Manual for EE2073 Lab Work

The work carried out in the lab is divided into the following parts.

Part 1 Labview programming and using ELVIS II in Weeks 3-5.
The reference materials are

- Introduction to LabVIEW
- Introduction to NI ELVIS II
- Data Acquisition Using LabVIEW & ELVIS

which are provided in NTULearn. Students should read through these materials before coming to the lab doing the exercises.

Part 2 Design, development, test and evaluation of subsystems and the integration of hardware and software subsystem modules to form a complete Automatic Volume Control for Audio Amplifier system. The reference materials are

- EE2073 Project Manual
- The data Sheets for CA3140, LM380 and SSM2018T
- Lecture Notes

Finally, guides for preparing and submitting the final report are also provided in the directory of Assessment Submission Matters.

- EE2073 Report Template
- How to Upload Weekly Logbooks
- Turnitin Guide for EE2073 Students

LABVIEW & ELVIS II EXERCISE

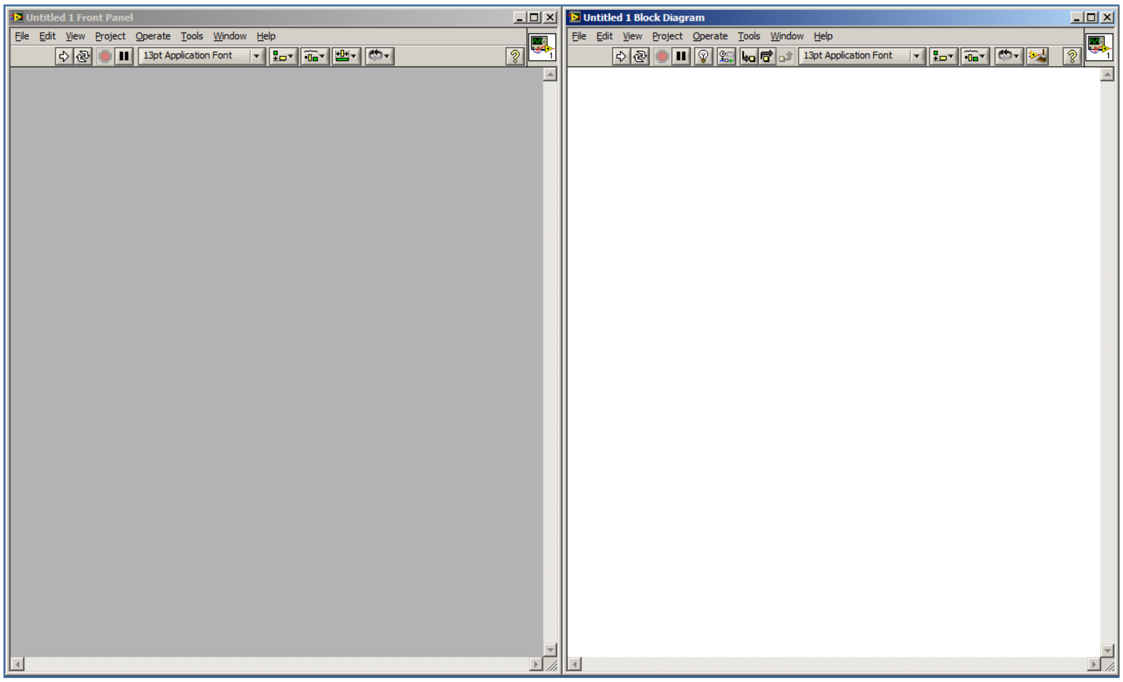
Part A. LabVIEW Exercise

1. OBJECTIVE

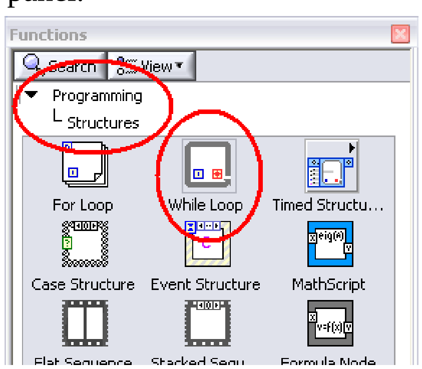
To create a LabVIEW VI that simulates a signal and displays it on the front panel.

2. EXERCISE

a) Open a blank VI from the Project Explorer by selecting **New» VI**.

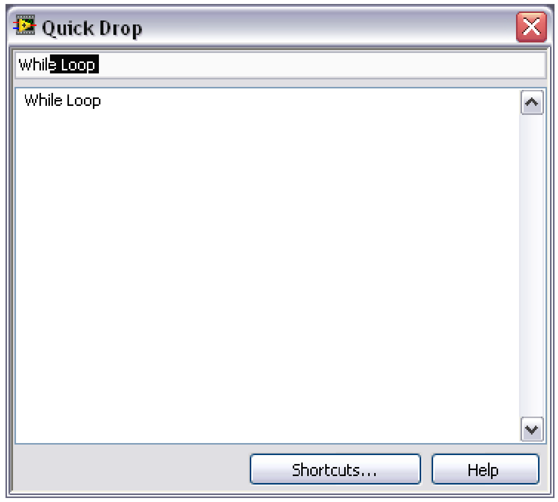


b) Add a While Loop to the block diagram window. Right-click on empty space of the block diagram window to bring up the Function palette, and then follow the path **Programming» Structures» While Loop**. Left-click mouse button on the While loop for selection and place it in the block diagram panel.

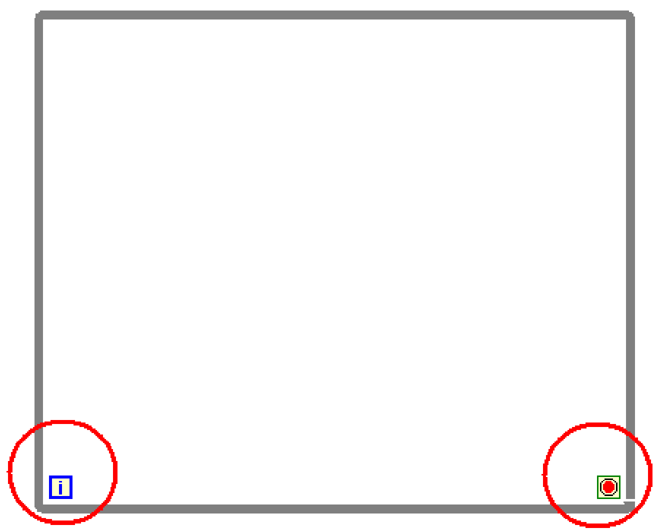


Click and drag diagonally to form the desired While loop area. You can also resize the While loop area by dragging any of the resizing boxes that appear when the cursor hovers above the loop's edges.

You can also create a While loop by pressing <Ctrl + Space Bar> to bring up the Quick Drop dialog. By typing “While Loop” to bring up a list of possible objects. Double- click on its name for selection and placing it in the block diagram window. Since you’ve already placed the while loop, release the while loop you found using Quick Drop by right-clicking.

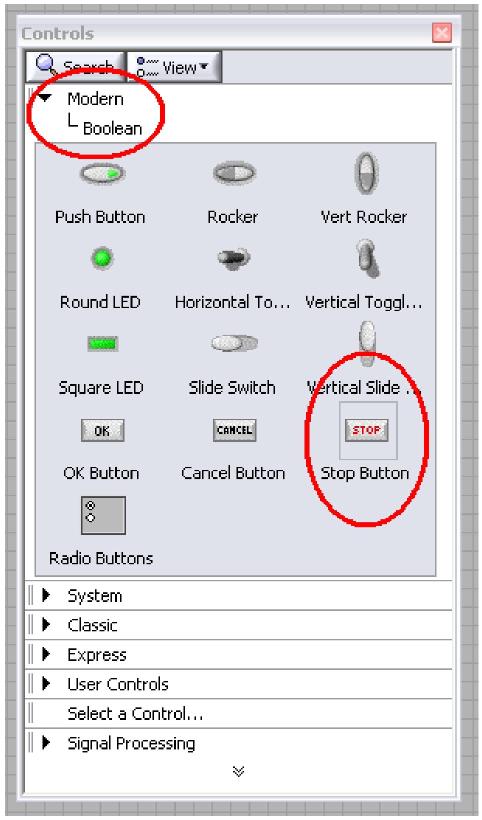


c) While loops have two terminals in their bottom left and right corners.



It is necessary to have a loop condition terminal  that is on the lower right corner. Since while loops keeps running until a stop condition is met, we must provide some kind of stop command so that the loop will not run indefinitely. Notice the broken run arrow in the upper left of the screen. LabVIEW cannot execute an application that contains a while loop with an un-wired conditional terminal (fuzzy). For our application, we need to create a stop button to be pressed to halt the while loop and exit the program. On the front panel, right click on any empty space to bring up the Controls palette and navigate to **Modern» Boolean» Stop Button**.

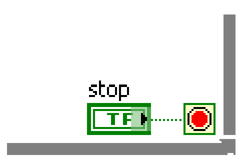
Left click on the stop button for selection and it will automatically follow the mouse cursor.



Left-click mouse button to place it on the front panel. You may resize the Stop button by dragging the edges of the Stop button with the mouse.

d) Look again at the block diagram window. Notice that a terminal for the stop button has appeared. This terminal acts as the connector from the front panel to the functionality of the block diagram window. Click on the stop terminal and drag it next to the loop condition terminal in the While loop.

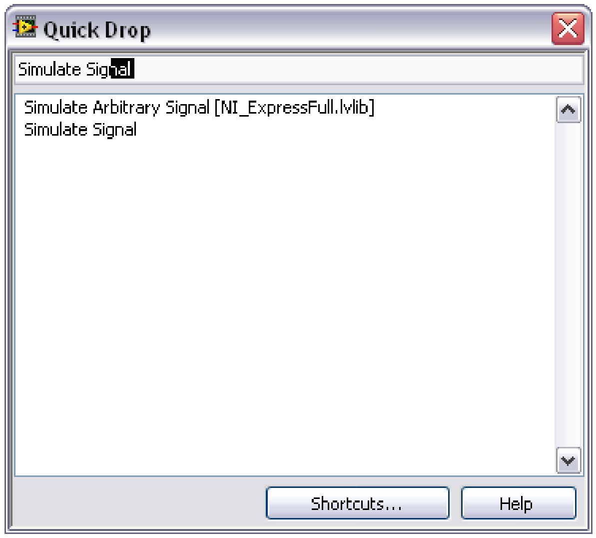
e) Move your cursor to the right edge of the stop terminal and notice that the edge of the terminal is blinking and the cursor now looks like a spool. This is the wiring tool that lets you draw wires between different objects on the block diagram. Left-click on the edge of the stop terminal and drag the cursor until you are hovering over the left edge of the While loop's condition terminal, and then release. The wire is now connected between the stop terminal and the conditional terminal.



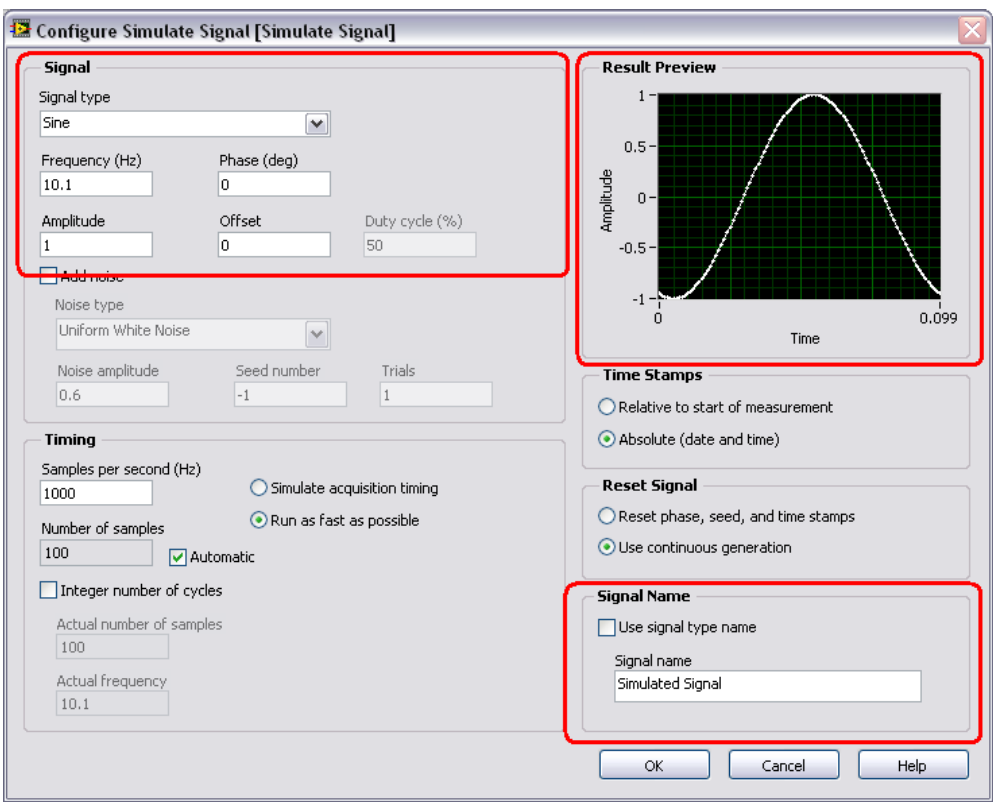
With the While loop now having a way to exit, the broken Run arrow is replaced with a Run arrow and your application is ready to run. However, you'll need to add more code to accomplish the tasks of this exercise.

f) The other terminal in the while loop is the loop iteration counter that counts the number of times the While loop has iterated. The counting information may be useful depending on your application, but we will not be using it today.

g) Create a simulated signal. Press <Ctrl + Space Bar> to bring up the Quick Drop dialog and begin to type "Simulate Signal." Double-Click "Simulate Signal" once to bring up the box seen below. The Simulate Signal Express VI will automatically appear on your cursor.

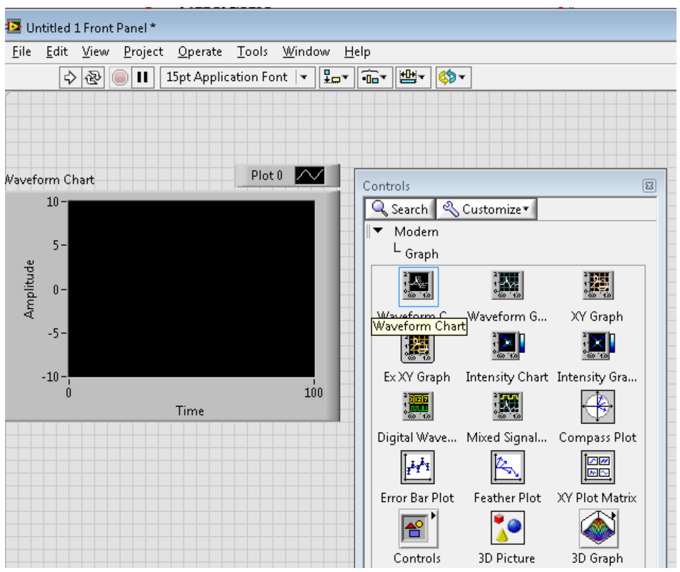


h) Left-click to place the Simulate Signal Express VI inside the While loop. A configuration dialog below will appear to allow you to set the parameters of the signal to be simulated.

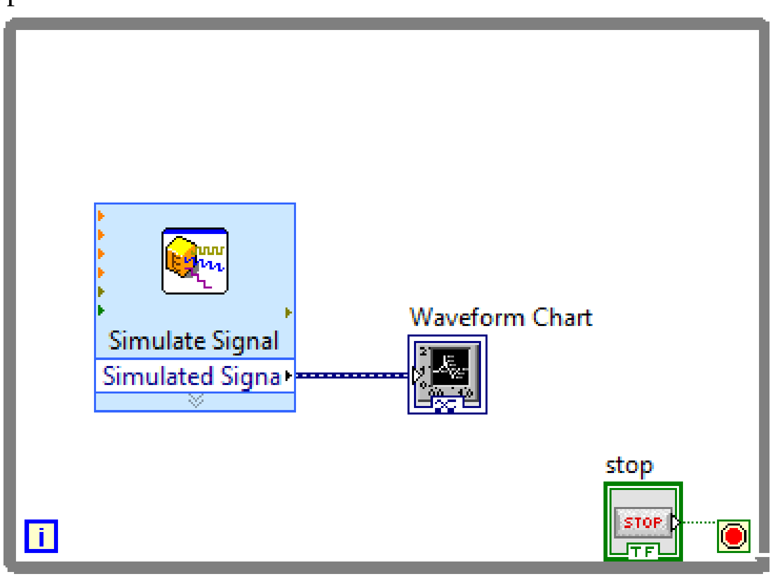


i) Change the Signal Type, Amplitude, Frequency, Offset and Phase values in the Signal portion of the dialog and see the changes in the Results Preview area. Deselect the “Use signal type name” box in the Signal Name section and enter “Simulated Signal” as the name. Once you have chosen the signal you want to display, press “OK.” The Simulate Signal Express VI has now been customized based on the settings you have provided.

j) Connect the simulated signal to a chart. Move to the front panel and bring up the Quick Drop dialog and type the word “chart.” Place the Waveform Chart on the front panel at the location you prefer.



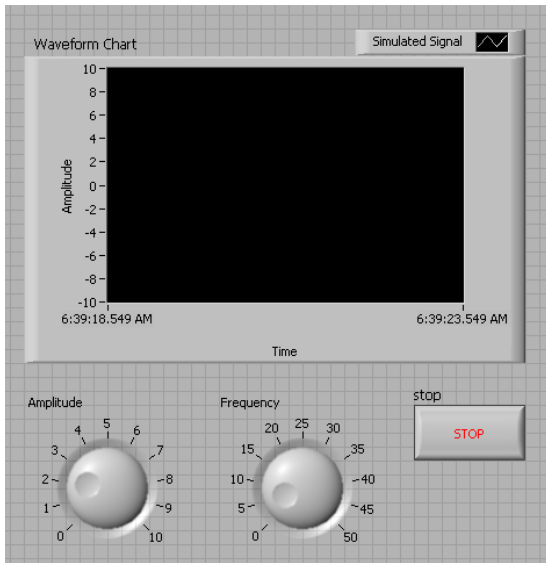
k) Return to the block diagram window and move the chart’s icon into the While loop to the right of the Simulate Signal Express VI. Connect the output of the Simulate Signal Express VI (“Simulated Signal”) to the chart terminal. Notice that the chart terminal changed colors to reflect the data type it receives.



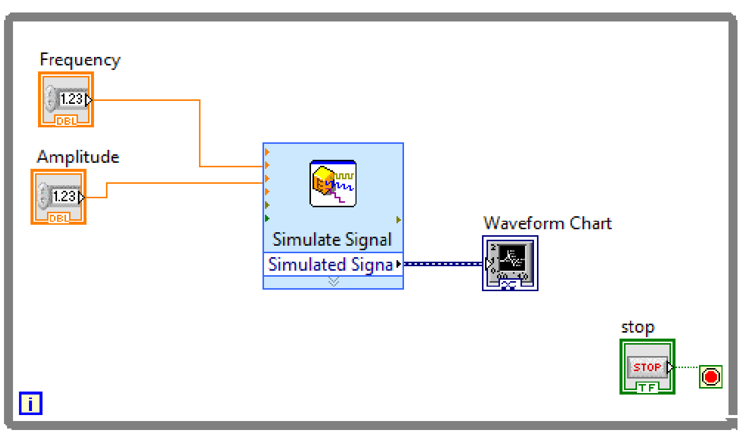
l) Return to the front panel and run the VI. The simulated signal you created in the Express VI is now displayed on the chart. Press the Stop button when you are done and ready to move on.

m) Add controls to adjust signal frequency and amplitude while the program is running. Right-click on an empty space on the front panel to bring up the Controls palette. Find the knob control (Modern» Numeric» Knob) and place it on the front panel. Double-click on the knob's label and change it to "Amplitude."

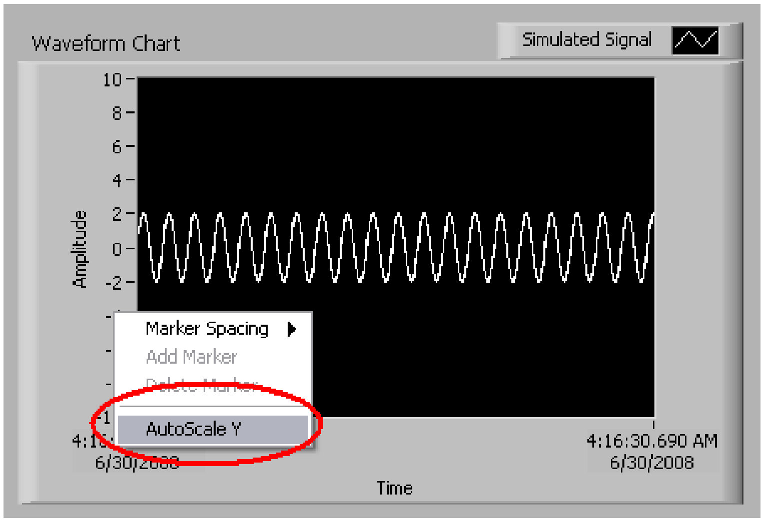
n) Repeat the above step to make another knob for frequency. Change its label to "Frequency". Double-click the maximum value on Frequency's scale and change it to 50. See below:



o) On the block diagram window, move the Amplitude and Frequency controls inside of the while loop and connect them to the associated inputs of the Simulate Signal Express VI. With both terminals inside the while loop and on the left side of the Simulate Signal Express VI, hover your cursor over the right side of each terminal until the wiring tool appears on the cursor. Left-click mouse button and drag the connection to the identically named input on the Express VI. Your block diagram should look like the following.



p) Run the VI. Press the run arrow and manipulate Amplitude and Frequency and observe the chart display changing accordingly. The Chart's y-axis auto-scales to maximize the signals magnitude the display. To disable that feature, right click on the chart and deselect "AutoScale Y."



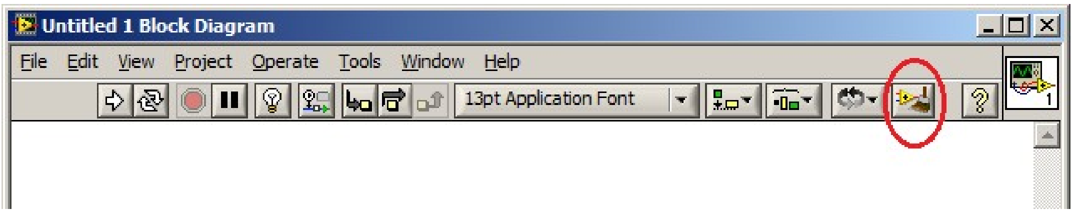
You can now change the upper and lower ranges of the Y-axis by clicking on the numbers along the axis and typing in new values.

q) Stop the VI by pressing the stop button.

Additional Steps

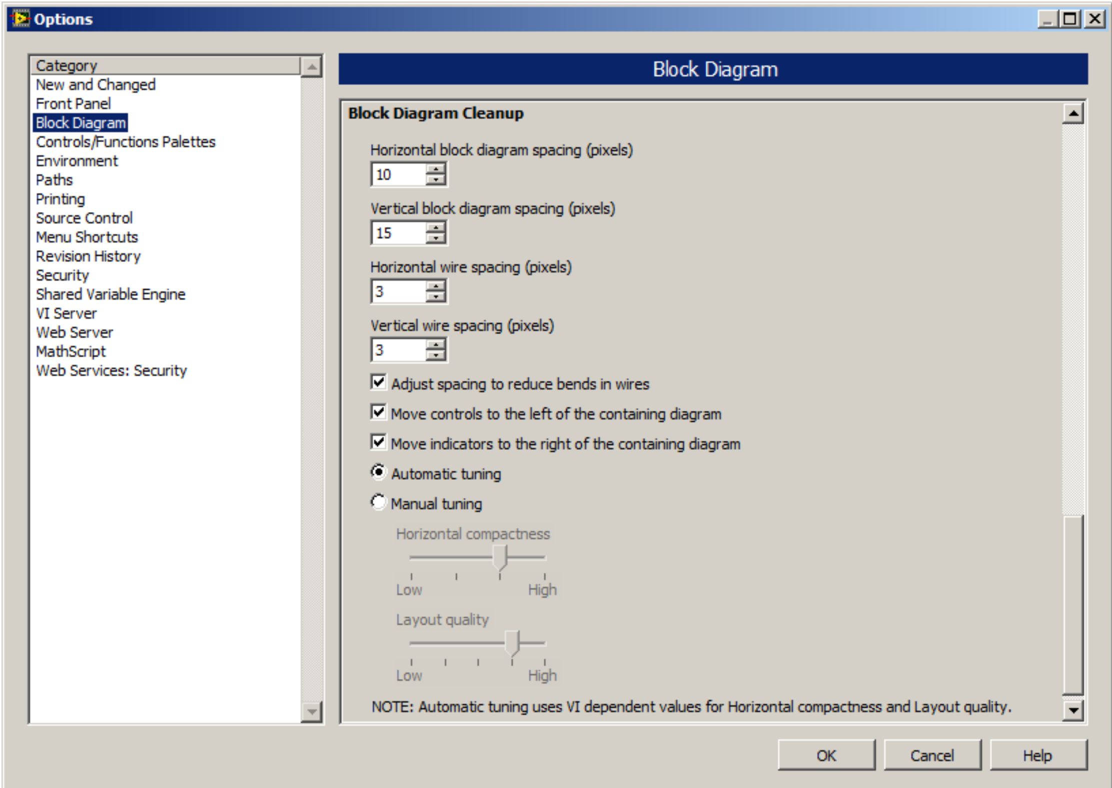
LabVIEW provides several tools that can help you develop your applications. The next few steps will show how to use some of the most important programming assistance tools.

r) Use Block Diagram Cleanup to organize your block diagram. As you program, and especially as you learn how to program in LabVIEW, you are not always thinking about layout and readability. This can result in poorly organized block diagram.
LabVIEW's Block Diagram Cleanup is a built-in tool that organizes your code, making it easier for you and others to understand how your program functions. Press the Block Diagram Cleanup icon found on the menu bar.



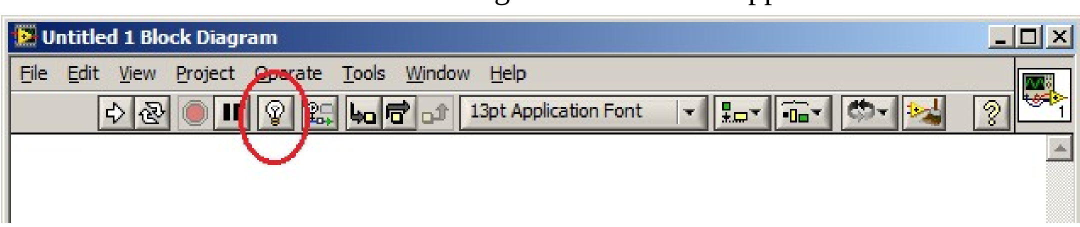
Your block diagram should now be organized, with tidied wires and an even distribution of code elements.

To customize how the Block Diagram Cleanup tool organizes your code, change settings in the "Block Diagram: Cleanup" section of the Options menu at **Tools» Options…**.



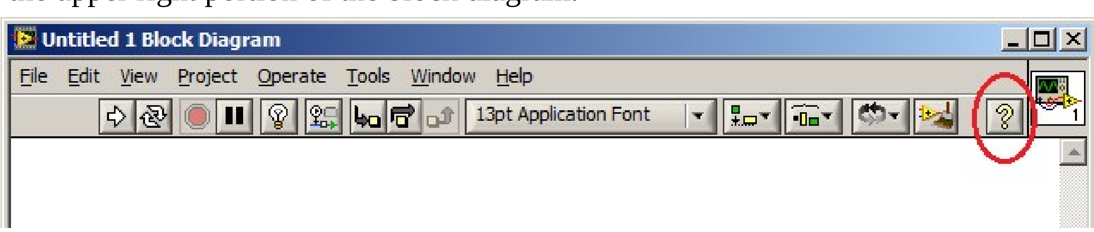
This menu lets you customize how far wires, structures, functions and terminals being spaced from each other and from the edges of your block diagram. Click OK when you are ready to move on.

s) Use Highlight Execution to observe how your application runs. Press the Highlight Execution button on the menu bar. Notice that the light bulb icon now appears to be on.

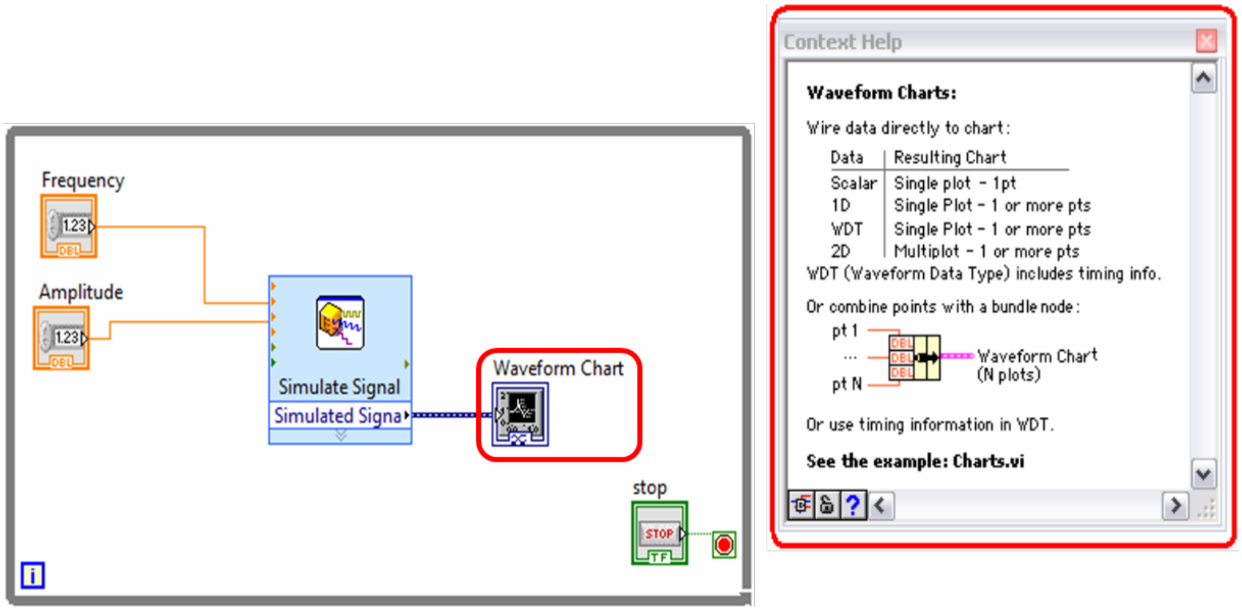


t) Run your application with Highlight Execution turned on. Press the run arrow and watch as your code executes step-by-step. While not always necessary for simple applications, the Highlight Execution tool is a powerful resource for trouble shooting complex programs and determining if your code performs as expected.

u) Use Context Help to identify object details while programming. Press the Context Help button in the upper right portion of the block diagram.



v) With the Context Help active, hover your cursor over different objects on the block diagram and front panel of Simulate Signal to Graph.vi. As you do so, the Context Help Window provides details including descriptions and wiring diagrams.



w) Right-click on the block diagram and navigate around the palettes. Notice that the Context Help window provides details on the objects while they are in the palettes. Also notice that for some objects, the Context Help window provides a link for "Detailed Help…" This link will open the LabVIEW Help and give you more information.

x) Save as "Simulate Signal to Graph.vi" and close.

Open Ended Questions

- In the configuration dialog of Simulate Signal Express VI, try to add noise to your signal and select various noise types. Discuss your observations.
- How to change while loop to for loop? Discuss the parameter change and the difference between the two loops.

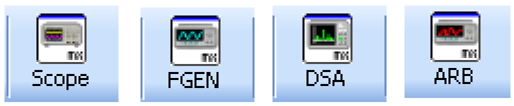
Part B. ELVIS II Exercise

1. OBJECTIVE

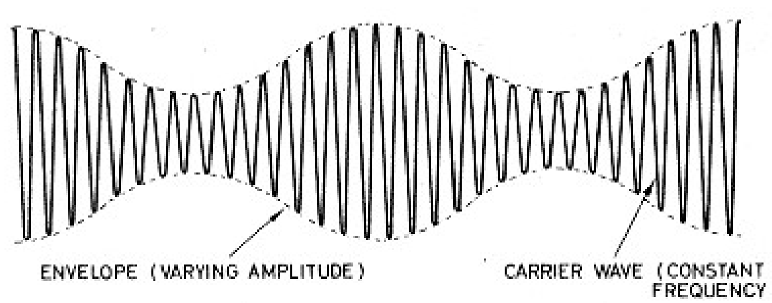
To introduce various instruments through exercises using NIELVIS II.

2. INTRODUCTION

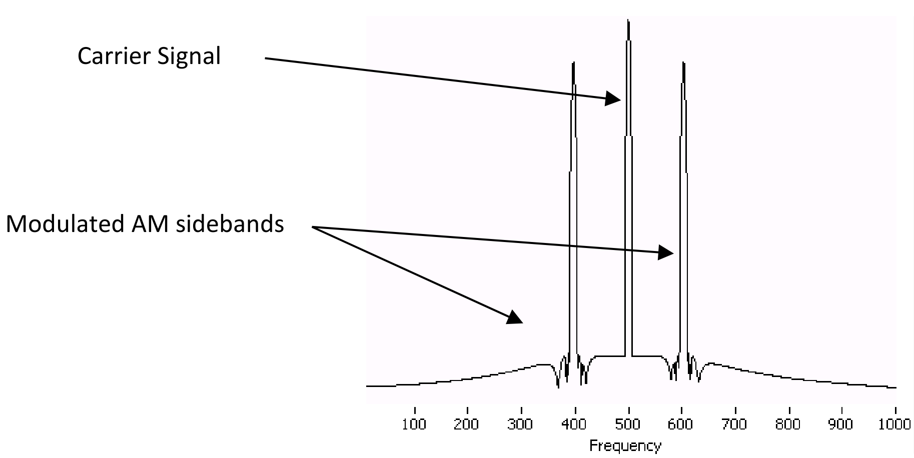
The exercises using NI ELVIS II involve the following instruments: Oscilloscope (SCOPE), Function Generator (FGEN), Dynamic Signal Analyzer (DSA) and Arbitrary Waveform Generator (ARB). These instruments are to be used to illustrate the concept of Amplitude Modulation in communication.



Amplitude Modulation (AM) is an analog modulation scheme where the amplitude of a fixed-frequency carrier signal is continuously varied to represent data in a message. The carrier signal is generally a high frequency sine wave used to “carry” the information on the envelope of the message. The result is a double-sideband signal, centered on the carrier frequency, with twice the bandwidth of the original signal.



Time domain of an AM signal wave



Frequency domain of an AM signal wave

The following equation is commonly used to describe amplitude modulation:

$$y(t) = C\sin(\omega_c t) + M\frac{\cos(\phi - (\omega_m - \omega_c)t)}{2} - M\frac{\cos(\phi + (\omega_m + \omega_c)t)}{2}$$

3. EQUIPMENT AND COMPONENTS

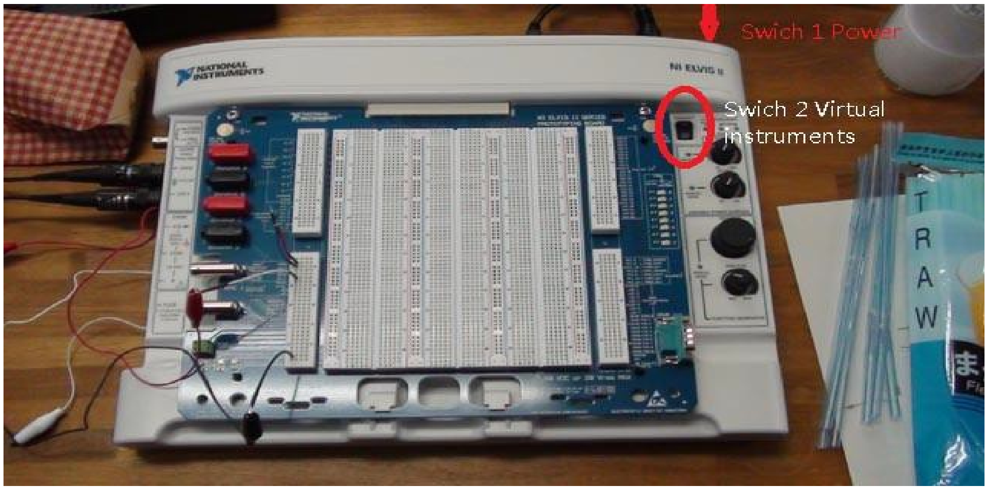
Equipment: Personal Computer (PC) with LabVIEW and NI ELVIS launcher/driver
NI ELVIS II

Components: Cables
Wires

4. EXERCISES

4.1 Function Generator & Oscilloscope

a) Switch on the NI ELVISmx prototype board. Find the two switches on the up right corner of the board, one for the overall power and the other for the NI ELVISmx Instrument. Switch both on.



b) Launch the NI ELVISmx Instrument Launcher, *START » All Programs » National Instruments » NI ELVISmx » NI ELVISmx Instrument Launcher*.

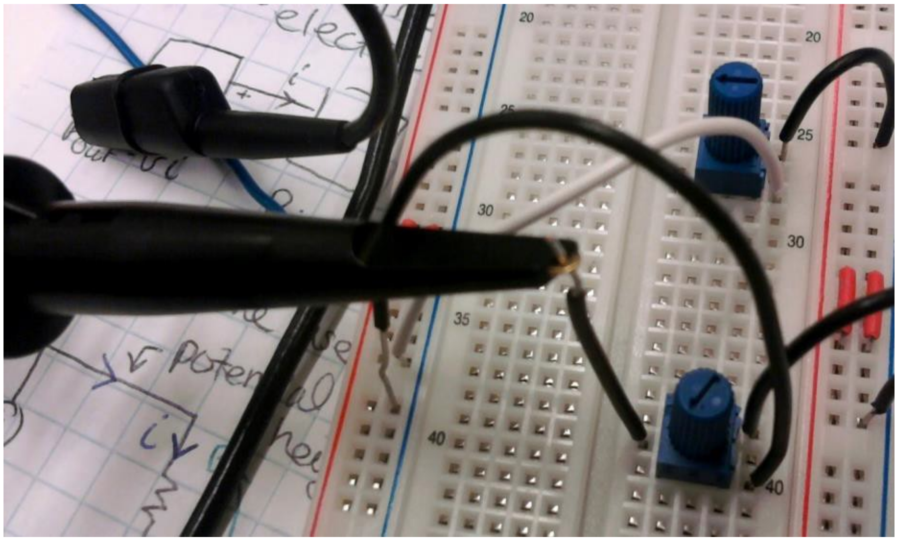
c) From the NI ELVISmx Instrument Launcher, open the Function Generator (FGEN). Run the instrument with the default settings. If the instruments are not functioning properly, firstly try to restart both the software and the hardware.

d) Launch the Oscilloscope (SCOPE) and select the following channel sources:

Channel 0 Settings: SCOPE CH0 ←FGEN

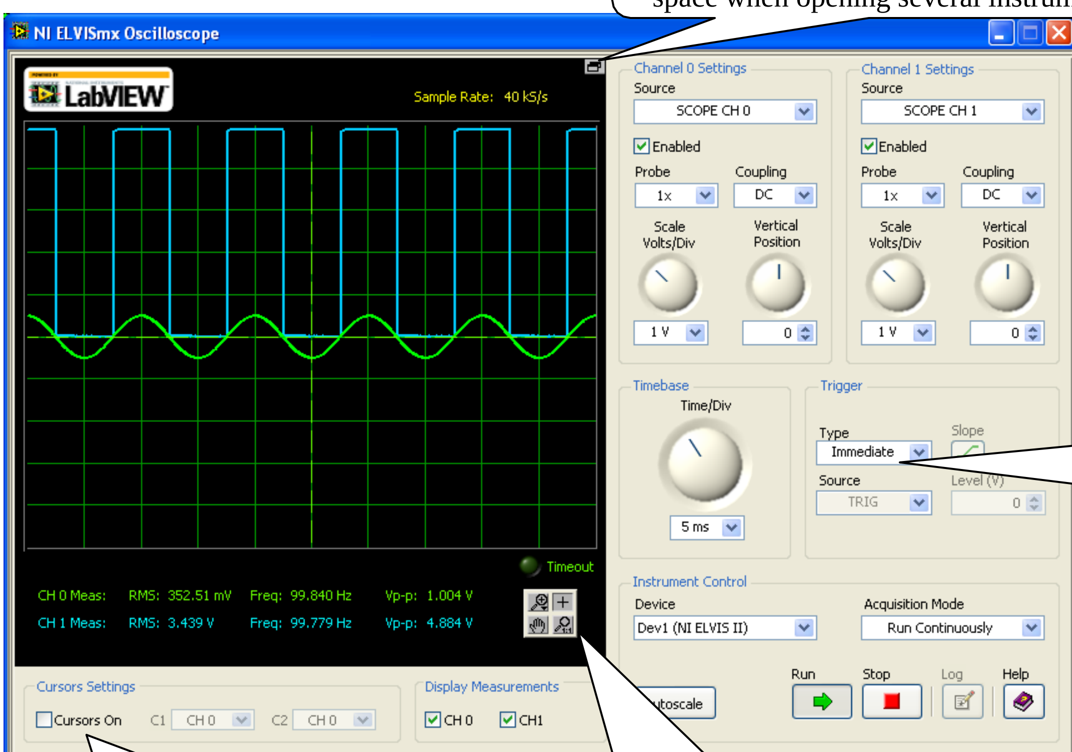
Channel 1 Settings: SCOPE CH 1 ← SYNC

where "←" represents a physical connection on the prototype board of the NI ELVIS. Physical connection means a connection using wire between the two junctions.



e) Run the Oscilloscope and observe the following. To observe signals from two channels, make sure the scale is properly set, both channel are enabled and the scale is properly set.

You can hide controls after presetting to save space when opening several instruments



Trigger

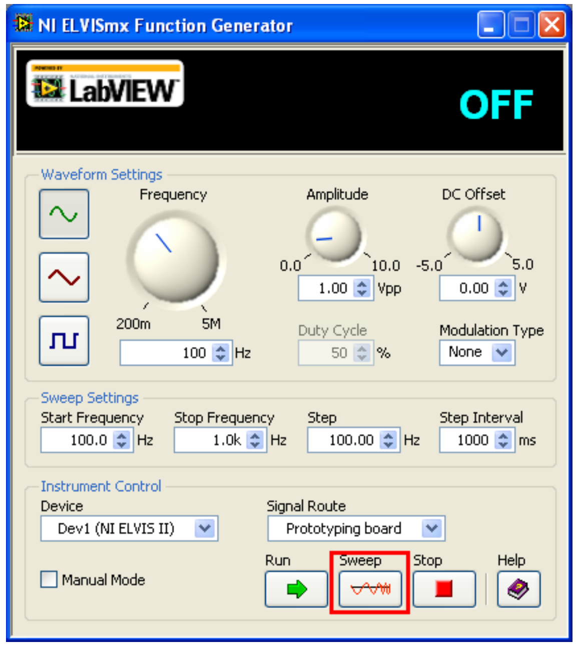
Same as traditional instruments

Show/Off cursors and display measurements.

Instruments created with LabVIEW have the flexibility of LabVIEW graphs

f) Stop the Function Generator. Keeping both instruments open.

g) Click on the Sweep button using the defaults settings to do a Frequency Sweep and observe it with the Oscilloscope.

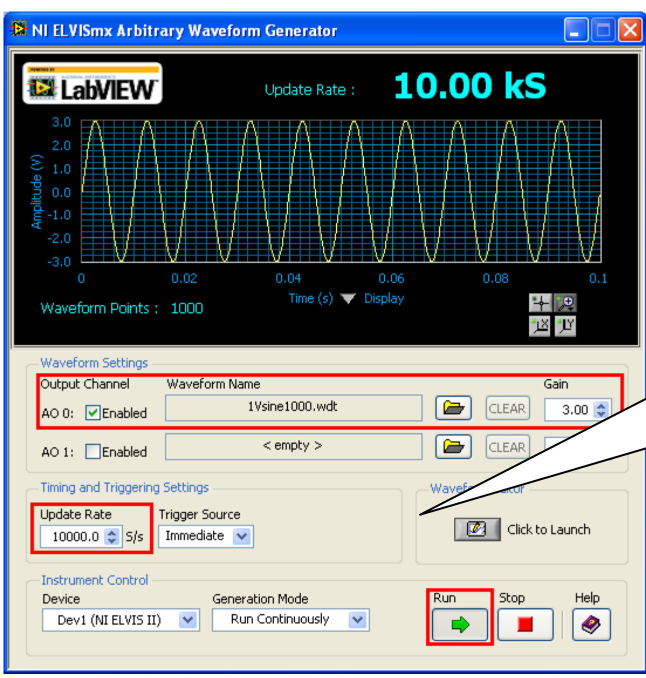


4.2 Arbitrary Waveform Generator & Dynamic Signal Analyzer

The AM and FM terminals provide analog inputs for the amplitude and frequency modulation of the function generator output.

a) Connect AO0 to the AM terminal and launch the Arbitrary Waveform Generator (ARB).

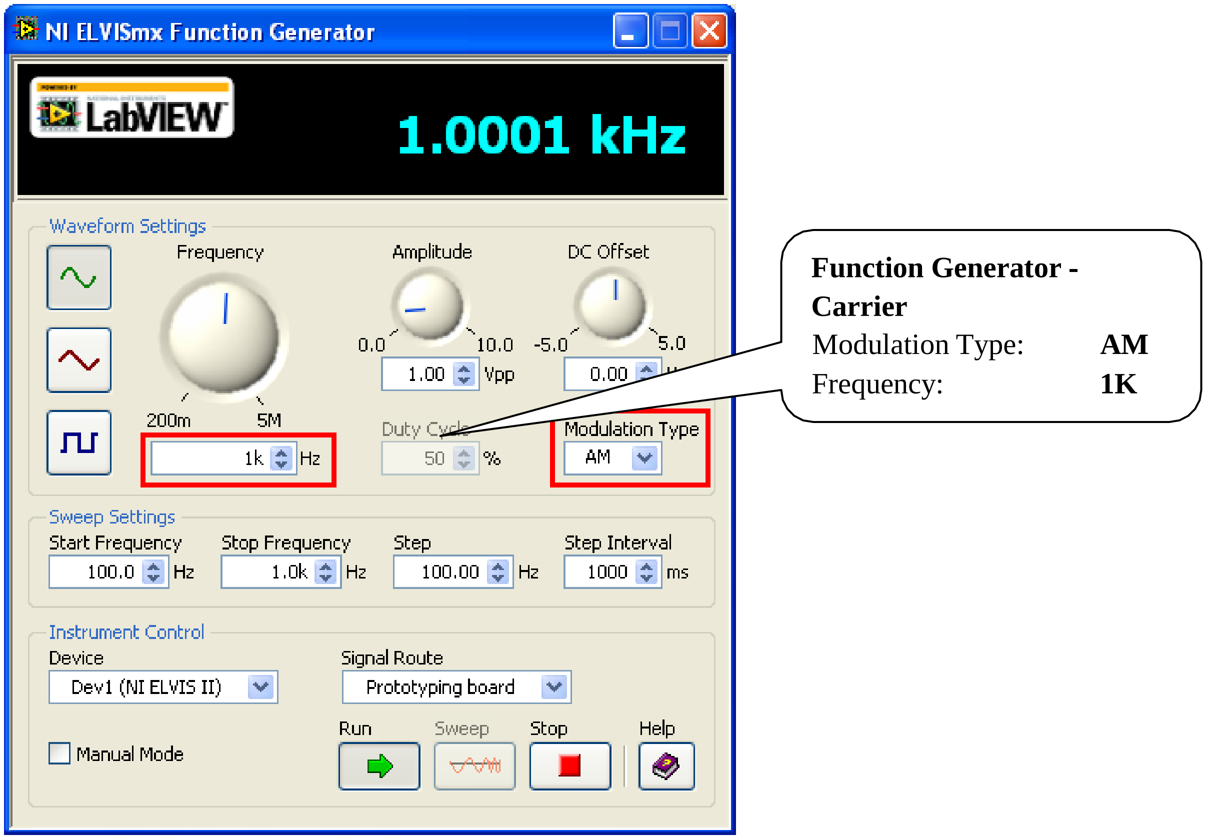
b) Load the “1Vsine1000.wdt” file that ships with NI ELVIS driver. Set the following settings and run the ARB:



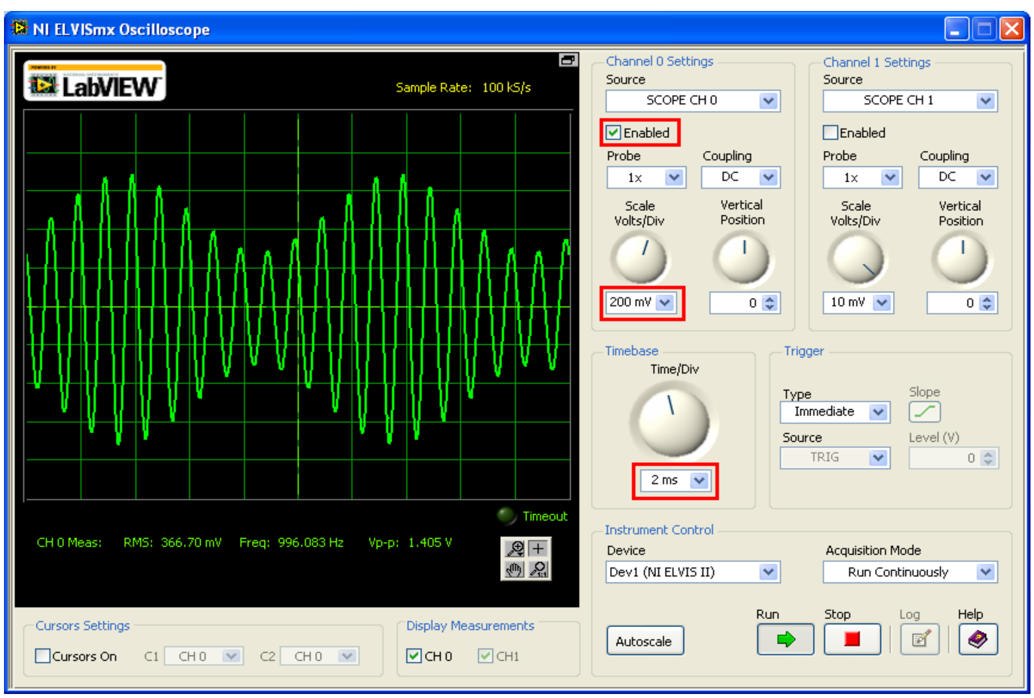
Arbitrary Waveform Generator – Tone

Load Waveform file:	**Vsine1000.wdt**
AO 0: Enabled	**Checked**
Gain:	**3V**
Update Rate:	**10k**

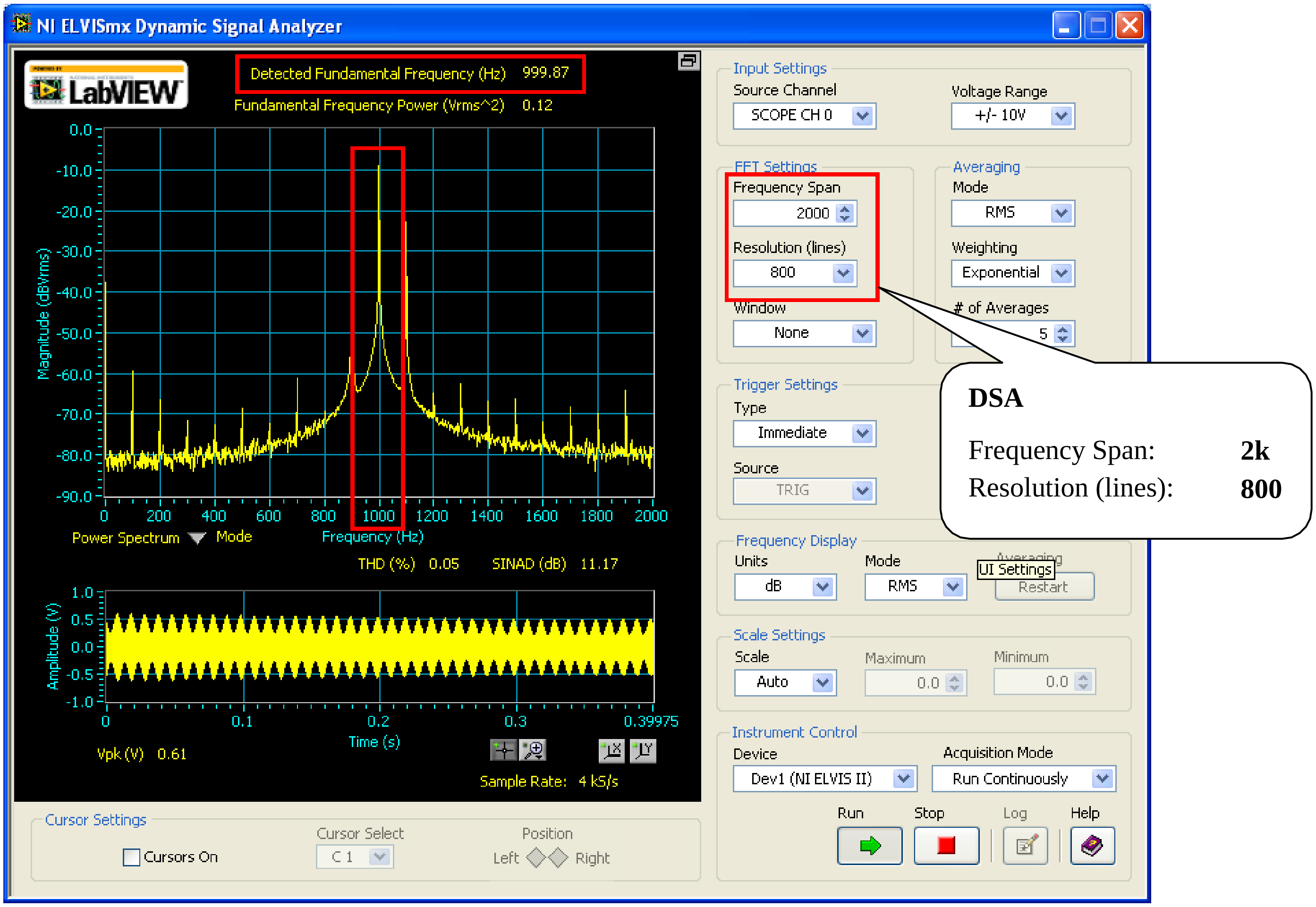
c) Launch the Function Generator, make the following changes and run:



d) Launch the Oscilloscope if not already open and observe the waveform. Note that the SCOPE CH0 is physically connecting with FGEN.



e) Close the Oscilloscope. Now Launch the Dynamic Signal Analyzer (DSA) and observe the frequency spectrum.



Amplitude Modulation on the DSA:

FGEN – 1 kHz Carrier (Fundamental Frequency)
ARB – 100 Hz Tone

Note that the 100Hz tone is ‘carried’ as satellite pulses in frequency domain locating on the both sides of the fundamental frequency. The frequency difference between a satellite pulse and the main pulse is 100Hz.

4.3 Logbook

Your logbook may consist of the following:

- Schematics or snap photos of circuits and instrument setups.
- Screen/window capture of waveforms and run-time outputs.
- Tabulation/graphs of measurement results and theoretical calculations.
- Record of observation key points during experiments.
- LabVIEW/other programs, block diagrams, front panels, etc.

At the end of the session, upload your (multiple) logbook files to a file server regardless whether you have completed all the tasks or not. You have to upload all that you have for the day and you are not permitted to change the logbook once uploaded until the next new session. All changes should be made only at the following new session and the revised logbook re-uploaded.

Open Ended Questions

Instead of sinusoidal signal, you may try with other signal types available from FGEN for the above exercises. You may even experiment with other modulation types using FGEN and/or other waveforms using ARB. Discuss the setups, procedures, results, observations, etc. in your attempts.

DATA ACQUISITION USING LABVIEW/ELVIS

1. OBJECTIVE

To implement and test data acquisition (DAQ) using LabVIEW/ELVIS.

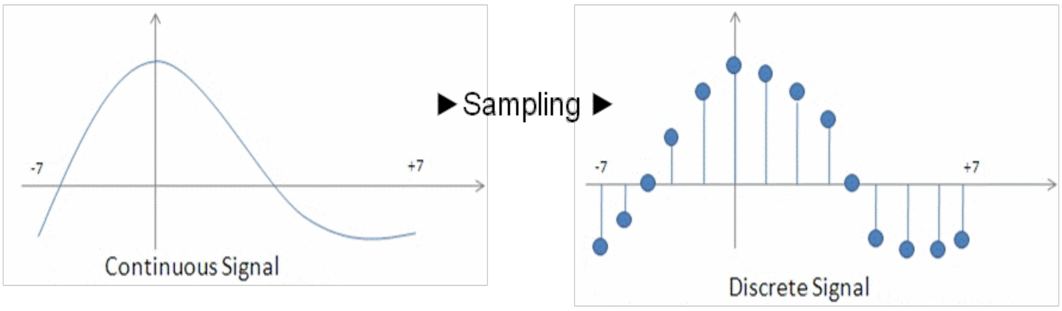
2. INTRODUCTION

There are several ways in which the data can be exchanged between instruments and a computer. Many instruments have a serial port or an IEEE 488 GPIB interface which can exchange data to and from a computer or another instrument.

Another way to measure signals and transfer the data into a computer is by using a DAQ card. A typical commercial DAQ card or module allows input of analog signals through an analogue-to-digital converter (ADC) and output of analog signals through a digital-to- analogue converter (DAC). In addition a DAQ card often facilitates input and output of digital signals as well.

Sampling

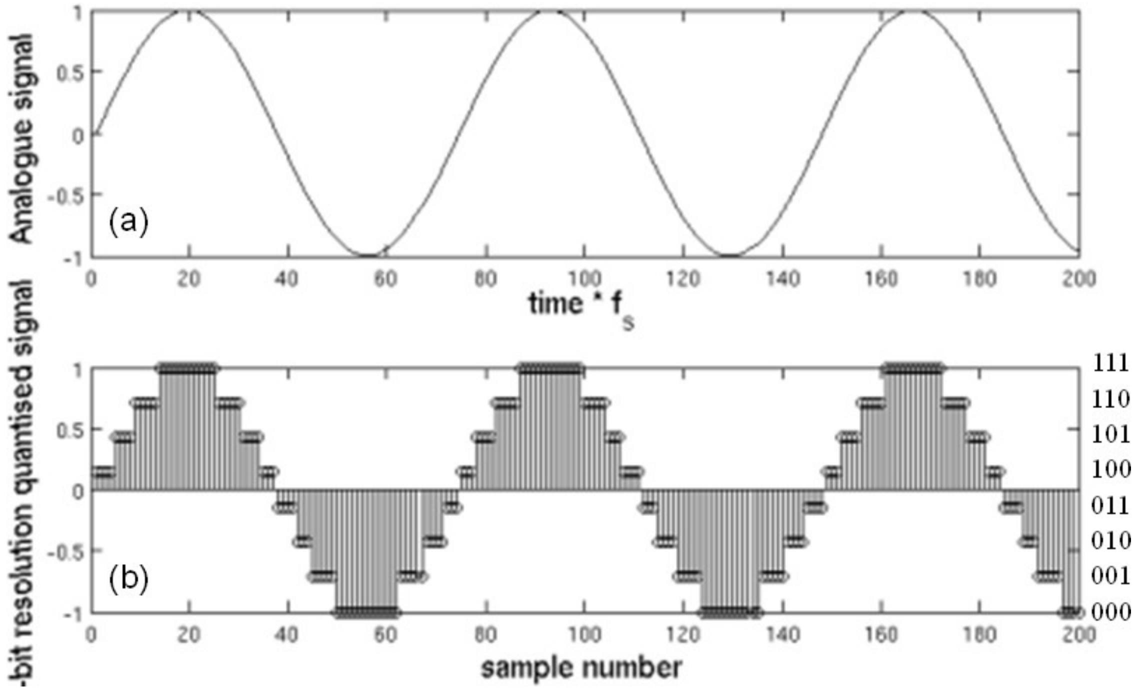
The data is acquired by an ADC using a process called sampling. Sampling an analog signal occurs at discrete time intervals. The rate (or frequency) at which the signal is sampled is known as the sampling rate (or frequency). The process of sampling generates values of the signal as a function of time as shown below:



The sampling rate determines the quality of the analog signal conversion process. A higher sampling rate achieves better accuracy representing the analog signals. The minimum sampling frequency required should be at least twice the maximum frequency of the analog signal to be converted, which is known as the Nyquist sampling frequency.

Analogue-to-Digital Converter

Once the signal has been sampled, the analog signal is converted into a digital format. This process is called analog to digital conversion, as illustrated below:



An example of 3-bit ADC

Commercially available boards allow to use sampling frequencies. The DAQ module on NI ELVIS II allows sampling rate up to 1.25 MS/s. Most boards also have a multiplexer that acts as a switch to feed different channels to the ADC. Therefore with 1 ADC, it is possible to have a multi-channel input DAQ board.

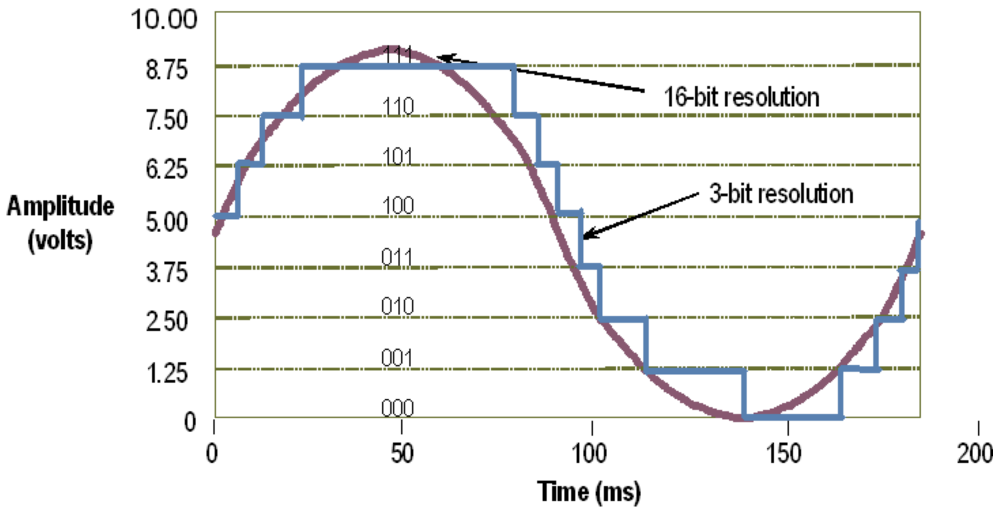
Resolution

Precision of the analog to digital conversion process is dependent upon the number of bits the ADC uses. The resolution of the converted signal is a function of the number of bits the ADC uses to represent the digital samples. The higher the resolution, the higher the number of divisions the voltage range is divided into, and therefore, the smaller the detectable voltage changes. An 8 bit ADC gives 256 levels (2^8) compared to a 12 bit ADC that has 4096 levels (2^{12}). The DAQ module on NI ELVIS II has a 16 bit resolution, 16 single-ended or 8 differential analog inputs.

The Least Significant Bit (LSB) varies with the operating input voltage range of the ADC. If the Full Scale (FS) of the input signal is 10V, then the LSB for a 3-bit ADC corresponds to $10/2^3 = 1.25$V, which is not very good! For a 12 bit ADC, the LSB will be $10/2^{12} = 10/4096 = 2.44$mV. If one needs to detect smaller changes, one has to use a higher resolution ADC. Clearly, the resolution is an important parameter of the DAQ board.

Digital-to-Analog Converter

The multifunction boards also have on-board digital to analog converters (DAC). A DAC can generate an analog output from a sequence of digital input samples. This allows the board to generate analog signals, both dc and ac voltages. Like the ADC, the DAC's performance is limited by the number of samples it can process and the number of bits that are used in converting the digital code into an analog signal.



The figure above shows how a sinusoid waveform is converted by a 3 bit DAC (a 16-bit one is also shown for comparison). A DAC with small settling time and high slew rate (the rate at which an amplifier can respond to change in input) can generate high frequency signals, because little time is needed to accurately change the output to a new voltage level.

Using high performance DAQ cards and fast computers, and data processing software like LabVIEW, one can achieve performance similar to expensive bench top instruments. The virtual instruments (VIs) can therefore control an output, process the input signals and log the data.

3. EQUIPMENT AND COMPONENTS

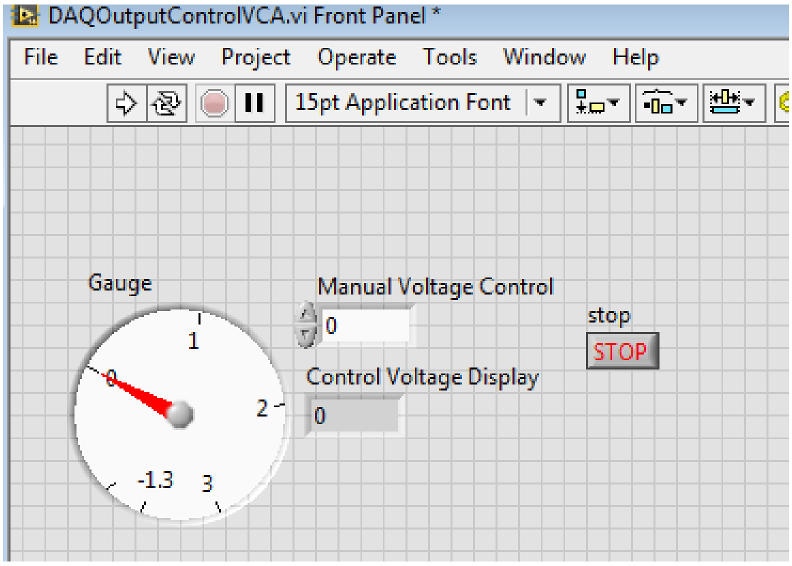
Equipment: Personal Computer (PC) with LabVIEW and NI ELVIS launcher/driver
NI ELVIS II

Components: Cables
Wires

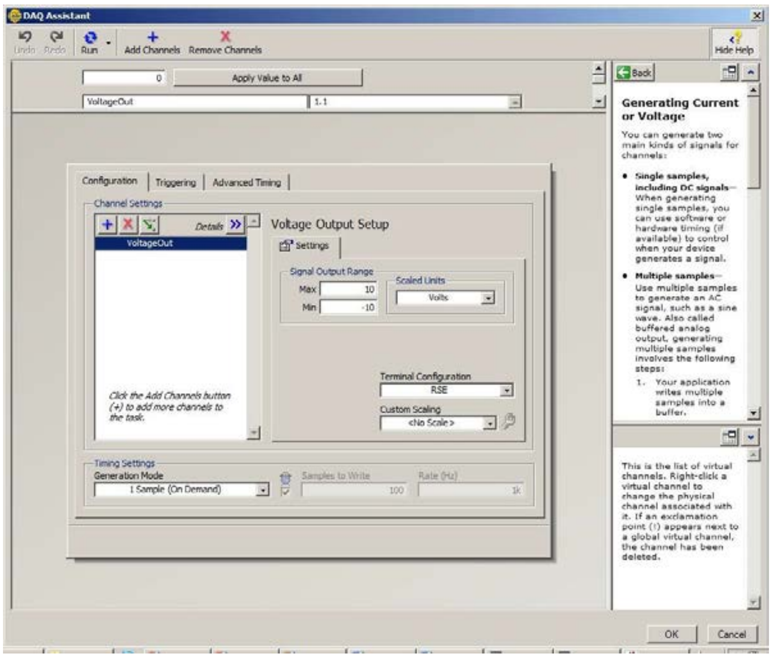
4. DATA ACQUISITION

4.1 Analog Output

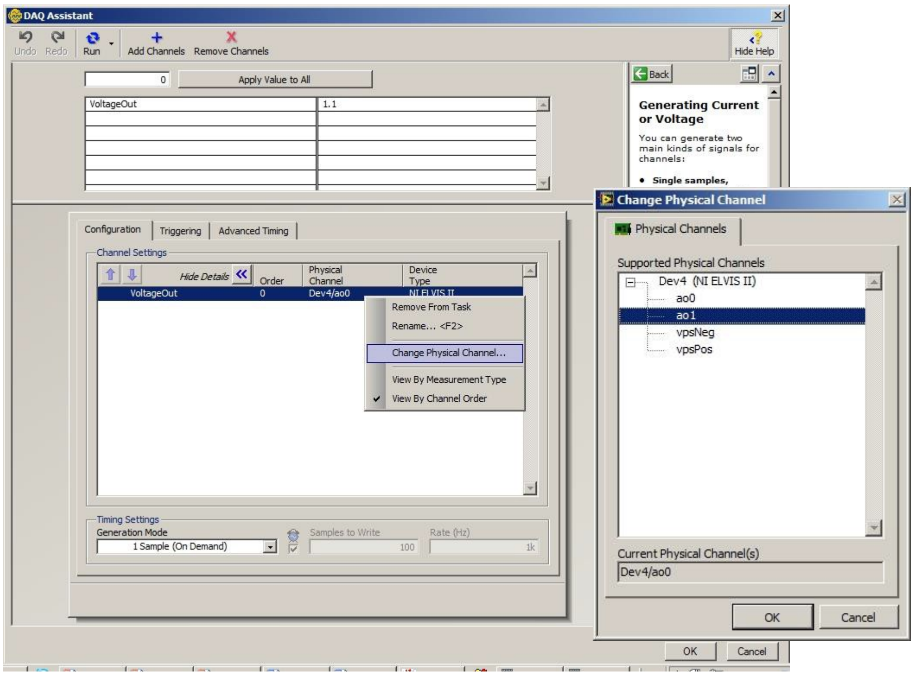
- Create a Front Panel as shown below:



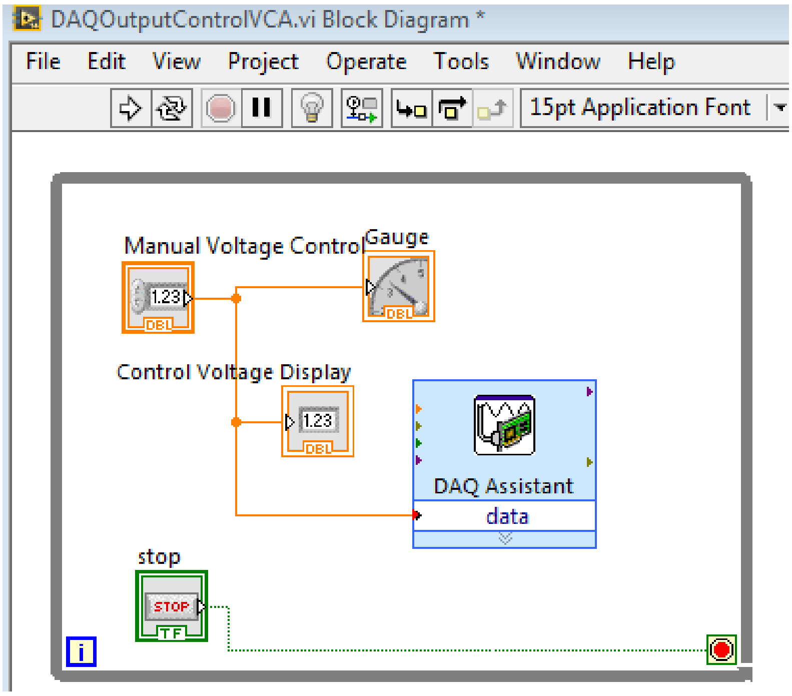
- On the Block Diagram, select Measurement I/O >> NI-DAQmx >> DAQ Assist and place the DAQ Assistant.
- When the NI-DAQ setup window pops up, select Generate Signals >> Analog Output >> Voltage >> Device (NI ELVIS II) >> AO 1, which means analog output channel 1 on NI ELVIS II. (Note when you are using the probe, make sure it is set to x1.
- After the NI-DAQ setup is finished, the configuration window pops up where you can configure Signal Output Range, Terminal Configuration and Timing Settings as



- In the Terminal Configuration, specify the grounding mode as RSE (Reference Single-Ended) where measurement is made with respect to ground.
- In the Timing Settings, set the Generation Mode to 1 Sample (On Demand).
- Under Channel Settings >> Details, you will see the Physical Channel selected where you may change to another channel if desired by right-click and select Change Physical Channel.



- Click OK to finish the configuration.
- Place a While Loop on the Block Diagram and wire up as below:

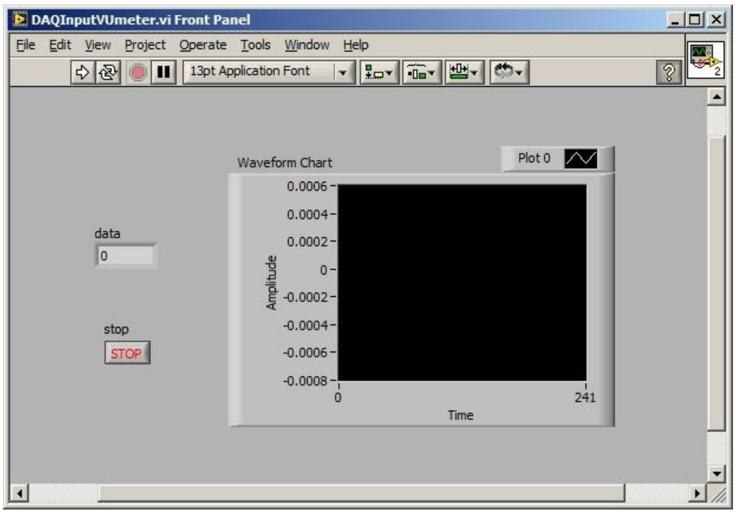


- Note: feel free to explore alternative designs; you should also add your group number on the Block Diagram and the Front Panel.
- Save the VI as DAQOutputControlVCA.vi
- Run the VI, play with various Gauge values, and observe the AO1 output on the oscilloscope.
- Capture the screen with both front panel and block diagram window side-by-side (use Ctrl-T) and paste into your weekly logbook to be uploaded to a file server.

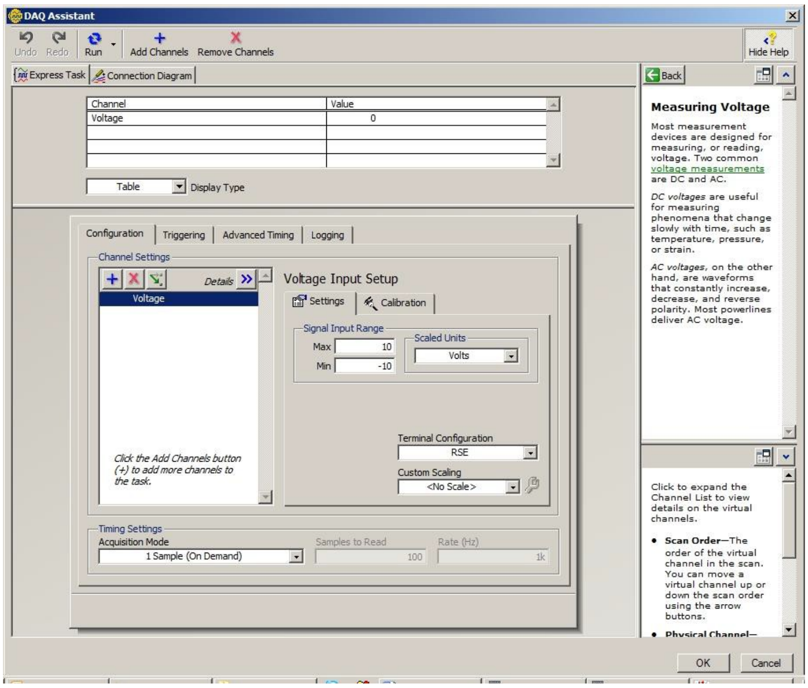
- When it is finished, click the stop (F) button.

4.2 Analog Input

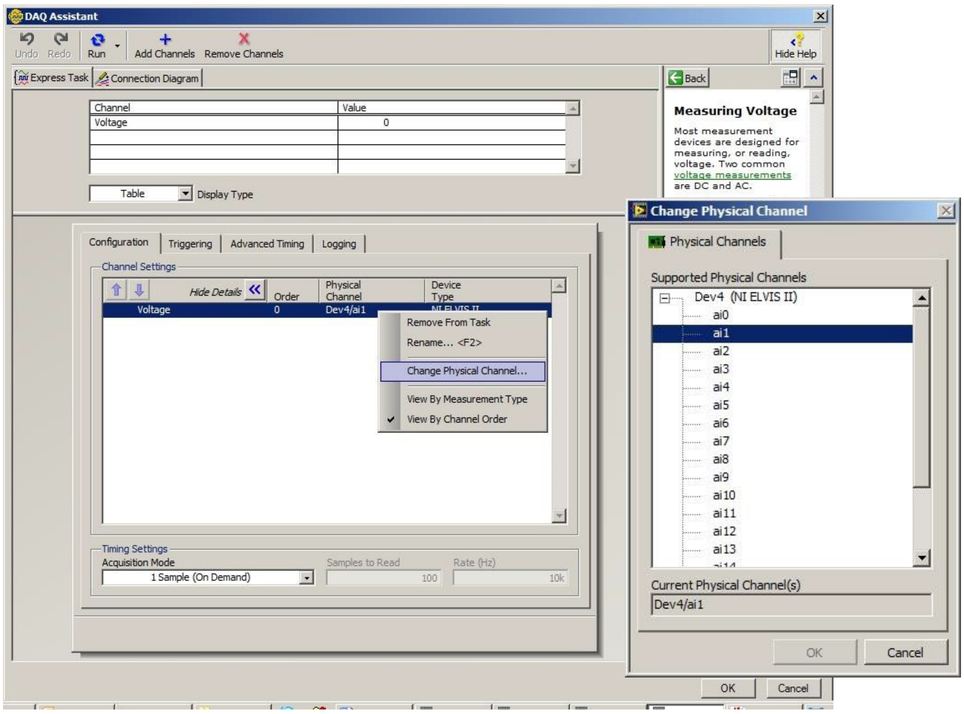
- Create a Front Panel as shown below:



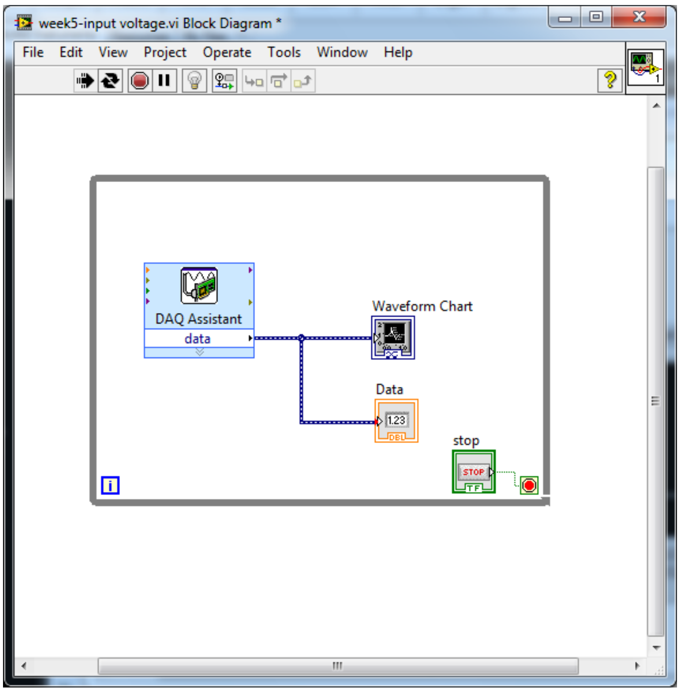
- Place the DAQ Assistant on the Block Diagram.
- When the NI-DAQ setup window pops up, select Acquire Signals >> Analog Input >> Voltage >> Device (NI ELVIS II) >> AI 1, which means analog input channel 1 on NI ELVIS II.
- After the NI-DAQ setup is finished, the configuration window pops up where you can configure Signal Input Range, Terminal Configuration and Timing Settings as



- In the Terminal Configuration, specify the grounding mode as RSE (Reference Single-Ended) where measurement is made with respect to ground.
- In the Timing Settings, set the Acquisition Mode to 1 Sample (On Demand).
- Under Channel Settings >> Details, you will see the Physical Channel selected where you may change to another channel if desired by right-click and select Change Physical Channel.



- Click OK to finish the configuration.
- Place a While Loop on the Block Diagram and wire up as below:



- Note: feel free to explore alternative designs; you should also add your group number on the Block Diagram and the Front Panel.

- Save the VI as DAQInputVUmeter.vi
- Run the VI, apply various Variable Power Supplies voltages to the AI1 input (launch ‘VPS’ from NI ElVISmx instrument launcher), and observe the Front Panel data and waveform.
- Capture the screen with both front panel and block diagram side-by-side (use Ctrl-T) and paste into your weekly logbook to be uploaded to a file server.
- When it is finished, click the stop (F) button.

4.3 Logbook

Your logbook may consist of the following:

- Schematics or snap photos of circuits and instrument setups.
- Screen/window capture of waveforms and run-time outputs.
- Tabulation/graphs of measurement results and theoretical calculations.
- Record of observation key points during experiments.
- LabVIEW/other programs, block diagrams, front panels, etc.

At the end of the session, upload your (multiple) logbook files to a file server regardless whether you have completed all the tasks or not. You have to upload all that you have for the day and you are not permitted to change the logbook once uploaded until the next new session. All changes should be made only at the following new session and the revised logbook re-uploaded.

Open Ended Questions

- Change the Generation/Acquisition Mode to other modes. You may experiment with various sampling rates and Samples to Write/Read. Discuss your observations.
- Use different type of wave to generate the signal. Observe the difference and note down in your logbook.
- Use waveform graph instead of waveform chart. Note that the output value will be different.

SIMULATION OF VU METER

1. OBJECTIVE

To perform simulation of a volume unit (VU) meter using LabVIEW.

2. SIMULATION

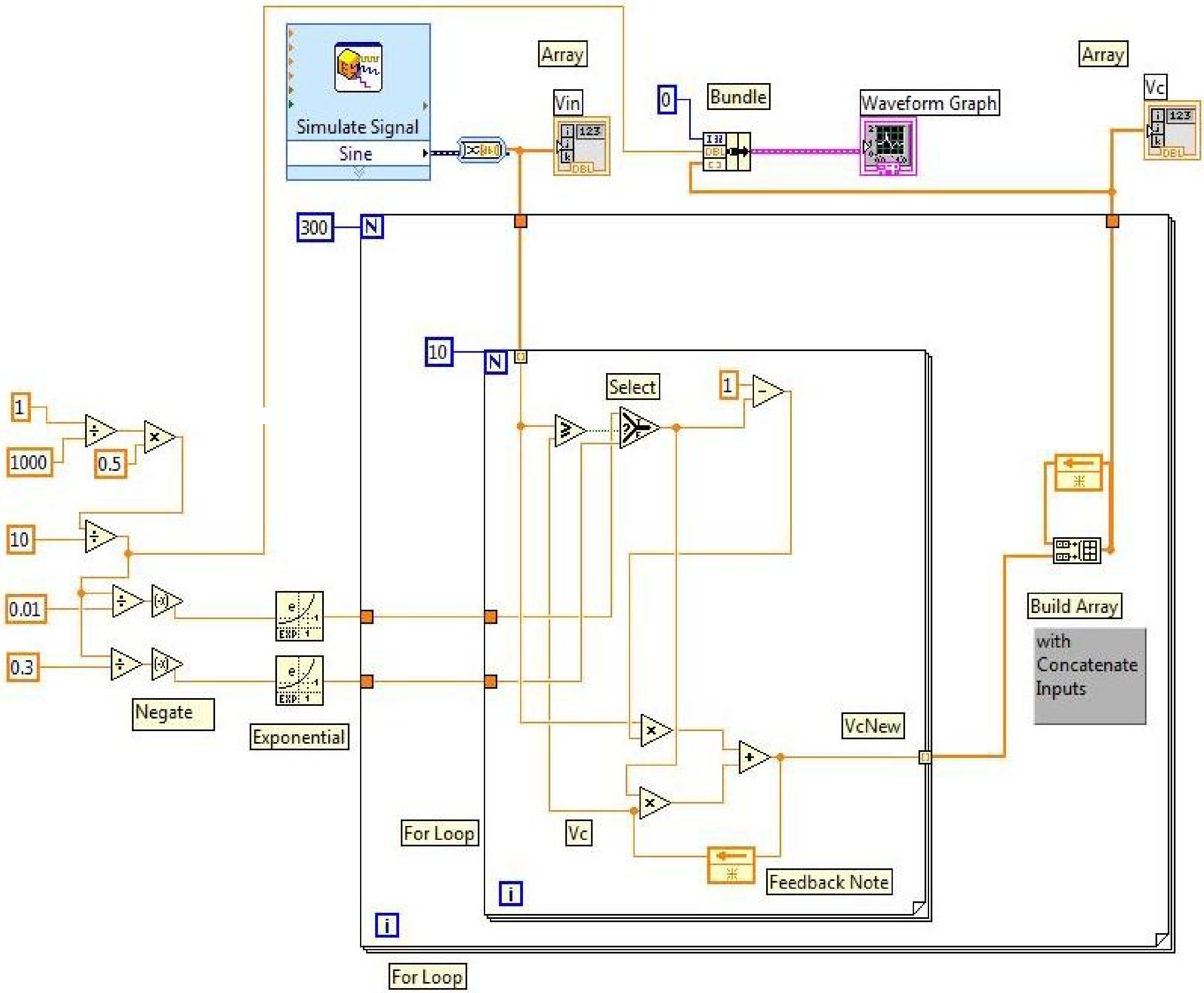
A VU meter is basically an envelope detector for audio signals. It can be designed as a half wave or full wave detector using OP-AMP circuits (as to be discussed later in the VU meter subsystem). The peak envelope detector (capacitor) output V_c for the rectified full-wave input waveform $|V_{in}|$ can be simulated using the simplified dual time constant model as:

$$(t_{n+1}) = (1 - T_c)|V_{in}(t_n)| + T_c V_c(t_n)$$

$$T_c = \begin{cases} T_{c1} = e^{-\Delta t/\tau_1}, & \text{attack mode: } |V_{in}(t_n) \geq V_c(t_n) \\ T_{c2} = e^{-\Delta t/\tau_2}, & \text{release mode: } |V_{in}(t_n) < V_c(t_n) \end{cases}$$

A “Simulate Signal” VI is used to generate an array of 10 samples of half a cycle of a 1000 Hz audio tone. In a FOR loop, the discrete-time linear equation is evaluated by stepping through 10 equal time steps, each of the size $\Delta t=1/(20f)$, starting from a zero initial condition at t=0. An outer FOR loop is then used to repeat this inner loop for 300 times. Effectively this generates a train of unit sine amplitude rectified full-wave input waveform starting from t=0. The 3000 output values of the VU meter are assembled as an array for display to a waveform graph and a list of numerical values.

The peak envelope detector time constants in the attack and release modes are $\tau_1=0.01$ s and $\tau_2=0.3$ s respectively. Observe the system rise time τ of the envelope detector circuit in the series of output samples.

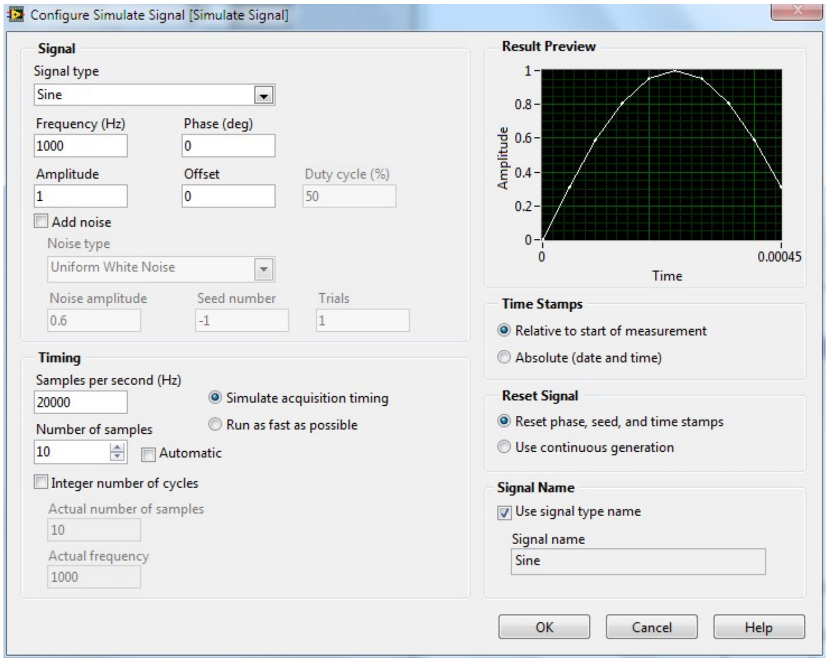


Block Diagram

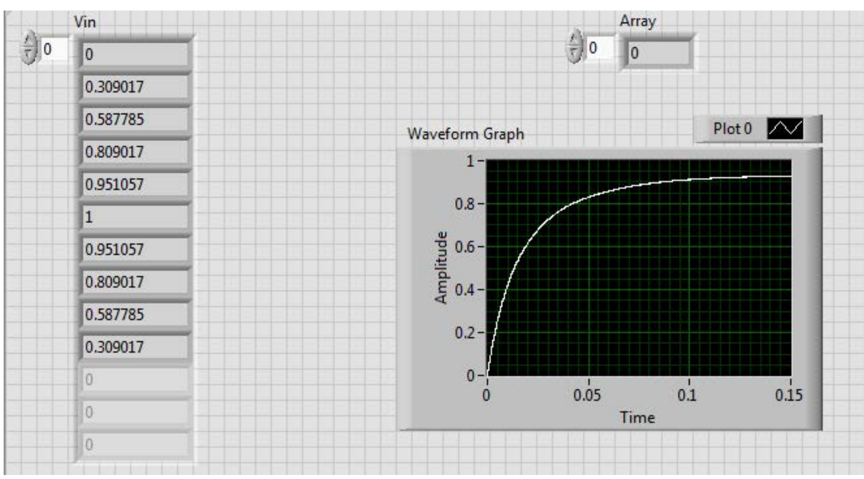
Note:

1. If you wire an array to a "For Loop", you can read and process every element in each loop in that array by enabling auto-indexing, or pass the entire array into the "For loop" by disabling auto-indexing. When you pass out a variable, you can enable auto-indexing to make a "For Loop" return an array of every value generated by every loop.
2. Before you wire the Build Array into the circuit, right click the Build Array and select **Concatenate**.

The Simulated signal should be set as



Then you can get the front panel as follows:



Open Ended Questions

- You may explore alternative designs to achieve the same objective above. For instance, the following may be attempted:
  - use shift register instead of feedback node
  - use While loop instead of For loop
- Describe the different symbols used in the simulation and how the signal is being pass down from input to output.

VOLTAGE CONTROLLED AMPLIFIER SUBSYSTEM

1. OBJECTIVE

To construct the Voltage Controlled Amplifier (VCA) subsystem as a part of the overall audio amplifier system and study its transfer characteristics.

2. INTRODUCTION

The VCA is an audio signal processing subsystem of the overall audio amplifier system whose gain/attenuation characteristic can be controlled by applying a control voltage (V_{C-}, pin 3) to its gain core element. A suitable integrated circuit (IC) for the VCA subsystem is the THAT 2180C (THAT Corporation) and OP 275 (Analog Devices). Figure 1a and 1b shows the equivalent circuit diagram and terminal configuration of THAT 2180C and OP 275, respectively.

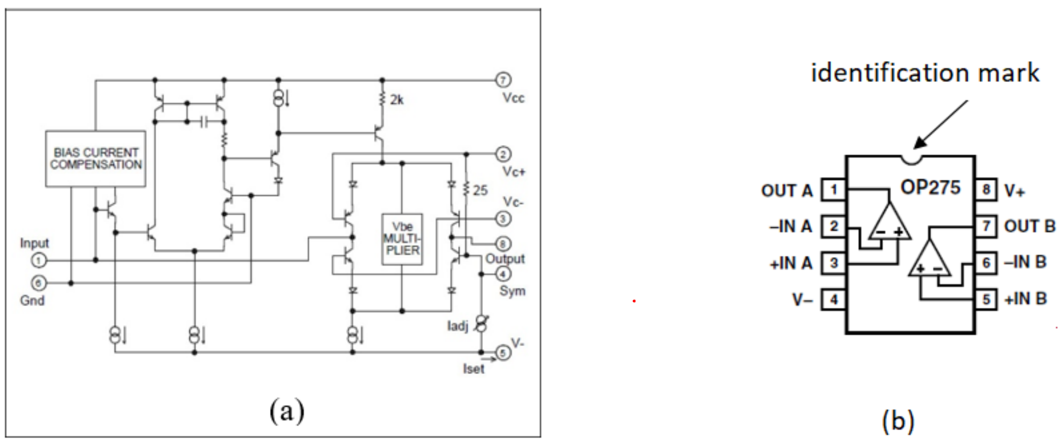


Figure 1: (a) equivalent circuit diagram of THAT 2180C; (b)terminal configuration of OP275

A basic VCA circuit configuration based on the standard dual power supplies ±15V will be studied in this experiment. For the theory of design and operation of the VCA, please refer to the project manual.

The audio signal gain of the VCA is given by

$$G = \frac{V_C}{(0.0061)(1+0.0033\Delta T)} \qquad (1)$$

where ΔT is the difference between room temperature (25°C) and the actual temperature, and Gain is in decibels, and V_C sensitivity is 6 mV/dB.

3. EQUIPMENT AND COMPONENTS

Equipment: Personal Computer (PC) with LabVIEW and NI ELVIS launcher/driver
NI ELVIS II.

Components: THAT 2180C Voltage Controlled Amplifier IC
OP275 Operational Amplifier
Resistors
Capacitors
Breadboard

4. PROJECT TASKS

4.1 Gain Measurement

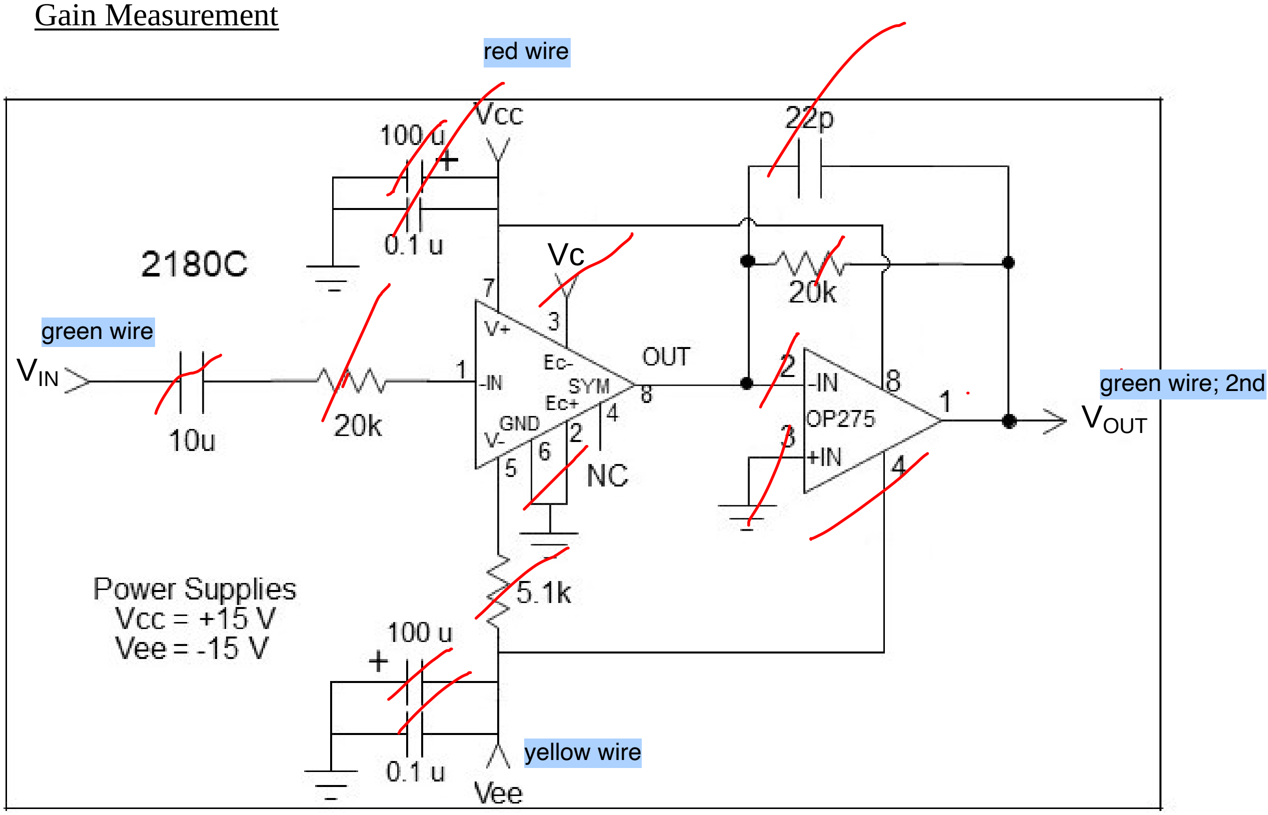
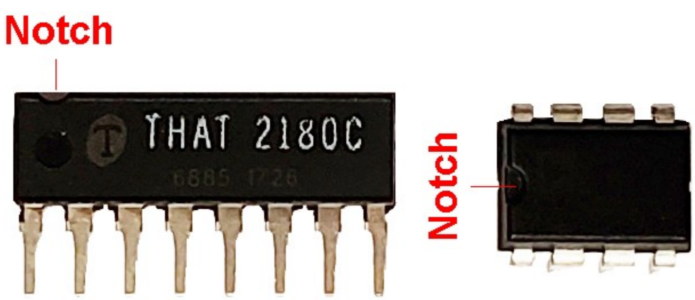
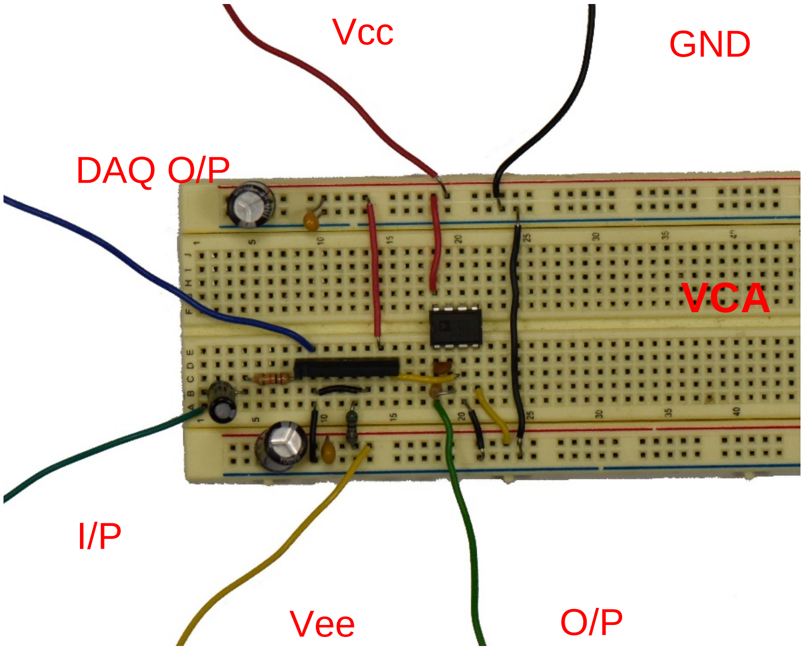


Figure 2: VCA Circuit Configuration and Gain Measurement Setup

Construct the circuit as shown in Figure 2 on the breadboard provided. (Note: please do not use the prototyping board on NI ELVIS II.) The Figure below provides an example.



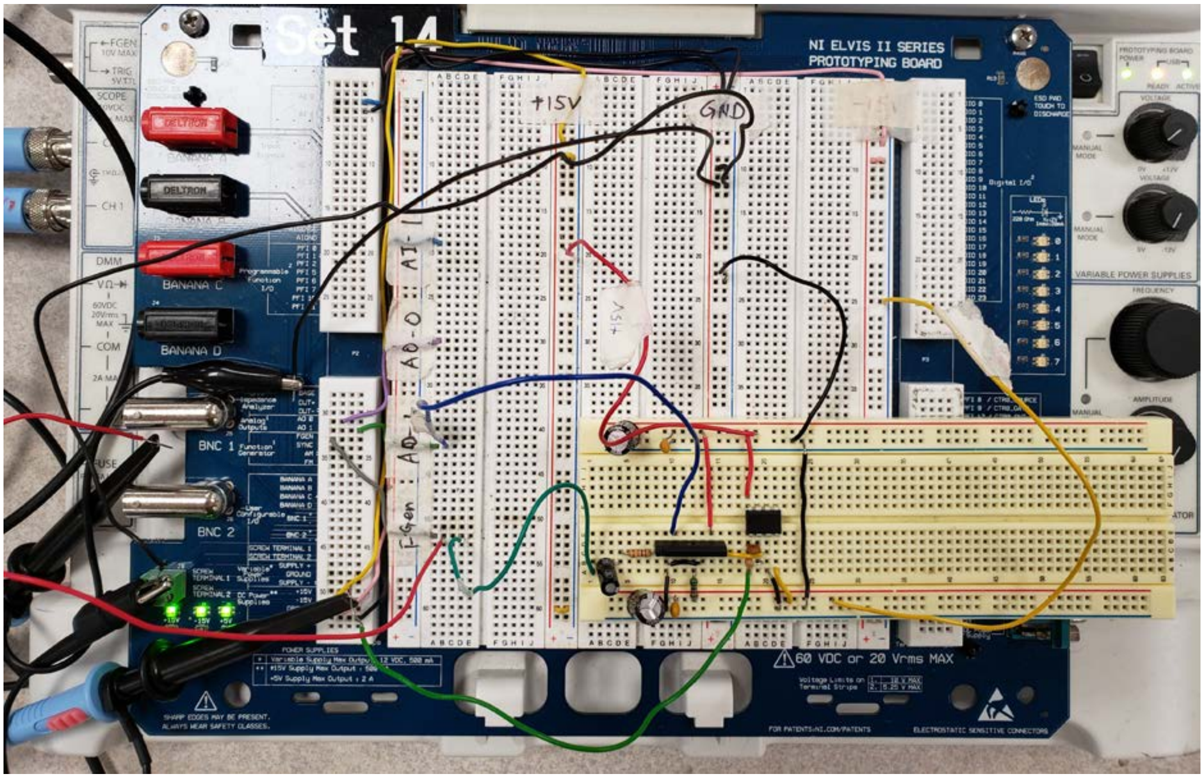


Run the NI ELVIS launcher and launch the following instruments: Scope (oscilloscope), FGEN (function generator), and if necessary, use DC Level.

Connect +15V and −15V of the VCA circuit to the corresponding DC power supply pins on the left panel of NI ELVIS II.

The figure below provides an example.

Red +15V	Yellow -15V	Blue DAQ O/P	Scope CH0 FGEN
Light green O/P	Dark green I/P	Black GND	Scope CH1 O/P



Note:

1. Please be extremely careful on the wire connections, especially for biasing with +15V, −15V and ground, e.g. **with only +15V and no/wrong −15V, the IC may get hot quickly, or even burned.**
2. Switch off the circuit when the IC component becomes very hot and check all the connections.
3. Make sure all the ground signals are connected properly.
4. Be careful on the positive and negative terminals of the IC components (if applicable).
5. Make sure all of the pins touch the bottom of the bread board. (The pin length inserted into the bread board is recommended to be around **8-10 mm**)

To provide the desired VCA control voltage, connect the V_C of the VCA to one of the two Analog Output ports on the left panel of NI ELVIS II (e.g. pin AO 1) and run DAQOutputControlVCA.vi (which you have written in LabVIEW/ELVIS sessions). In case your DAQOutputControlVCA.vi could not work well, you may connect the V_C of the VCA to the DC Level provided by NI ELVIS II.

Connect the FGEN to the audio input of the VCA, V_{IN}. Connect one channel of the oscilloscope (Scope) to V_{IN} and the other channel to the VCA output V_{OUT} to observe the waveforms. Make sure **all grounds** are connected to the appropriate GND. Set the FGEN to generate a sinusoidal waveform of frequency 1 kHz.

Vary the peak-to-peak amplitude of the sinusoidal waveform from the FGEN (V_{IN}) and V_C according to the values given in Table 1. The last digit 'x' for the value of V_{IN} should be filled up according to the digits of your matriculation number starting from left to right and recycling as necessary. Record the peak-to-peak amplitude of the VCA output (V_{OUT}) in Table 1. The theoretical gain can be calculated using equation (1).

Hint: *Gain (dB) = 20* log_{10} *(Vout / Vin)*

V_{IN} (V_{pp})	V_C (V)	V_{OUT} (V_{pp})	Measured Gain = V_{OUT}/V_{IN}	Measured Gain (dB)	Theoretical Gain (dB)
1.x	0.50				
0.5x	0.36				
0.5x	0.18				
0.3x	0.06				
0.3x	0.00				
0.1x	−0.06				
0.1x	−0.12				
0.1x	−0.15				

Table 1: Gain Measurement

4.1(a) Using Microsoft Excel, plot the graph of Gain (dB) versus V_C for both measured and theoretical gains.

4.1(b) From the graph, deduce the V_C sensitivity which is the inverse of the slope of the graph and compare it with the theoretical value.

4.2 Logbook

Your logbook may consist of the following:

- Schematics or snap photos of circuits and instrument setups.
- Screen/window capture of waveforms and run-time outputs.
- Tabulation/graphs of measurement results and theoretical calculations.
- Record of observation key points during experiments.
- LabVIEW/other programs, block diagrams, front panels, etc.

At the end of the session, upload your (multiple) logbook files to a file server regardless whether you have completed all the tasks or not. You have to upload all that you have for the day and you are not permitted to change the logbook once uploaded until the next new session. All changes should be made only at the next new session and the revised logbook re-uploaded.

Open Ended Question

Please describe how the choice of input resistor will affect the distortion. Will there be a difference if the input resistor is replaced by a 1kΩ one?

POWER AMPLIFIER SUBSYSTEM

1. OBJECTIVE

To construct the Power Amplifier (PA) subsystem as a part of the overall audio amplifier system and to study its Bode frequency response.

2. INTRODUCTION

The PA is the core to provide the required gain and power amplification to drive the load (speaker). A suitable integrated circuit (IC) for the PA subsystem is LM380N whose pin diagram is shown in Figure 1. This IC is to be powered by a single power supply of +15V. The voltage gain is internally fixed at 34dB (50).

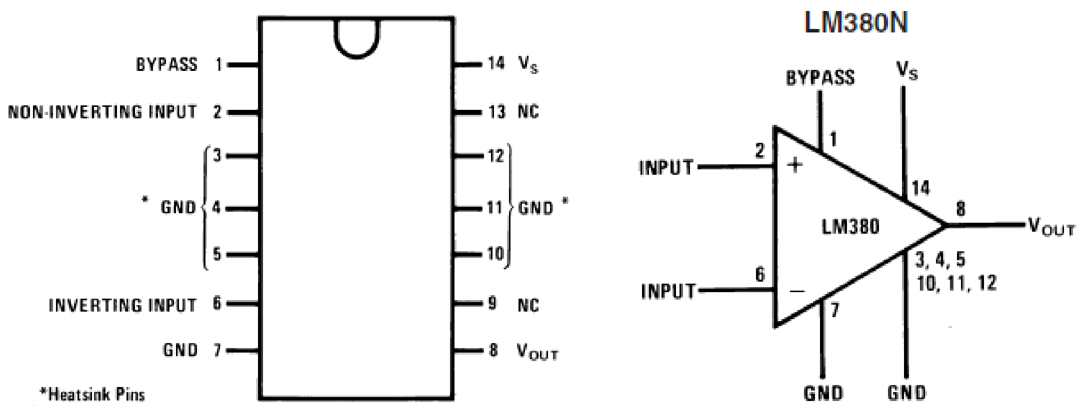


Figure 1: LM380N Power Amplifier IC

3. EQUIPMENT AND COMPONENTS

Equipment: Personal Computer (PC) with LabVIEW and NI ELVIS launcher/driver
NI ELVIS II

Components: LM380N Power Amplifier IC
Resistors
Capacitors
Breadboard
Speaker (optional)

4. PROJECT TASKS

4.1 Frequency Response Measurement

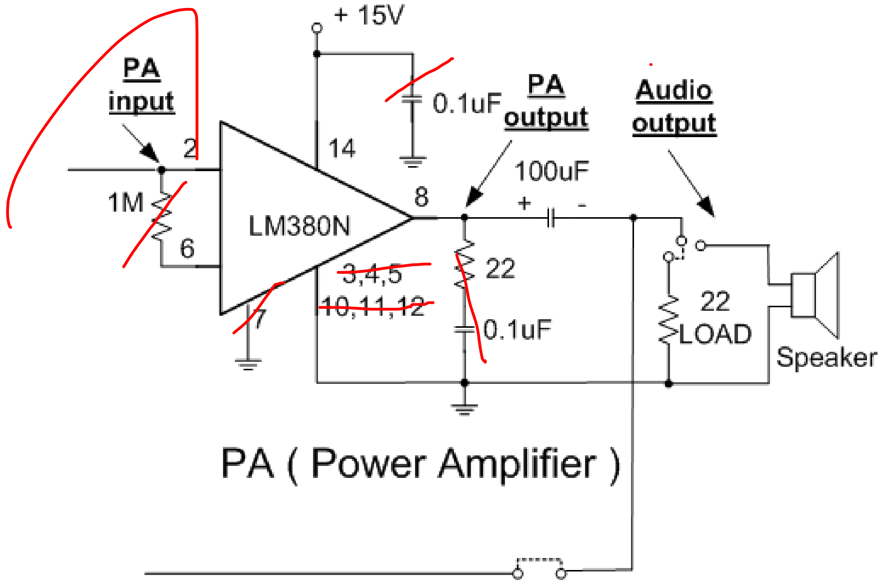
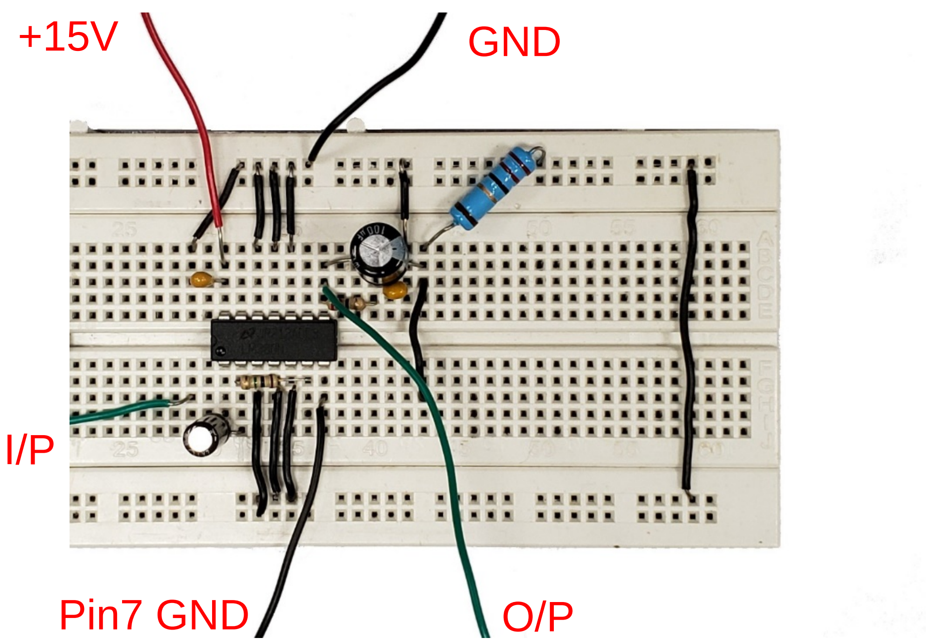


Figure 2: Power Amplifier Application Circuit

Connect the circuit components as shown in the PA application circuit of Figure 2 on the breadboard provided. **(Note: please do not use the prototyping board on NI ELVIS II.)** You are required to measure and analyze the frequency response of the PA. The Figure below shows a circuit implementation of the PA.

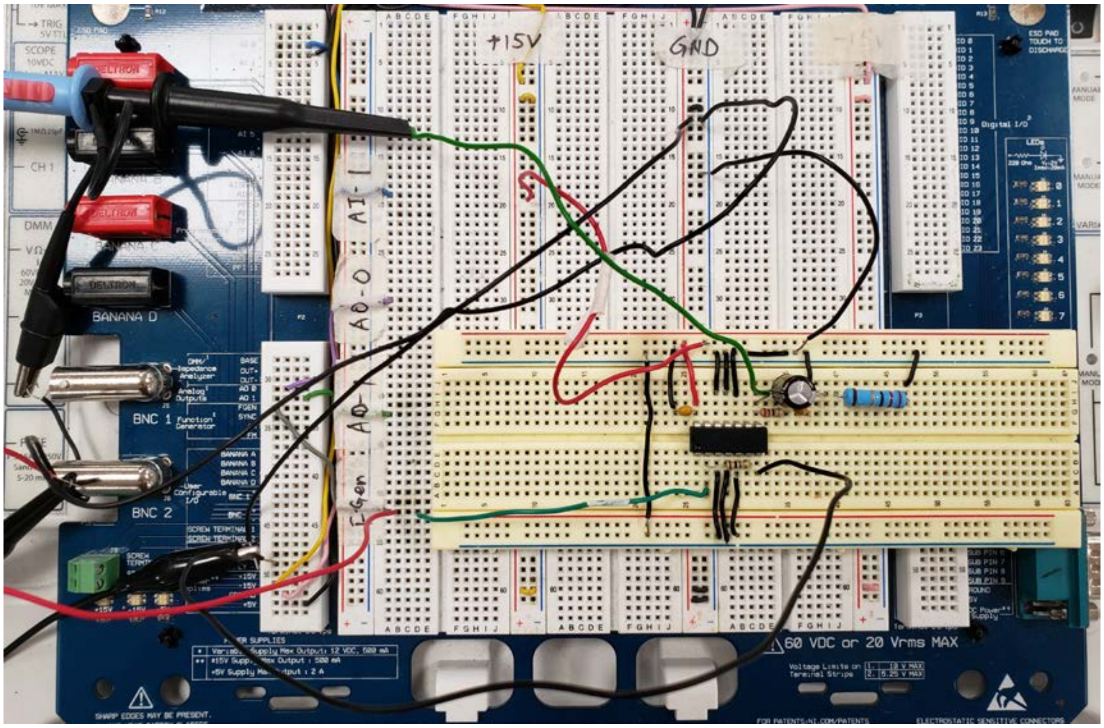


Note: please ground the pin 7 separately.

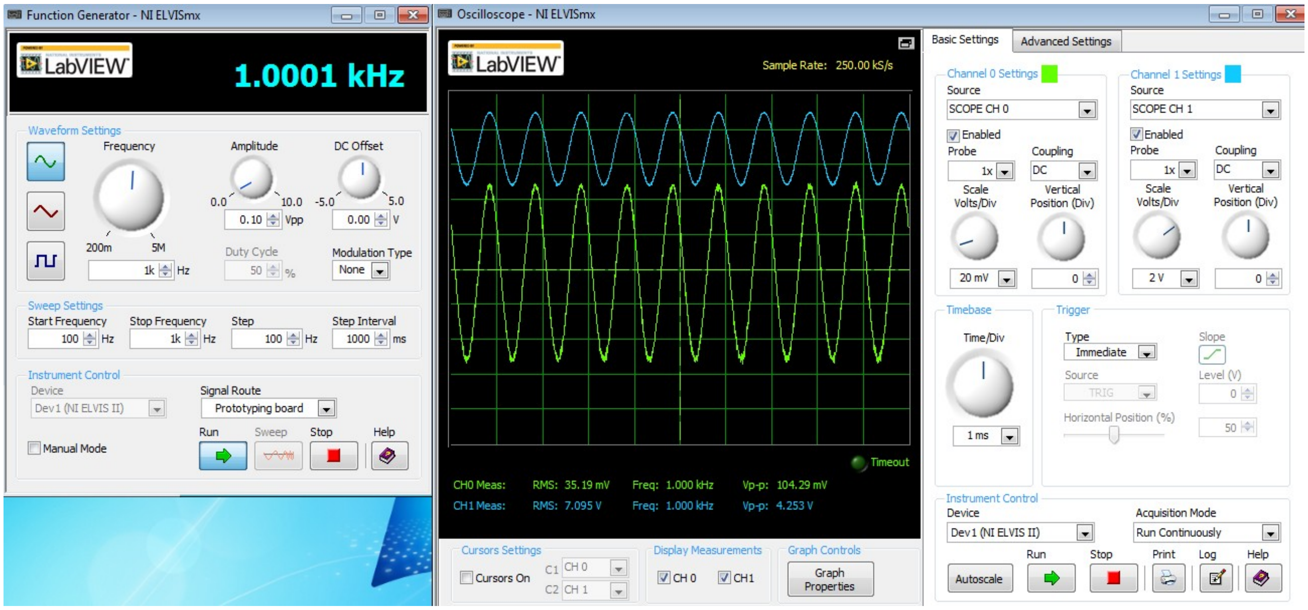
Launch FGEN and Scope from NI ELVIS launcher. Set the FGEN to 1kHz sinusoidal waveform with peak-to-peak amplitude of $V_{pp} = 0.1V$ and connect the FGEN to PA input. Now connect the Scope CH0 to the PA input and the Scope CH1 to the PA output to monitor the signals respectively. Check that the waveform is not distorted. Compute the gain of PA using the expression: Gain (dB) = $20 \log_{10} (Vout / Vin)$. What is the calculated gain? Does it tally with the expected value?

The figure below shows an example of the connection with NI ELVIS..

Red	+15V	Dark green	I/P	Light green	O/P
Black	GND	Scope CH0	FGEN	Scope CH1	O/P



The figure below shows an example of the result on the scope. You are suggested to put the breadboard on the NI ELVIS, and make sure the connecting wires as short as possible to reduce the extra resistance introduced to the circuit.



Close the scope, launch the Bode Analyzer, you can get the following result:

To characterize the PA over a range of frequencies, it is convenient to use NI ELVISmx Bode Analyzer that can perform a frequency sweep measurement and return the entire frequency response of Bode plot. To that end, close both FGEN and Scope, and launch the Bode Analyzer. Connect the FGEN from prototype board to the PA input and Scope CH0 (or 'AI 0' of Analog Input ports), which is selected as the Stimulus Channel for the Bode Analyzer. Connect the PA output to Scope CH1 (or 'AI 1' of the Analog Input ports), which is selected as the Response

Channel for the Bode Analyzer. Set Start/Stop Frequency as 100Hz/200kHz and Steps as 20 per decade. Set the peak amplitude to $V_p = 0.02V$ and click run on the Bode Analyzer, the gain and phase response will then be plotted. Discuss whether the frequency response is what you are expecting.

Next repeat the procedure for different input peak amplitudes according to your matriculation number. Vary the peak amplitude according to the format of V_p = 0.0x and 0.1x V as in Table 1, where the last digit ‘x’ should be filled up according to the nonzero digit of your matriculation number until all different nonzero digits have been used up. For each Bode plot with different peak amplitude, you should capture the Bode Analyzer window (Alt-Prt Sc) and paste into your weekly logbook. After all measurements, switch off NI ELVIS II to prevent the circuit getting too hot.

Note: Place the cursor at the -3dB position of the amplitude and then capture the screen.

V_p (V)	Bode Analyzer Window Capture
0.02	
0.0x	
0.0x	
0.0x	
0.0x	
0.1x	
0.1x	
0.1x	
0.1x	

Table 1: Frequency Response Measurement

4.1(a) Refer to your Bode plots, discuss some of their interesting cases and trends.

4.1(b) Discuss and compare various gains of PA obtained from specification, Scope waveforms and Bode plots.

4.2 Logbook

Your logbook may consist of the following:

- Schematics or snap photos of circuits and instrument setups.
- Screen/window capture of waveforms and run-time outputs.
- Tabulation/graphs of measurement results and theoretical calculations.
- Record of observation key points during experiments.
- LabVIEW/other programs, block diagrams, front panels, etc.

At the end of the session, upload your (multiple) logbook files to a file server regardless whether you have completed all the tasks or not. You have to upload all that you have for the day and you are not permitted to change the logbook once uploaded until the next new session. All changes should be made only at the following new session and the revised logbook re-uploaded.

Open Ended Question

What type of filter does the Bode Analyzer show?

VOLUME UNIT METER SUBSYSTEM

1. OBJECTIVE

To construct the Volume Unit Meter (VU Meter) subsystem as a part of the overall audio amplifier system and to study its functionality.

2. INTRODUCTION

The VU Meter is used for measurement of the output signal amplitude from the PA subsystem; which will be feedback to the controller to control the input amplitude to the PA. Based on the rectifier concepts, the VU Meter is built using CA3140 operational amplifier integrated circuit (IC) whose pin diagram is shown in Figure 1. This IC is to be powered by a single power supply of +15V.

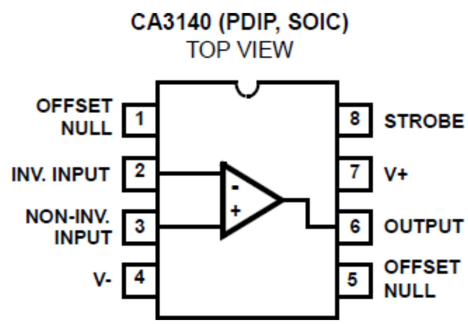


Figure 1: Pin diagram of CA3140

3. EQUIPMENT AND COMPONENTS

Equipment: Personal Computer (PC) with LabVIEW and NI ELVIS launcher/driver
NI ELVIS II

Components: CA3140 Operational Amplifier (IC).
Resistors
Capacitors
Diodes
Printed circuit board (PCB)

4. PROJECT TASKS

4.1 Gain Measurement

Note: this week you are not required to build up VU circuit on breadboard, but to directly solder the VU components on PCB (Veroboard).

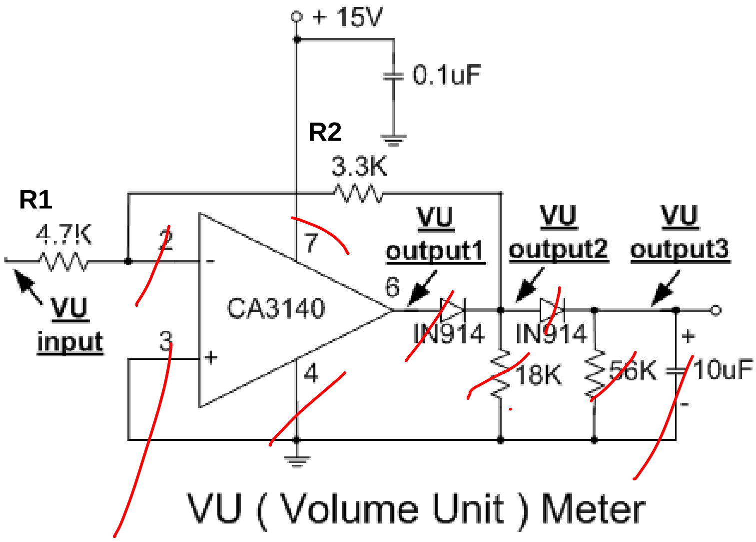
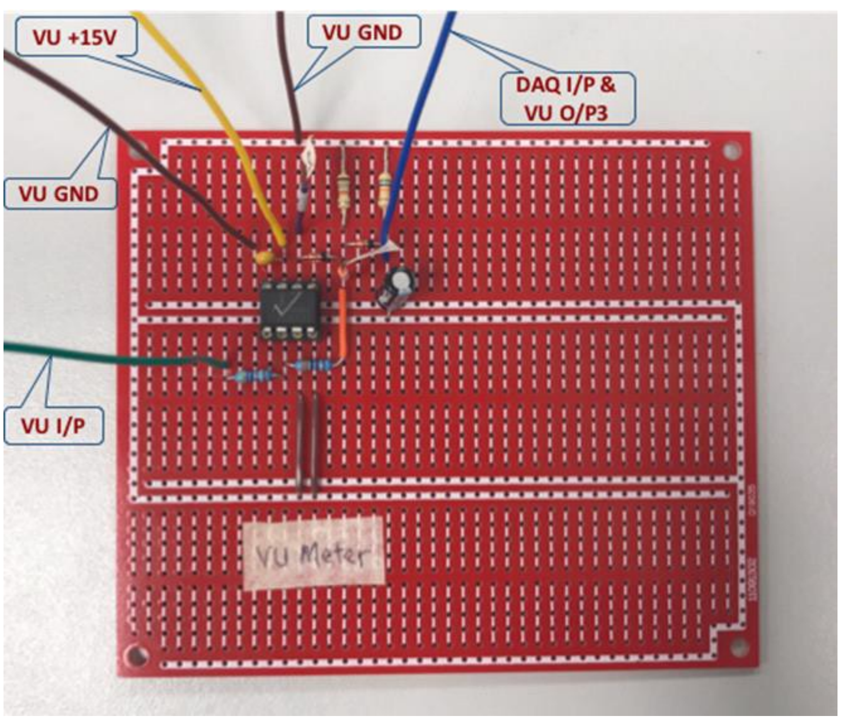


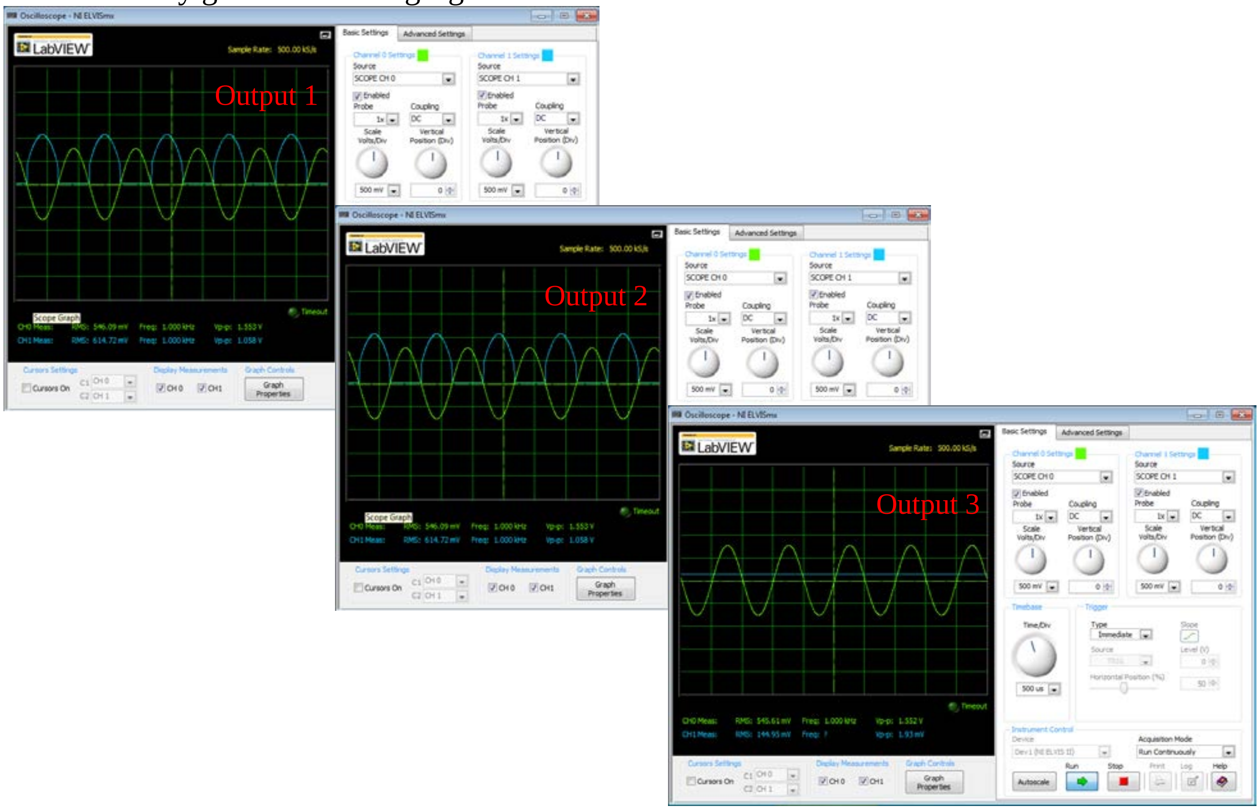
Figure 2: VU Meter Application Circuit

Solder the circuit components as shown in the VU Meter application circuit of Figure 2 on the Veroboard provided. **(Note: please do not use the prototyping board on NI ELVIS II)** Plan the layout of your circuit judiciously. Observe the safety/healthy rules while operating with the soldering tools. You are required to measure the output voltages/waveforms of VU Meter at $VU_{output1}$, $VU_{output2}$ and $VU_{output3}$. The figure below shows the circuit of VU:



Set the FGEN to 1kHz sinusoidal waveform with peak-to-peak amplitude of V_{pp} = 5 V and connect the FGEN to the VU Meter input, VU_{input}. Now connect Scope CH0 to VU_{input} and Scope CH1 to each of $VU_{output1}$, $VU_{output2}$ and $VU_{output3}$ to monitor the respective signal waveform. Capture all the Scope windows (Alt-Prt Sc) and discuss the waveform shapes of $VU_{output1}$, $VU_{output2}$ and $VU_{output3}$.

You may get the following figure:



Note: Please record the VUoutput3 in RMS value.

Record the voltages obtained at $VU_{output1}$, $VU_{output2}$ and $VU_{output3}$ into Table 1 accordingly. Compute also the measured gain in Table 1 and compare with the theoretical gain given by $-R_2/R_1$. Next repeat the procedure for different peak-to-peak amplitude of VU_{input} according to the number format in Table 1. In particular, the last digit 'x' should be filled up according to the digits of your matriculation number starting from left to right and recycling as necessary.

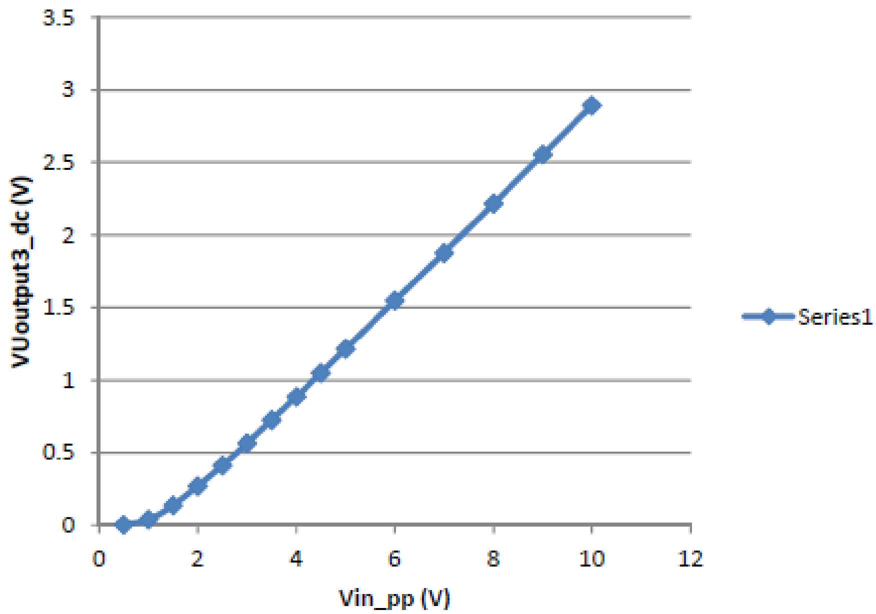
VU_{input} (V_{pp})	$VU_{output1}$ (V_{pk})	$VU_{output2}$ (V_{pk})	$VU_{output3}$ (V_{RMS})	Measured Gain = 2 $VU_{output2}$ / VU_{input}
5				
9.x				
4.5x				
3.5x				
2.5x				
1.5x				
0.5x				
0.2x				

Table 1: Gain Measurement

4.1(a) Using Microsoft Excel, plot the graph of Measured Gain versus VU_{input}. Discuss and compare the results with the theoretical gain.

4.1(b) Plot also the graph of $VU_{output3}$ versus VU_{input} and discuss if the functionality of VU Meter could be met.

You may get the following figure:



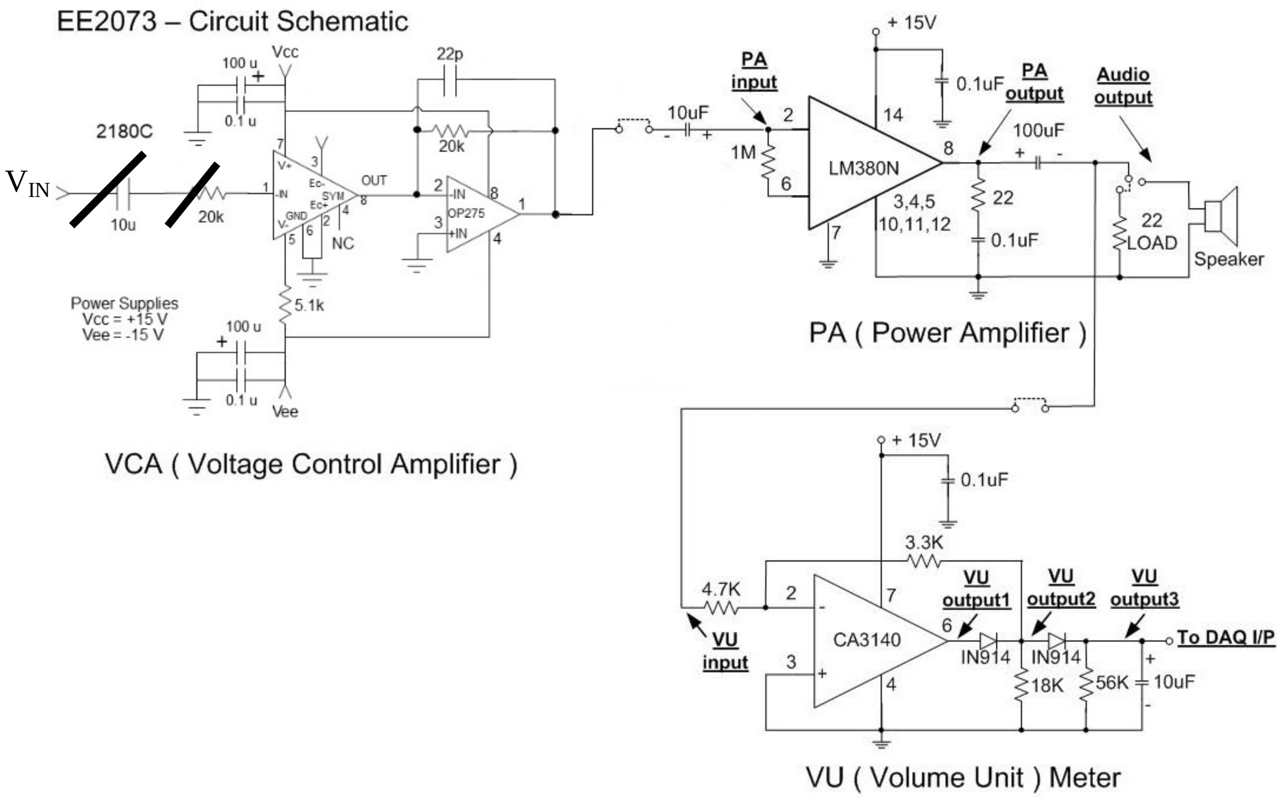
INTEGRATION FOR AUDIO AMPLIFIER SYSTEM

1. OBJECTIVE

To integrate the subsystem circuits constructed so far to form and test a complete audio amplifier system. Note that this is an open system having no feedback. It is important to have a thorough test of the system before you deal with a system with a feedback loop after next week.

2. INTRODUCTION

The complete audio amplifier system is resultant from the integration of VCA, PA and VU Meter subsystems as shown in the figure below.



Audio Amplifier System

3. EQUIPMENT AND COMPONENTS

Equipment: Personal Computer (PC) with LabVIEW and NI ELVIS launcher/driver
NI ELVIS II

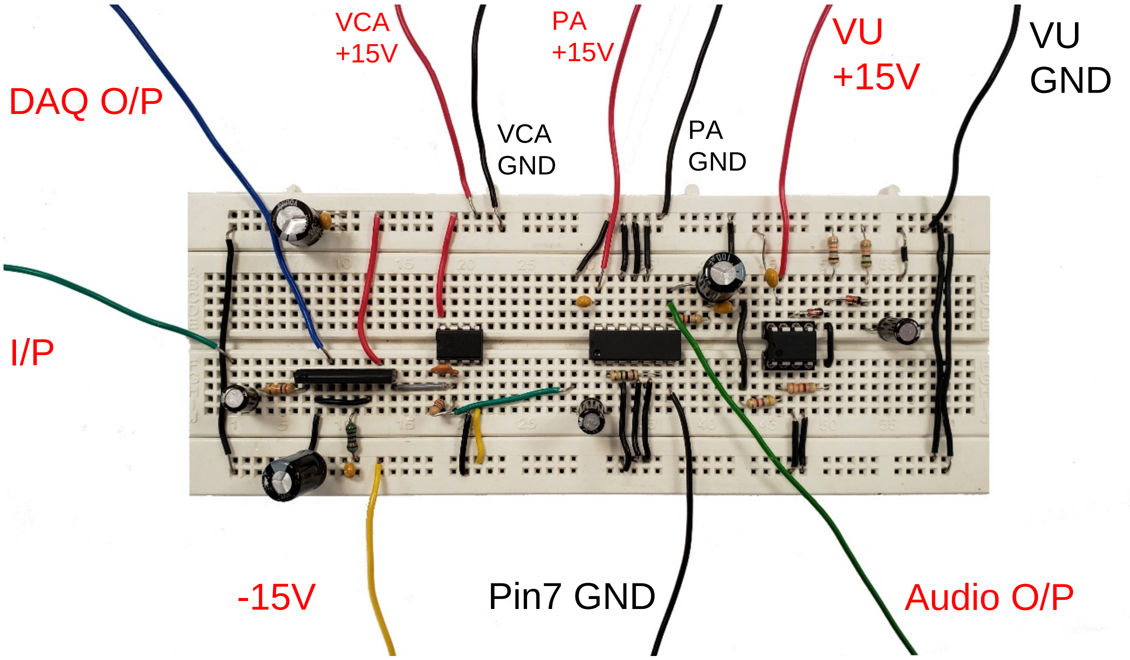
Components: Voltage Control Amplifier (VCA) subsystem
Power Amplifier (PA) subsystem
Volume Unit (VU) Meter subsystem
Speaker

4. PROJECT TASKS

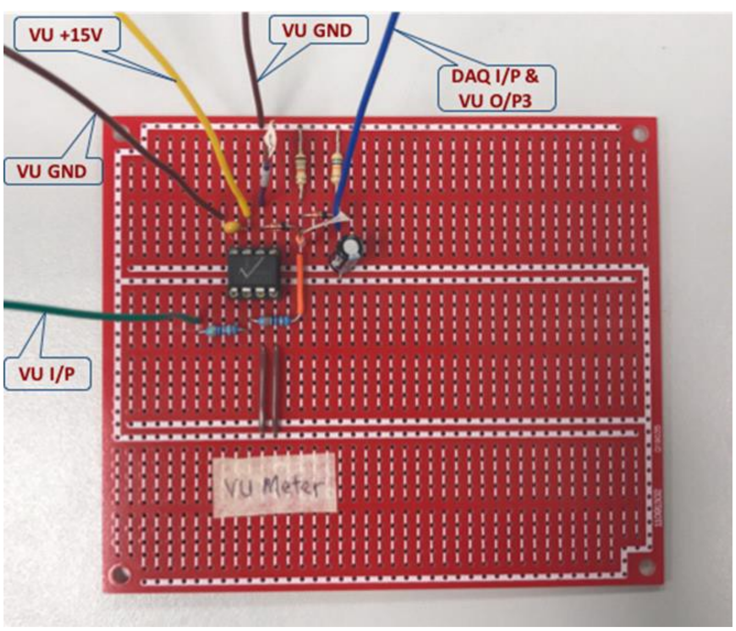
4.1 Integration and Testing

By now, you should have constructed and tested the individual VCA, PA and VU Meter subsystem circuits (if not, continue to work or troubleshoot on them individually). Integrate the individual subsystem circuits to form a complete open loop audio amplifier system.

The figure below shows the entire circuit on breadboard:



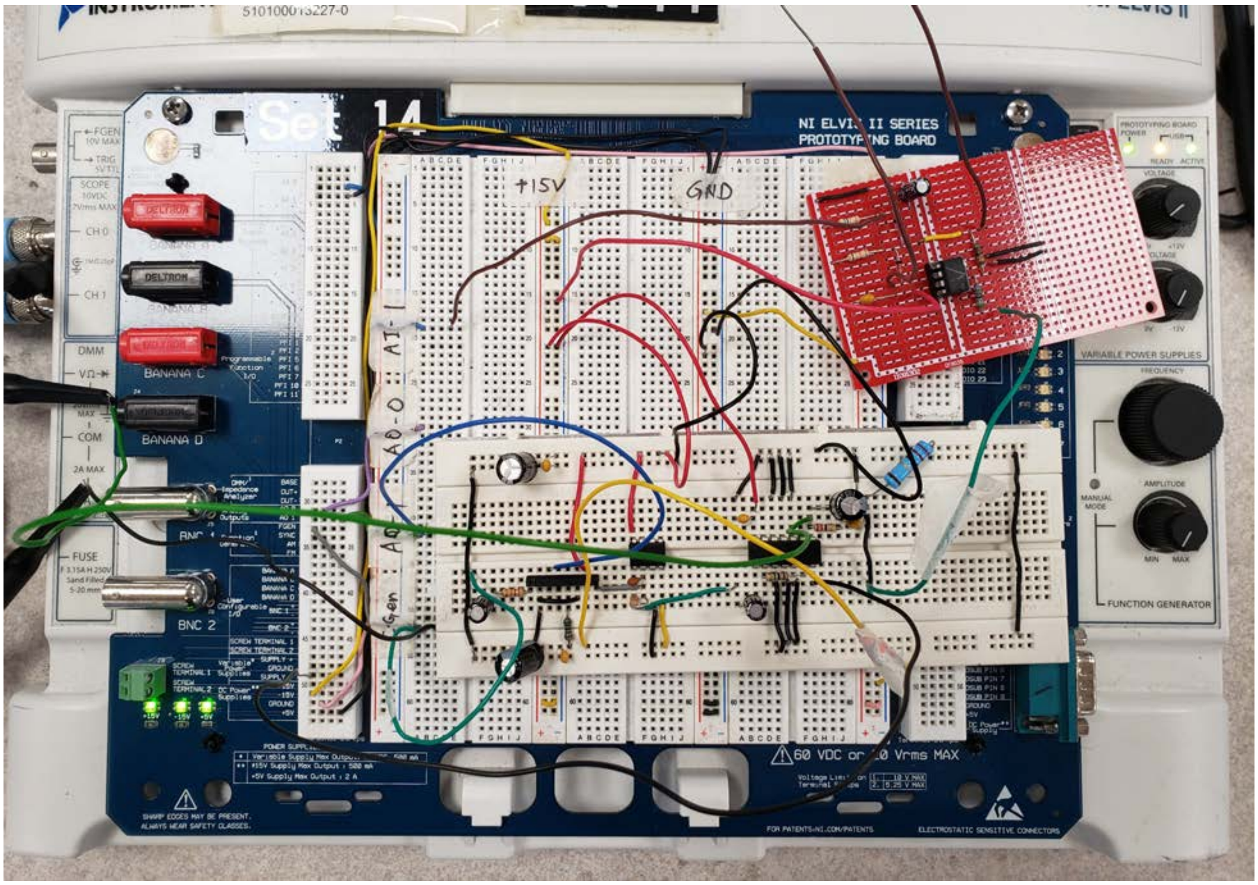
and VU Meter on veroboard:



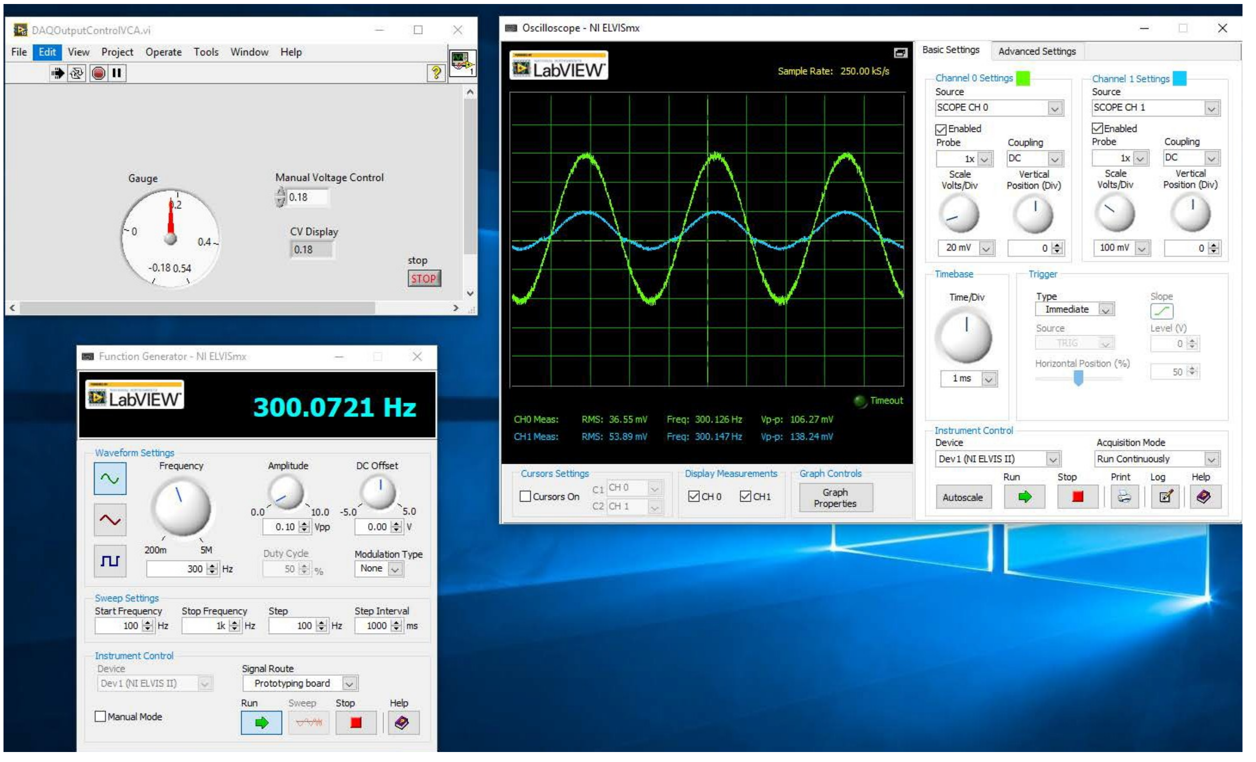
Connect +15V and −15V of the integrated circuit to the corresponding DC power supply pins on the left panel of NI ELVIS II. To provide the desired VCA control voltage, connect the V_C of the VCA to one of the two Analog Output ports on the left panel of NI ELVIS II (e.g. pin AO 1) and run DAQOutputControlVCA.vi (which you have written in LabVIEW/ELVIS sessions). In case your DAQOutputControlVCA.vi could not work well, you may connect the V_C of the VCA to the DC Level provided by NI ELVIS II.

Connect the FGEN output from the left panel of NI ELVIS II to the Audio input of the VCA. Connect one channel of the oscilloscope (Scope) from the left panel of NI ELVIS II to the Audio input of the VCA and the other channel of the oscilloscope to the Audio output to observe the waveforms. Make sure all grounds are connected to the appropriate GND. Connect the Audio output from the PA to a speaker and disconnect the 22 **Ω** load resister. Set the FGEN to generate a sinusoidal waveform of frequency 300 Hz. You should hear the sound of a tone from the speaker.

You may follow the example below to finish the test.



When inputting a sinusoidal waveform to the VCA with a peak-to-peak amplitude (V_{pp}) of 0.1V, we may get the following response when setting V_C to be around 0.18V.



Vary the peak-to-peak amplitude of the sinusoidal waveform from the FGEN according to the values given in Table 1. The last digit ‘x’ for the value of Audio input should be filled up according to the digits of your matriculation number starting from left to right and recycling as necessary (e.g student with matriculation number U1022916M should use this sequence 10229161). Observe the peak-to-peak amplitude of the waveform at the Audio output and record the values in Table 1.

Audio Input (V_{pp})	V_C (V)	Audio Output (V_{pp})	Gain (dB)	$VU_{output3}$ (V_{RMS})
1.x	0.50			
0.5x	0.36			
0.5x	0.18			
0.3x	0.06			
0.3x	0.00			
0.1x	−0.06			
0.1x	−0.12			
0.1x	−0.15			

Table 1: Audio Amplifier System Testing

4.1(a) Using Microsoft Excel, plot the graph of Gain (dB) versus Vc. Does the output performance of the audio amplifier system meet the desired objective?

4.1(b) Increase the frequency of the FGEN to 100 kHz. Explain what happens and why.

4.2 Logbook

Your logbook may consist of the following:

- Schematics or snap photos of circuits and instrument setups.
- Screen/window capture of waveforms and run-time outputs.
- Tabulation/graphs of measurement results and theoretical calculations.
- Record of observation key points during experiments.
- LabVIEW/other programs, block diagrams, front panels, etc.

At the end of the session, upload your (multiple) logbook files to a file server regardless whether you have completed all the tasks or not. You have to upload all that you have for the day and you are not permitted to change the logbook once uploaded until the next new session. All changes should be made only at the following new session and the revised logbook re-uploaded.

Open Ended Questions

Please describe the problems you encountered when integrating the circuit. How did you troubleshoot the problems?

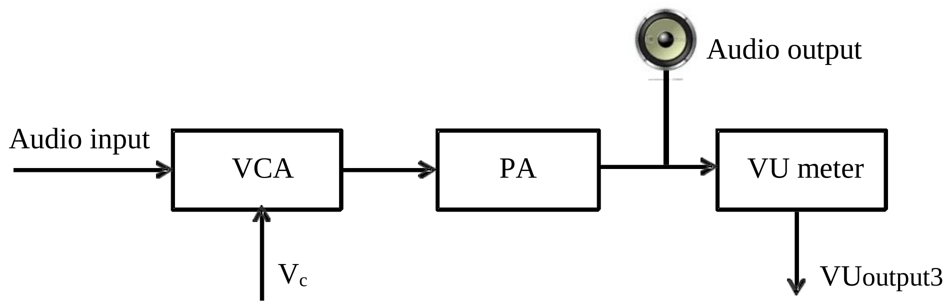
MANUAL VOLUME CONTROL FOR AUDIO AMPLIFIER SYSTEM

1. OBJECTIVE

To implement and test the manual volume control for audio amplifier system using LabVIEW/ELVIS.

2. INTRODUCTION

The manual volume control for the audio amplifier system is essentially an operator-assisted volume control system in which the operator provides the necessary adjustment of the volume control knob based on the VU meter reading (indicating loudness). As there is no feedback path in the system, it can be considered as an open-loop system whose block diagram representation is shown as follows:



Block Diagram Representation of Open-Loop System

3. EQUIPMENT AND COMPONENTS

Equipment: Personal Computer (PC) with LabVIEW and NI ELVIS launcher/driver
NI ELVIS II

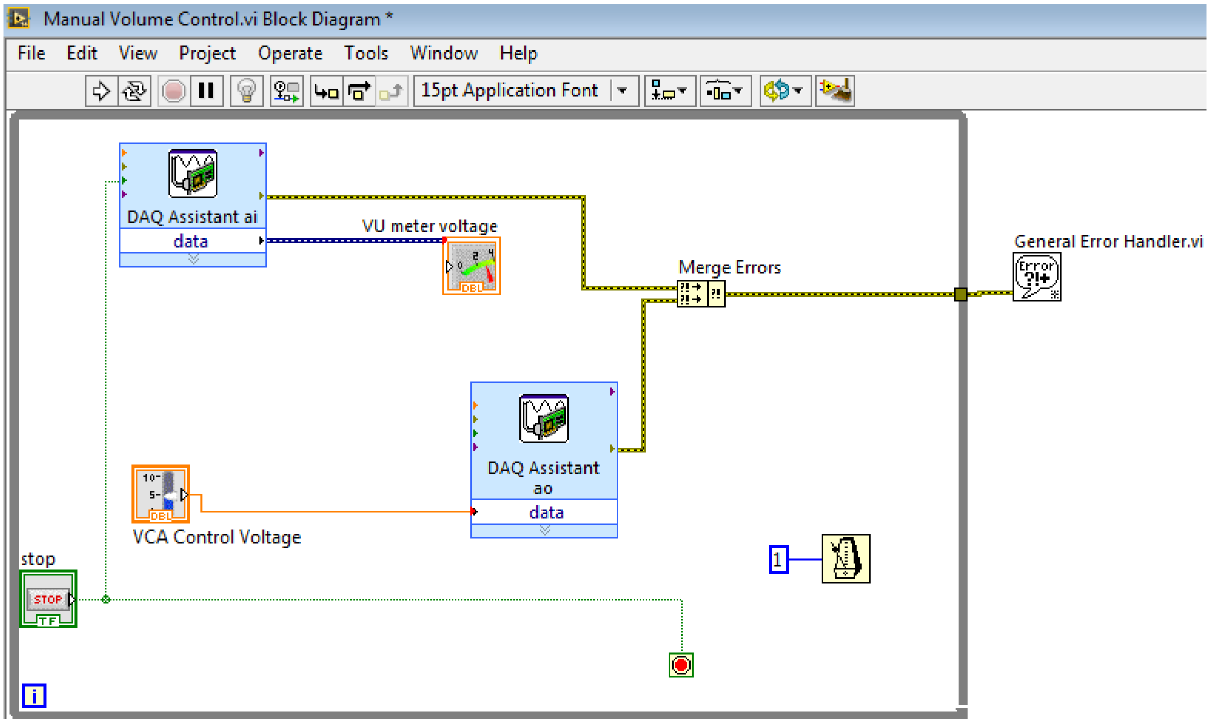
Components: Integrated audio amplifier system
Speaker

4. PROJECT TASKS

4.1 Implementation and Testing

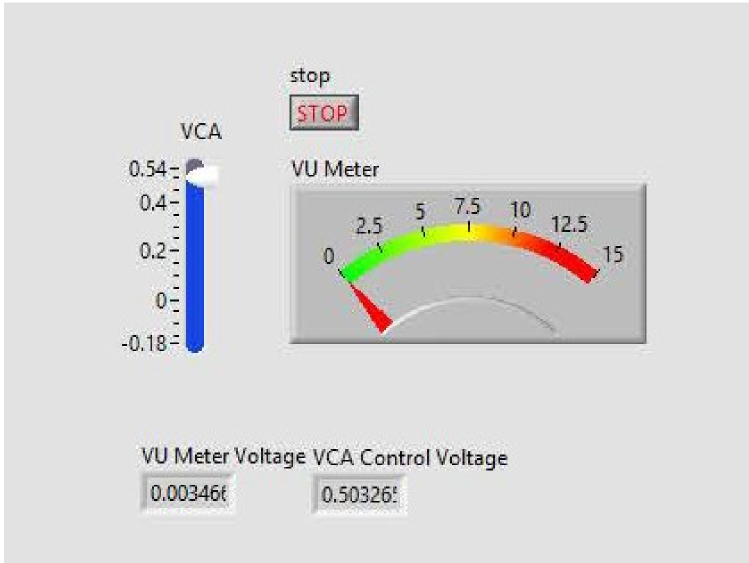
Connect +15V and −15V of the integrated audio amplifier system to the corresponding DC power supply pins on the left panel of NI ELVIS II. Connect an analog output channel from NI ELVIS II to the VCA gain control input. Connect an analog input channel from NI ELVIS II to the VU meter audio level output.

Implement the manual volume control for audio amplifier system in LabVIEW. The block diagram may look like the following: (**Note: feel free to explore alternative designs; you should also add your group number on the block diagram**)



Use the DAQ Assistant to setup and configure the output and input channels for the manual volume control system. The data acquisition is set to “1 sample (on demand)” mode for the selected output and input channels. Limit on the output and input voltage ranges are set to the appropriate values. In line with its specification, the VCA control voltage should only range from −0.18V to +0.54V at V_C.

The front panel may look like the following: (**Note: feel free to explore alternative designs; you should also add your group number on the front panel**)



Connect the FGEN output from the left panel of NI ELVIS II to the Audio input of the VCA. Connect the Audio output from the PA to a speaker. Set the FGEN to generate a sinusoidal waveform of frequency 300 Hz. You should hear the sound of a tone at the speaker output. Try different audio signal levels and different VCA control voltage values. Record and discuss your observations.

4.2 Logbook

Your logbook may consist of the following:

- Schematics or snap photos of circuits and instrument setups.
- Screen/window capture of waveforms and run-time outputs.
- Tabulation/graphs of measurement results and theoretical calculations.
- Record of observation key points during experiments.
- LabVIEW/other programs, block diagrams, front panels, etc.

At the end of the session, upload your (multiple) logbook files to a file server regardless whether you have completed all the tasks or not. You have to upload all that you have for the day and you are not permitted to change the logbook once uploaded until the next new session. All changes should be made only at the following new session and the revised logbook re-uploaded.

Open Ended Questions

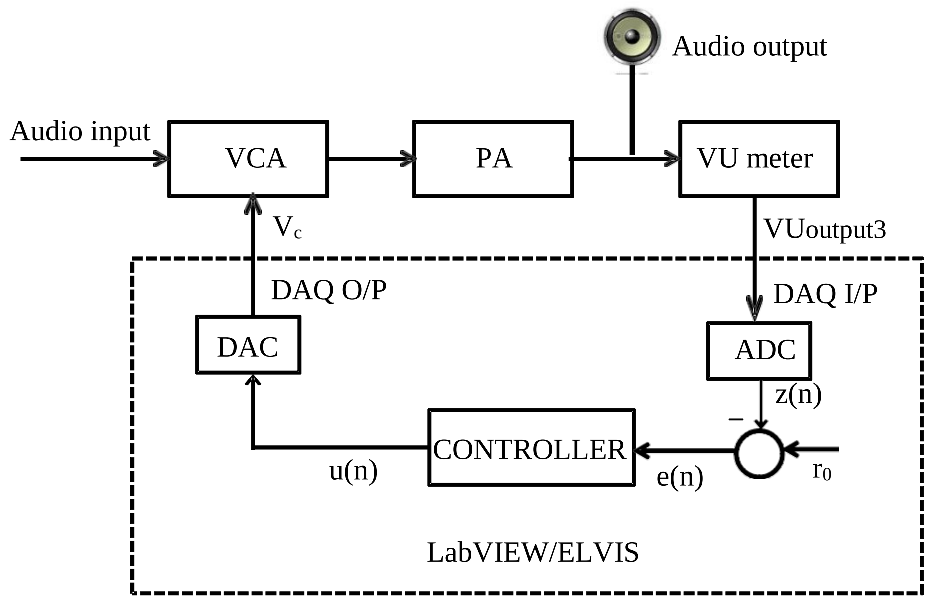
Please describe any problems you encountered when implementing manual volume control. How did you solve the problems?

AUTOMATIC VOLUME CONTROL FOR AUDIO AMPLIFIER SYSTEM

1. OBJECTIVE

To implement and test the automatic volume control for audio amplifier system using LabVIEW/ELVIS.

2. INTRODUCTION



Block Diagram Representation of Closed-Loop System

The automatic volume control for the audio amplifier system can be regarded as a closed-loop system whose block diagram representation is shown as above. The gain control in the VCA forms the actuator to change the audio volume for a given audio input signal, while the VU meter is the sensor for the output audio signal level (envelope detector voltage). The feedback path is passed through a suitable control algorithm to be executed by the computer. A simple control algorithm is the Step-Up-Down controller to be implemented in the LabVIEW software environment. Ideally the automatic volume control should hold the audio output level constant at the set point level for any input signal level.

3. EQUIPMENT AND COMPONENTS

Equipment: Personal Computer (PC) with LabVIEW and NI ELVIS launcher/driver
NI ELVIS II

Components: Integrated audio amplifier system
Speaker

4. PROJECT TASKS

4.1 Implementation and Testing

Step-Up-Down Controller:

$$u(n) = \begin{cases} u(n-1) - \Delta & e(n) > 0, z(n) < r_0 \\ u(n-1) + \Delta & e(n) < 0, z(n) > r_0 \end{cases}$$

where $e(n) = r_0 - z(n)$

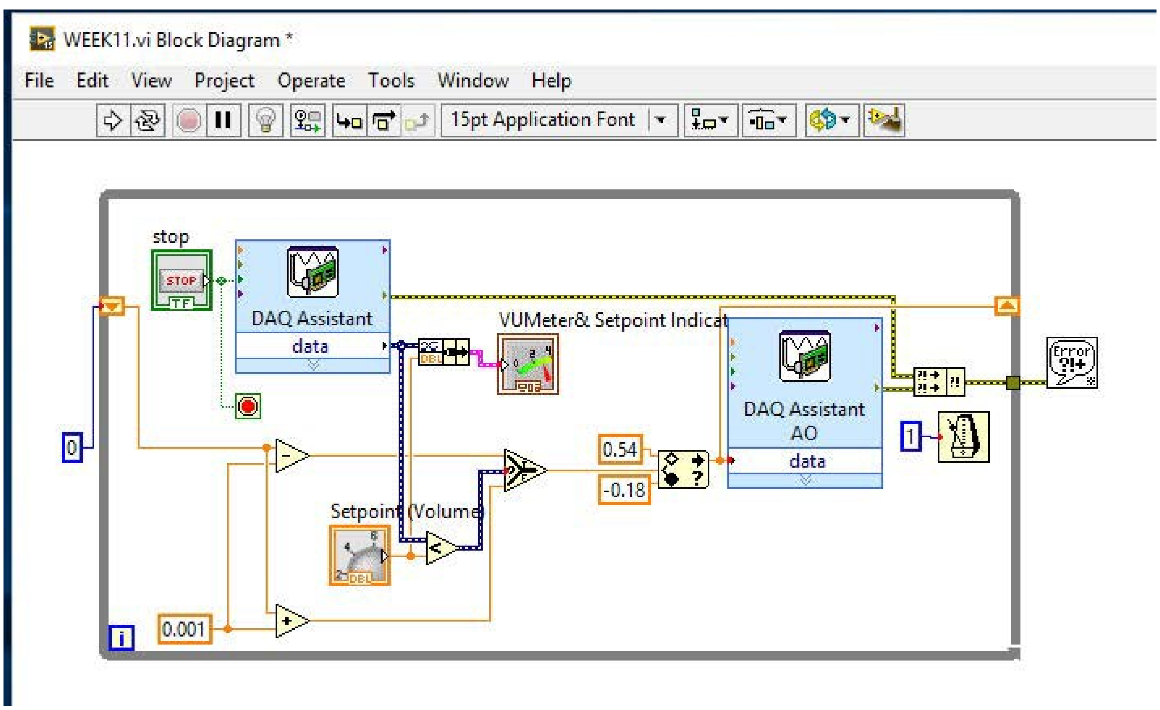
Δ is the controller parameter variable (step size),

u(n) is the actuator control voltage for VCA,

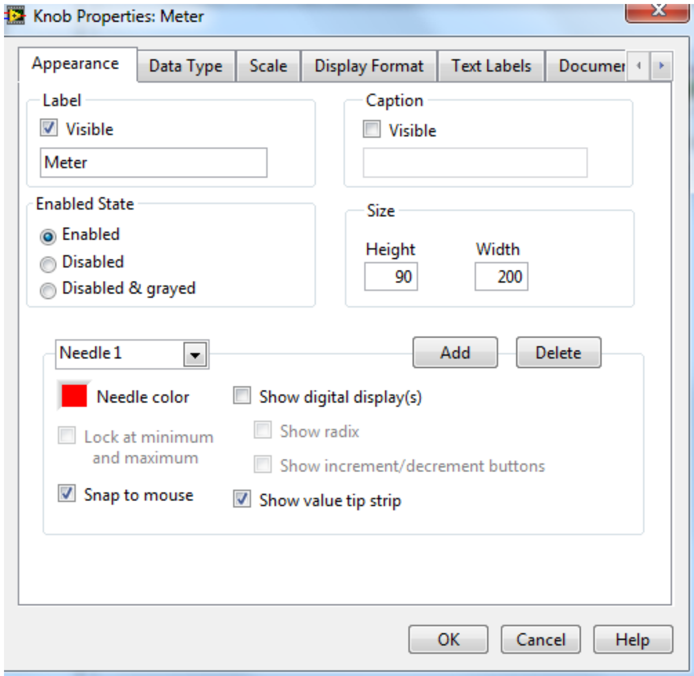
z(n) is the VU meter envelope detector output sensor value

r_0 is the set point value.

Implement the controller according to the algorithm above in LabVIEW. The block diagram may look like that in the figure below (**Note: feel free to explore alternative designs; you should also add your group number on the block diagram**).

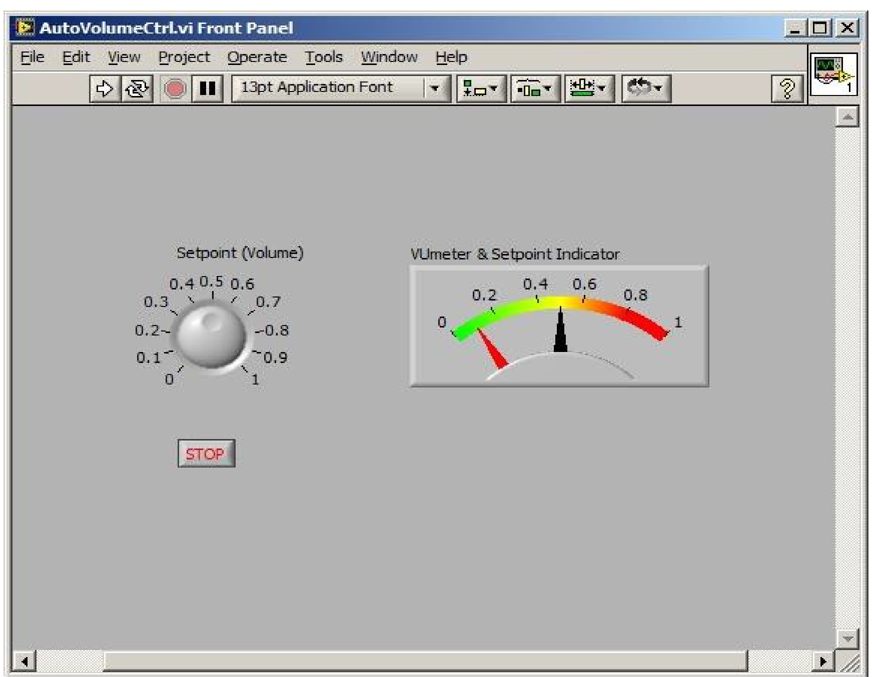


* In order to connect the “VUmeter & Setpoint Indicator” with the pink colour line, you need to add one more needle as shown in the following figure:



The data acquisition setup and configuration are similar to those in the manual volume control system. In order to prevent error exception (which may suspend the running of the LabVIEW application) due to the control voltage level exceeding the limits, it is necessary to use the "in range and coerce" vi to clip the control voltage before sending it to the output channel in NI ELVIS II.

The front panel may look like that in the figure below (**Note: feel free to explore alternative designs; you should also add your group number on the front panel**).



The black needle indicates the set point value r_0 that can be changed by turning the control knob.

The red needle indicates the value of $z(n)$.

Connect the FGEN output from the left panel of NI ELVIS II to the Audio input of the VCA. Connect the Audio output from the PA to a speaker. Set the FGEN to generate a sinusoidal waveform of frequency 300 Hz. You should hear the sound of a tone at the speaker output.

For each set point value r_0, input different audio signal levels and listen to the speaker output.

Record and discuss your observations. You should repeat and try with different set point values. Investigate also the cases of different values of the controller parameter variable Δ .

4.2 Logbook

Your logbook may consist of the following:

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Open Ended Questions

Does the chip on your circuit heat up during operation? If so, please explain what causes this phenomenon and suggest possible solutions to solve this problem.