much frequency change is affected by an input voltage change. As such it is measured in units of kHz/V.

2.9 For the GAIN setting of maximum, what is the deviation for this VCO module?

(111 – 88kHz)/ 3.6 V = 6.4kHz / V

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