Part 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, 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), 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.

This experiment was adopted from Emona DATEx Lab Manual.
Equipment

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona DATEx 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](sinewave.png)

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

![Figure 2](squarewave.png)
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 DATEx experimental add-in module into the NI ELVIS II.

3. Set the Control Mode switch on the DATEx module (top right corner) to Manual.

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 “ELVIS - Instrument Launcher” will be visible (see Figure 3).

![NI ELVISmx Instrument Launcher](image)

**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.

8. 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).

![Image of NI ELVIS Digital Multimeter](image)

Figure 4

The digital multimeter's measurement options are selected using the Measurement and Settings controls on the virtual instrument (near the mouse-pointer in Figure 4).

9. 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.
10. 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 ELVIS II for that particular measurement.

Importantly, simply launching the DMM virtual instrument doesn’t activate the instrument’s hardware. This must be done every time the DMM virtual instrument is launched using its Run control (the button with the green arrow).

11. Click on the DMM’s Run control.

12. 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 and current instead of zero?

If you examine the DMM virtual instrument closely you’ll notice that there are other settings on the DMM virtual instrument 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.
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 DATEx. Its operation is briefly discussed next.

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

**Note 1:** Don’t close the NI ELVISmx DMM virtual instrument because you’ll be using it to verify the operation of the Variable Power Supplies.

**Note 2:** If the Variable Power Supplies virtual instrument has launched successfully, the instrument’s window will be visible (see Figure 5).

![NI ELVISmx Variable Power Supplies Window](image)

**Figure 5**

14. Put the NI ELVIS II Variable Power Supplies into Manual mode by checking the boxes next to the word Manual on both the positive and negative sides of the virtual instrument.

**Tip:** One of the boxes is near the mouse-pointer in Figure 5.

**Note:** Once you’ve performed this step, you’ll notice that the virtual controls fade. This tells you that the virtual power supplies’ outputs are controlled manually using the controls on the top right of the NI ELVIS II (directly below the USB Ready & Active indicators).
15. Click on the DMM's control to put the unit into DC voltage measuring mode.

16. Set the two Variable Power Supplies Voltage controls to about half of their travel.

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

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

**Note:** As you perform this step, you should see some activity on the DMM virtual instrument and the measurement on its readout change to about 6V.

![Figure 6](image)

18. Use the Voltage control to determine the Variable Power Supplies' minimum and maximum positive output voltages. Record these in Table 1 below.

19. Connect the DMM to the Variable Power Supplies' negative output and repeat Step 18.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Minimum output voltage</th>
<th>Minimum output voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive (+) output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative (-) output</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
While the DMM can be used for measuring the Variable Power Supplies' outputs, the instrument can monitor its own outputs freeing the digital multimeter for other uses. The next steps demonstrate this.

20. Check the box at the top of the NI ELVIS II Variable Power Supplies' virtual instrument shown in Figure 7 below.

![Figure 7](image)

21. Vary the Variable Power Supplies' negative Voltage control and compare the values on the displays of the two virtual instruments - they should be the same.
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.

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

23. 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 8).

![Figure 8](image)

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 DATEx experiments.
Procedure for setting up the NI ELVIS II Oscilloscope

24. 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 by the NI ELVIS II Oscilloscope at the time of writing this manual.

**General**

i) Check that the *Cursor On* box is 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 **1X**.

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** 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**.

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

25. Activate the scope’s hardware by clicking on its **Run** control.
The next part of this experiment lets you familiarise yourself with NI ELVIS II Oscilloscope by observing and measuring a DATEx signal.

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

**Note:** 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 DATEx.
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 10. 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 cycle and this is also shown in Figure 10. 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 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 11 below.
27. Record the scope's measured values for voltage (RMS and peak-to-peak) and frequency in Table 2 below.

28. 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>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS voltage</td>
</tr>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Pk-Pk voltage</td>
</tr>
<tr>
<td>Period</td>
</tr>
</tbody>
</table>
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 and at various frequencies to terminals on the Emona DATEX. Its operation is briefly discussed next.

29. 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 12).

![NI ELVISmx Function Generator](image)

**Figure 12**

30. Check the box that puts the function generator into *Manual Mode*.

   **Note**: Once you've performed this step, you'll notice that the virtual controls fade. This tells you that the function generator’s output is now a sinewave whose amplitude and frequency are controlled manually by the *Frequency* and *Amplitude* controls on the right side of the NI ELVIS II.

31. Set the function generator’s *Amplitude* control on the right side of the NI ELVIS II to about half its travel.
32. To observe the function generator’s output, connect the set-up shown in Figure 13 below.

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

![Figure 13](image_url)

33. Adjust the scope’s *Timebase* control for *1ms/div*.

**Note:** Once this step has been performed, you should see one complete cycle of a sinewave.

34. Vary the function generator’s *Amplitude* control left and right and observe the effect on the function generator’s output.

35. Determine the function generator’s manually adjustable minimum and maximum output voltages and record your measurements in Table 3 below.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum output V</td>
<td></td>
</tr>
<tr>
<td>Maximum output V</td>
<td></td>
</tr>
</tbody>
</table>
36. Vary the function generator's *Frequency* control on the right side of the NI ELVIS II and observe the effect on the function generator's output.

**Note 1:** If this control doesn't seem to have an effect, keeping turning it.

**Note 2:** This control can vary the frequency of the function generator's output between 0.2Hz and 5MHz. However, it would take a lot of turns of the manual *Frequency* control to sweep between them. Experiment 3 introduces you to the controls on the function generator's virtual instrument which are more convenient to use.
Part 2 – An introduction to the DATEx experimental add-in module

Preliminary discussion
The Emona DATEx experimental add-in module for the NI ELVIS II is used to help people 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 1 below.

Block diagrams are used to explain the principle of operation of electronic systems (like a radio transmitter for example) 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 DATEx has a collection of blocks (called modules) that you can put together to implement dozens of communications and telecommunications block diagrams.

The experiment
This experiment is in three stand-alone parts (2-1, 2-2 and 2-3) and each introduces you to one or more of the DATEx’s analog modules. It’s expected that you’ve completed Experiment 1 or have already been introduced to the NI ELVIS II system and its virtual instruments software.

It should take you about 50 minutes to complete experiment 2.1, another 50 minutes to complete 2.2 and about 25 minutes to complete 2.3.

Equipment

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona DATEx experimental add-in module
- Two BNC to 2mm banana-plug leads
- Assorted 2mm banana-plug patch leads
- For 2.1 only: One set of headphones (stereo)
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.

Two signals that are in phase with each other reach key points in the waveform (like the peaks and zero-crossing points) at exactly the same time regardless of their size.

Two signals that out of phase reach key points in the waveform at different times. An example is shown in Figure 3 below.

Phase difference describes how much two signals are out of phase and is measured in degrees (like degrees in a circle). Signals that are in phase have a phase difference of 0°. Signals that are out of phase have a phase difference > 0° but < 360°.

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

![Figure 2](image)

A cosine wave is simply a sinewave that is out of phase with another sinewave by exactly 90°. A sinewave and a cosine wave are shown in Figure 3. (They’re not marked because, in this case, it doesn’t matter which one is which.)

![Figure 3](image)
2.1 - 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 six outputs providing the following:

<table>
<thead>
<tr>
<th>Analog</th>
<th>Digital</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 2.083kHz sinewave</td>
<td>A 2.083kHz squarewave (digital)</td>
</tr>
<tr>
<td>A 100kHz sinewave</td>
<td>An 8.33kHz squarewave (digital)</td>
</tr>
<tr>
<td>A 100kHz cosine wave</td>
<td>A 100kHz squarewave (digital)</td>
</tr>
</tbody>
</table>

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

Procedure

1. Ensure that the NI ELVIS II power switch at the back of the unit is off.
2. Carefully plug the Emona DATEx experimental add-in module into the NI ELVIS II.
3. Set the Control Mode switch on the DATEx module (top right corner) to Manual.
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 “ELVIS - Instrument Launcher” will be visible.
1. Connect the set-up shown in Figure 1 below.

![Figure 1](image1.png)

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

![Figure 2](image2.png)

2. Launch and run the NI ELVIS II Oscilloscope and set it up per the procedure in Experiment 1 (page 1-12) ensuring that the Trigger Source control is set to CH 0.

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 (peak-to-peak) of the Master Signals module’s 2kHz SINE output. Record this in Table 1 on the next page.

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

6. Repeat Steps 12 to 14 for the Master Signals module’s other two analog outputs.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Output voltage</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2kHz SINE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100kHz COSINE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100kHz SINE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
You have 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 several communications and telecommunications systems that there be two (or more) 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 3 below.

**Note:** Insert the black plugs of the oscilloscope leads into a ground (GND) socket.
8. Activate the scope’s Channel 1 input by checking (that is, putting a tick in) the Channel 1 Enabled box as shown in Figure 4 below.

**Note 1:** When you do, you should see a second signal appear on the display that’s a different colour to the Channel 0 signal.

**Note 2:** You may notice that the two signals don’t look like the clean sinewaves that you saw earlier. Importantly, the signals haven’t changed shape. The distortion tells us that we’re beginning to operate the NI ELVIS II at the limits of its specification (for reasons not discussed here).

![Figure 4](image.png)

**Question 1**
By visual inspection of the scope’s display, which of the two signals is leading the other? Explain your answer.
The Speech module
Sinewaves are important to communications. They’re used extensively for the carrier signal in many communications systems. Sinewaves also make excellent test signals. However, the purpose of most communications equipment is the transmission of speech (among other things) and so it’s useful to examine the operation of equipment using signals generated by speech instead of sinewaves. The Emona DATEx allows you to do this using the Speech module.

9. Deactivate the scope’s Channel 1 input.

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

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

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

12. Talk and hum into the microphone while watching the scope’s display. Be sure to say “one” and “two” several times.
The Amplifier module
Amplifiers are used extensively in communications and 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 DATEx can do both.

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

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

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

![Figure 6](image_url)

This set-up can be represented by the block diagram in Figure 7 below.

![Figure 7](image_url)
15. Adjust the scope’s *Timebase* control to view two or so cycles of the Amplifier module’s input.

16. Activate the scope’s Channel 1 input.

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

18. Measure and record the amplitude of the Amplifier module’s output.

![Table 2](image)

<table>
<thead>
<tr>
<th>Input voltage</th>
<th>Output voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 compared to its input then a negative sign is usually put in front of the gain figure to highlight this fact.

**Question 2**

Calculate the Amplifier module’s gain (on its present gain setting).
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.

19. Turn the Amplifier module’s Gain control fully anti-clockwise then turn it clockwise just a little until you can just see a sinewave.

20. Resize the Amplifier module’s output signal on the scope’s display by adjusting Channel 1’s Scale control to an appropriate setting.

21. Measure and record the amplitude of the Amplifier module’s new output.

<table>
<thead>
<tr>
<th>Table 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input voltage</strong></td>
</tr>
<tr>
<td>See Table 2</td>
</tr>
</tbody>
</table>

**Question 3**
Calculate the Amplifier module’s new gain.

**Question 4**
In terms of the gain figure, 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:

22. Turn the Amplifier module's Gain control fully clockwise.

23. 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?

24. Turn the Amplifier module's Gain control fully anti-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 DATEx.

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.
25. Ensure that the Amplifier module’s Gain control is turned fully anti-clockwise.

26. Without wearing the headphones, plug them into the Amplifier module’s headphone socket.

27. Put the headphones on.

28. Turn the Amplifier module’s Gain control clockwise and listen to the signal.

29. Disconnect the plugs from the Master Signals module’s 2kHz SINE output and connect them to the Speech module’s output.

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

31. Disconnect the plugs from the Speech module’s output and connect them to the Master Signals module’s 100kHz SINE output.

32. Carefully turn the Amplifier module’s Gain control clockwise and listen for a signal.

**Question 6**
Why is the Master Signals module’s 100kHz SINE output inaudible?

________________________________________________________________________

________________________________________________________________________

33. Turn the Amplifier module’s Gain control fully anti-clockwise again.
2.2 - The Adder and Phase Shifter modules

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

Procedure

1. If your equipment is still set up from the previous experiment then jump to Step 9. If not, continue on to Step 2.
2. Ensure that the NI ELVIS II power switch at the back of the unit is off.
3. Carefully plug the Emona DATEx experimental add-in module into the NI ELVIS II.
4. Set the Control Mode switch on the DATEx 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 “ELVIS - Instrument Launcher” will be visible.
9. Launch and run the NI ELVIS II Oscilloscope and set it up per the procedure in Experiment 1 (page 1-12) ensuring that the *Trigger Source* control is set to *CH 0*.

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

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

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

   **Note:** Although not shown, insert the black plugs of the oscilloscope leads into a ground (*GND*) socket.

![Figure 1](image)

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

![Figure 2](image)
13. Adjust the scope’s Timebase control to view two or so cycles of the Master Signals module’s 2kHz SINE output.

14. Activate the scope’s Channel 1 input (by checking the Channel 1 Enabled box) to view the Adder module’s output as well as the Master Signals module’s 2kHz SINE output.

15. Vary the Adder module’s G control left and right and observe the effect.

**Question 1**
What aspect of the Adder module’s performance does the G control vary?

16. Use the scope’s measuring function to measure the voltage on the Adder module’s Input A. Record your measurement in Table 1 below.

17. Turn the Adder module’s G control fully clockwise.

18. Measure and record the Adder module’s output voltage.

19. Calculate and record the voltage gain of the Adder module’s Input A.

20. Turn the Adder module’s G control fully anti-clockwise.

21. Resize the Adder module’s output signal on the scope’s display by adjusting Channel 1’s Scale control to an appropriate setting.

22. Repeat Steps 18 and 19.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Input voltage</th>
<th>Output voltage</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input A</td>
<td>Maximum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Question 2**
What is the range of gains for the Adder module’s A input?
23. Leave the Adder module’s $G$ control fully anti-clockwise.

24. Disconnect the Master Signals module’s 2kHz SINE output from the Adder module’s Input $A$ and connect it to the Adder’s Input $B$.

25. Turn the Adder module’s $g$ control fully clockwise.

26. Resize the Adder module’s output signal on the scope’s display by adjusting Channel 1’s Scale control to an appropriate setting.

27. Measure the Adder module’s output voltage. Record your measurement in Table 2 below.

28. Calculate and record the voltage gain of the Adder module’s Input $B$.

29. Turn the Adder module’s $g$ control fully anti-clockwise.

30. Repeat Steps 26 to 28.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Input voltage</th>
<th>Output voltage</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input B</td>
<td>Maximum</td>
<td>See Table 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Question 3**

Compare the results in Tables 1 and 2. What can you say about the Adder module’s two inputs in terms of their gain?
31. Turn both of the Adder module's *Gain* controls fully clockwise.

32. Connect the Master Signals module's 2kHz SINE output to both of the Adder module's inputs.

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

34. Measure the Adder module's new output voltage. Record your measurement in Table 3 below.

<table>
<thead>
<tr>
<th>Table 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adder's output voltage</td>
</tr>
</tbody>
</table>

**Question 4**

What is the relationship between the amplitude of the signals on the Adder module's inputs and output?
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.

35. Locate the Phase Shifter module and set its Phase Change switch to the $0^\circ$ position.

36. Set the Phase Shifter module's Phase Adjust control to about the middle of its travel.

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

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

**Note 2:** The LED on the Phase Shifter module will turn on but don't be concerned by this. The LED is used to indicate that the module has automatically adjusted itself for your low frequency input.

![Figure 3](image-url)
The set-up in Figure 3 can be represented by the block diagram in Figure 4 below.

![Block Diagram](image)

**Figure 4**

38. Adjust the scope's *Scale* control for both channels for signals that are a suitable size on the display.

39. Vary the Phase Shifter module's *Phase Adjust* control left and right and observe the effect on the two signals.

40. Set the Phase Shifter module's *Phase Change* control to the 180° position.

41. Vary the Phase Shifter module's *Phase Adjust* control left and right and observe the effect on the two signals.

**Question 5**
This module's output signal can be phase shifted by different amounts

- but it always leads the input signal.
- but it always lags the input signal.
- and can either lead or lag the input signal.
2.3 - The Voltage Controlled Oscillator (VCO)
A VCO is an oscillator with an adjustable output frequency that is controlled by an external voltage source. It’s a very useful circuit for communications and telecommunications systems as you’ll see. The NI ELVIS II Function Generator’s operation can be modified by the Emona DATEx to function as a VCO if required.

Procedure

1. If your equipment is still set up from the previous experiment then jump to Step 9. If not continue on to Step 2.

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

3. Carefully plug the Emona DATEx experimental add-in module into the NI ELVIS II.

4. Set the Control Mode switch on the DATEx 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 “ELVIS - Instrument Launcher” will be visible.
9. Launch and run the NI ELVIS II Oscilloscope and set it up per the procedure in Experiment 1 (page 1-12) ensuring that the **Trigger Source** control is set to **CH 0**.

10. Set the NI ELVIS II Variable Power Supplies' controls (near the top right of the unit) as follows:
   - **Positive Voltage** to the **OV** position (that is, fully anti-clockwise)
   - **Negative Voltage** to the **OV** position (that is, fully anti-clockwise)

11. Launch the NI ELVIS II Variable Power Supplies' virtual instrument and check the **Manual** boxes to put them into manual mode.

   **Note:** Recall that checking these boxes hands control of the Variable Power Supplies' outputs over to the controls that you adjusted for Step 10.

12. Launch and run the NI ELVIS II Function Generator virtual instrument.

13. Type **5000** in the function generator's **Hz** window and press **Enter** on the keyboard.

   **Note:** Once you've done this, the window's value will change to "5k" as shown in Figure 1 below.

   ![Waveform Settings](image)

   *Figure 1*


15. Set the function generator's **Modulation Type** to **FM**.

   **Note:** This step puts the function generator in to VCO mode.
16. Connect the set-up shown in Figure 2 below.

**Note:** Although not shown, insert the black plug of the oscilloscope lead into a ground (GND) socket.

![Figure 2](image)

17. Adjust the scope’s *Timebase* control to view two or so cycles of the function generator’s output.

18. Use the scope’s measuring function to find the frequency of the function generator’s output. Record your measurement in Table 1 below.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function generator’s output</td>
<td></td>
</tr>
</tbody>
</table>
19. Modify the set-up as shown in Figure 3 below.

Before you do...
The set-up in Figure 3 builds on Figure 2 so don't pull it apart. Existing wiring is shown as dotted lines to highlight the patch leads that you need to add.

Figure 3

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

Figure 4
20. Activate the scope's Channel 1 input to view the function generator's DC input voltage as well as its AC output voltage.

21. Set the scope's Channel 1 Scale control to the 5V/div position.

22. Set the scope's Channel 1 Coupling control to the DC position.

23. Increase the Variable Power Supplies' positive output voltage while watching the scope's display.

**Question 1**
What happens to the function generator's output when you increase its positive DC input voltage?

24. Set the Variable Power Supplies' positive output voltage to 10V.

25. Measure the function generator's new output frequency. Record your measurement in Table 2 below.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function generator's new output</td>
<td></td>
</tr>
</tbody>
</table>

**Question 2**
Use the information in Tables 1 and 2 to determine the function generator's VCO sensitivity (that is, how much its output frequency changes per volt).

**Note:** The VCO sensitivity is different for ELVIS I and ELVIS II. Be aware of this difference if you have both in your lab. You may wish to compare the difference if you have the time. If you do, make sure that you take readings at several frequencies across the range.
Importantly, the function generator's VCO sensitivity is different for different frequency decades.

26. Repeat this process to determine the sensitivity of the function generator's VCO at 500Hz and 50kHz. Record your measurements in Table 3 below.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>500Hz setting</td>
<td></td>
</tr>
<tr>
<td>50kHz setting</td>
<td></td>
</tr>
</tbody>
</table>
27. Modify the set-up as shown in Figure 5 below.

![Diagram](image)

**Figure 5**

This set-up can be represented by the block diagram in Figure 6 below.

![Block Diagram](image)

**Figure 6**
28. Increase the Variable Power Supplies' negative output voltage while watching the scope's display.

Question 3
What happens to the function generator's output when you increase its negative DC input voltage?