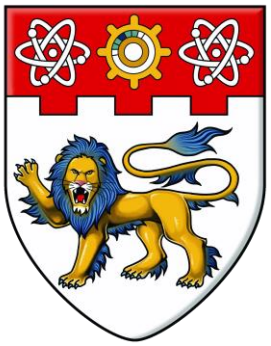


NANYANG TECHNOLOGICAL UNIVERSITY

EE2073 Project Report

Automatic Volume Control for Audio Amplifier System

School of Electrical and Electronic Engineering

Academic Year 2014/15

Semester 1

Content:

Chapter 1: Introduction

The purpose of the project is to design an automated controller system to keep the volume out of an audio system remain at an adjustable value set by the user. To achieve this purpose, a digital system was designed and implemented as shown in Figure 1.1.

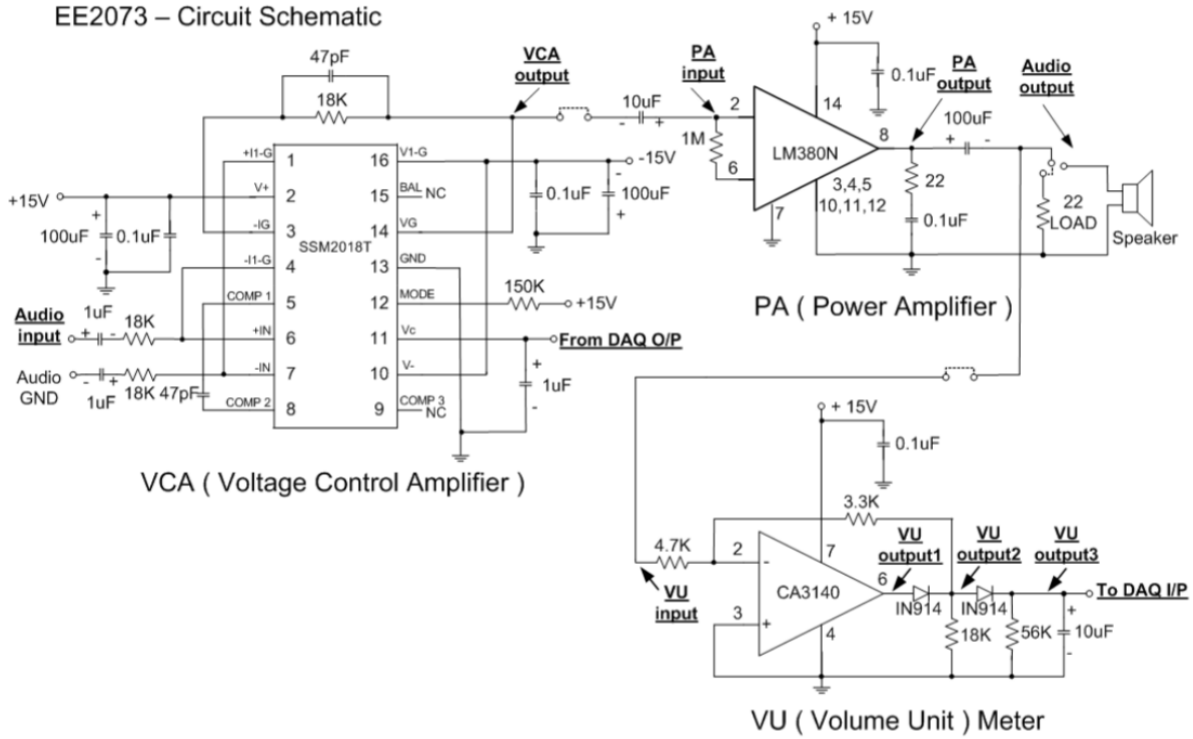


Figure 1.1 The circuit schematic for the entire system

The system contains three major part in the order of:

a) **Volume Unit Meter** playing the role of **output level sensor**
b) Voltage Controlled Amplifier(VCA) playing the role of **gain control block or actuator**
c) **Power Amplifier** playing the role of amplifying the signal

In practical implementation of such a digital system, Data Acquisition Block and LabVIEW was used to act as the perfect and integrated platform in the **discrete-time, sampled-data dimension.** The design starts from individual design and testing of VCA, PA and VU sub-circuits and integration of the three. Then an adding of a "forced" or "manual" feedback signal to test the open-loop circuit function. At last, adding of a closed loop feedback system.

Chapter 2: VCA subsystem

The Voltage Controlled Amplifier is an signal subsystem, which could be used to control the gain by applying the control voltage (V_c)

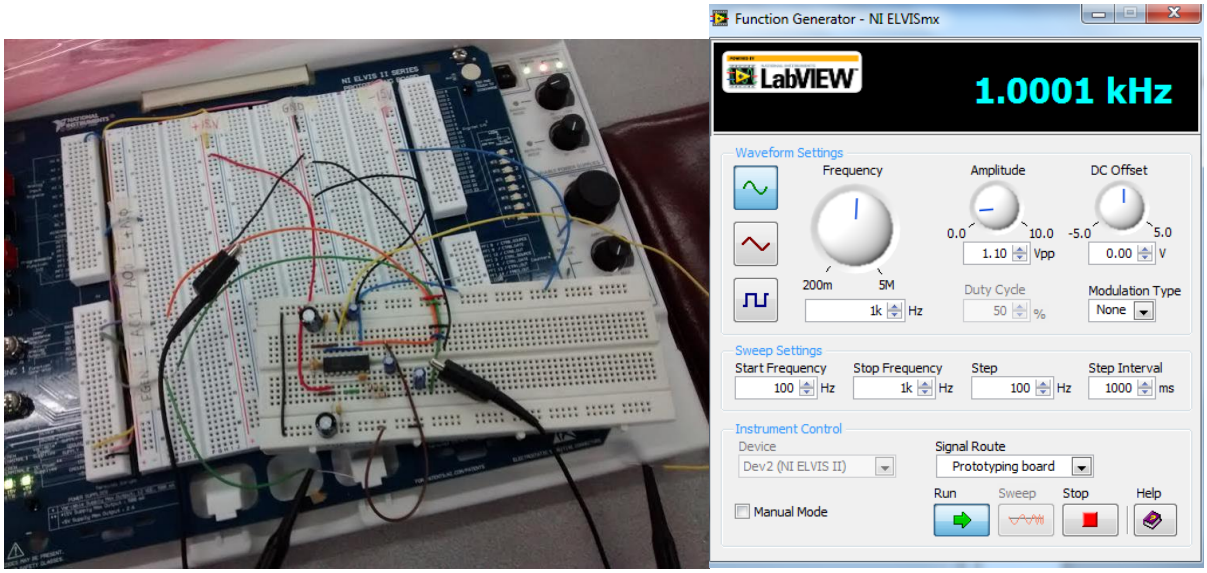


Figure 2.1 Breadboard connection and function generator setting

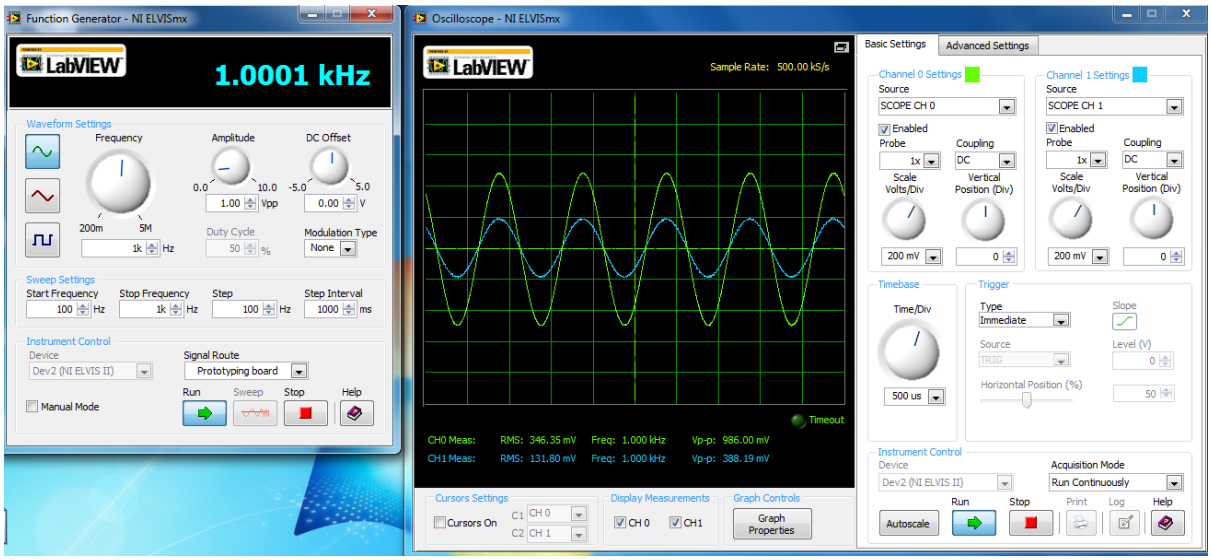


Figure 2.2 Output result sample for the VCA

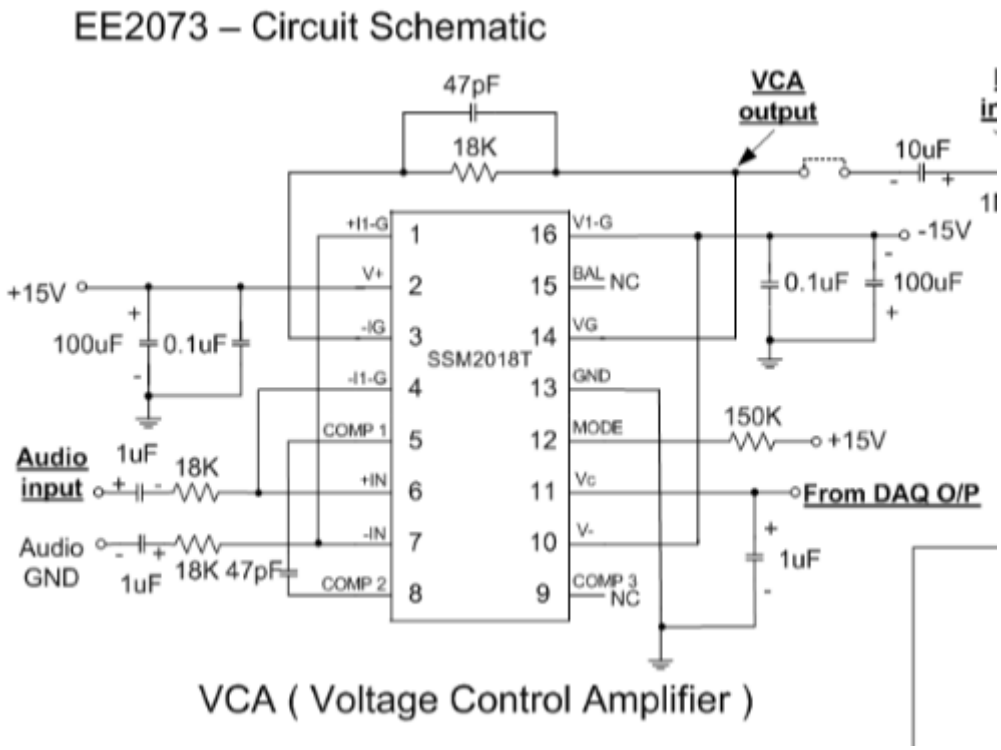


Figure2.3 Circuit Schematic of VCA

After the assemble of the subsystem, practical experiments have been done on it using a set of values as shown in Table 2.1. Based on the experiment results, Measured Gains were calculated and used to compare with Theoretical Gain. The theoretical gain is computed using the following formula and used as a benchmark:

$$\textbf{Gain} = e^{-aVc},$$

where a=3.623 when the chipsets are working normally under room temperature. If converted into dB, the following formulas was used instead:

$$\textbf{Gain (dB)} = 20\log(e^{-aVc})$$

VIN (Vpp)	VC (V)	VOUT (Vpp)	Measured Gain = VOUT/VIN	Measured Gain (dB)	Theoretical Gain	Theoretical Gain (dB)
Liu Song:						
1.1	1.5	0.02	0.018181818	-34.80725379	0.004363416	-47.20346724
1.1	1	0.04	0.036363636	-28.78665388	0.026702449	-31.46897816
1.2	0.5	0.2	0.166666667	-15.56302501	0.16340884	-15.73448908
1.2	0.25	0.48	0.4	-7.958800173	0.404238592	-7.86724454
1.7	0	1.65	0.970588235	-0.259299543	1	0
0.4	-0.25	0.97	2.425	7.694234859	2.473786567	7.86724454
0.7	-0.5	4.23	6.042857143	15.62484655	6.119619981	15.73448908
0.7	-1	N/A			37.44974871	31.46897816

Table 2.1 Record of the test and calculation results of VCA subsystem

To interpret the measured results intuitively, we have drawn the measured gain against Vc in figure 2.4. The graph of the theoretical gain against Vc is also drawn in figure 2.5 as a comparison.

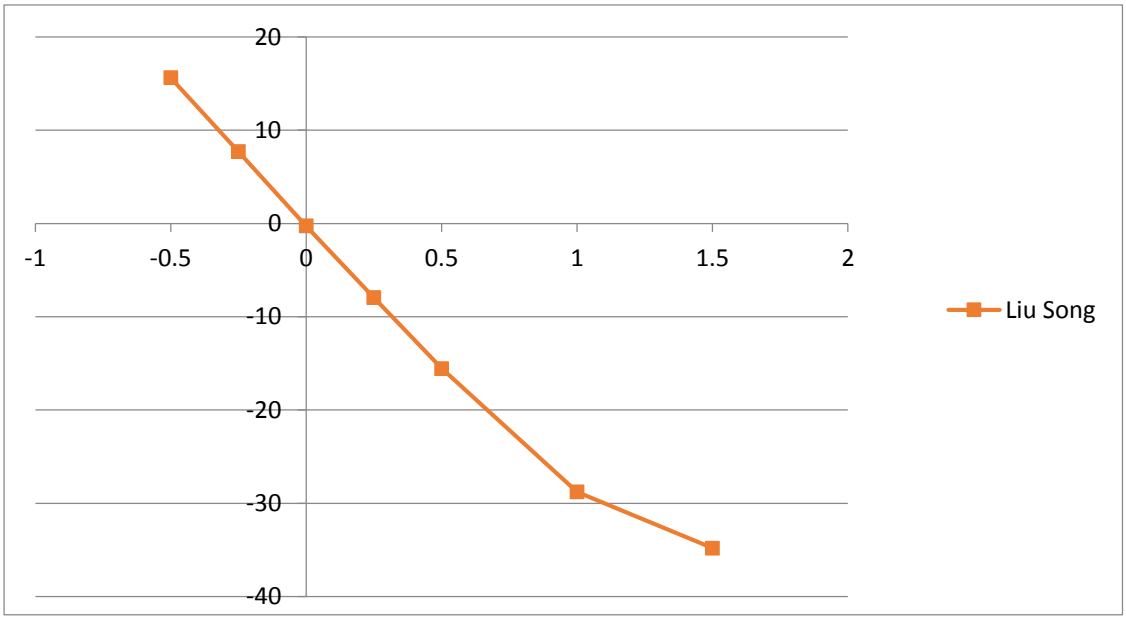


Figure 2.4 Measured Gain against Vc

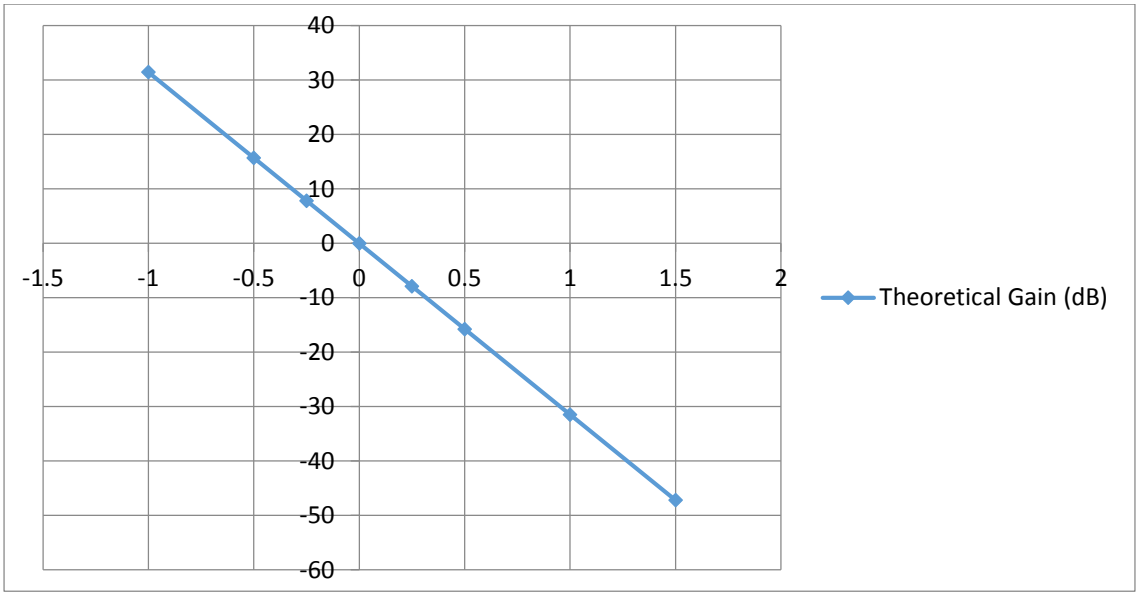


Table 2.5 Theoretical Gain against Vc

The Vc sensitivity is computed as the inverse of the slope of the graph:

$$\text{Sensitivity on Vc} = \frac{1}{(15.269 - (-15.4))/(-0.5 - 0.5)} \approx -0.0326\, V/dB$$

This measured and computed value of sensitivity of 32.5 mV/dB is very close the theoretical value of 31.78 mV/dB under the room temperature. The errors were trial and could be ignored. Hence the VCA subsystem is generally satisfactory at this stage.

Chapter 3 Power Amplifier (PA)

Power amplifier is the central component in the entire system that enlarge the signal level to a certain level enough to drive an audio speaker. The breadboard of this subsystem is connected according to the circuit schematic as shown in Figure 3.1

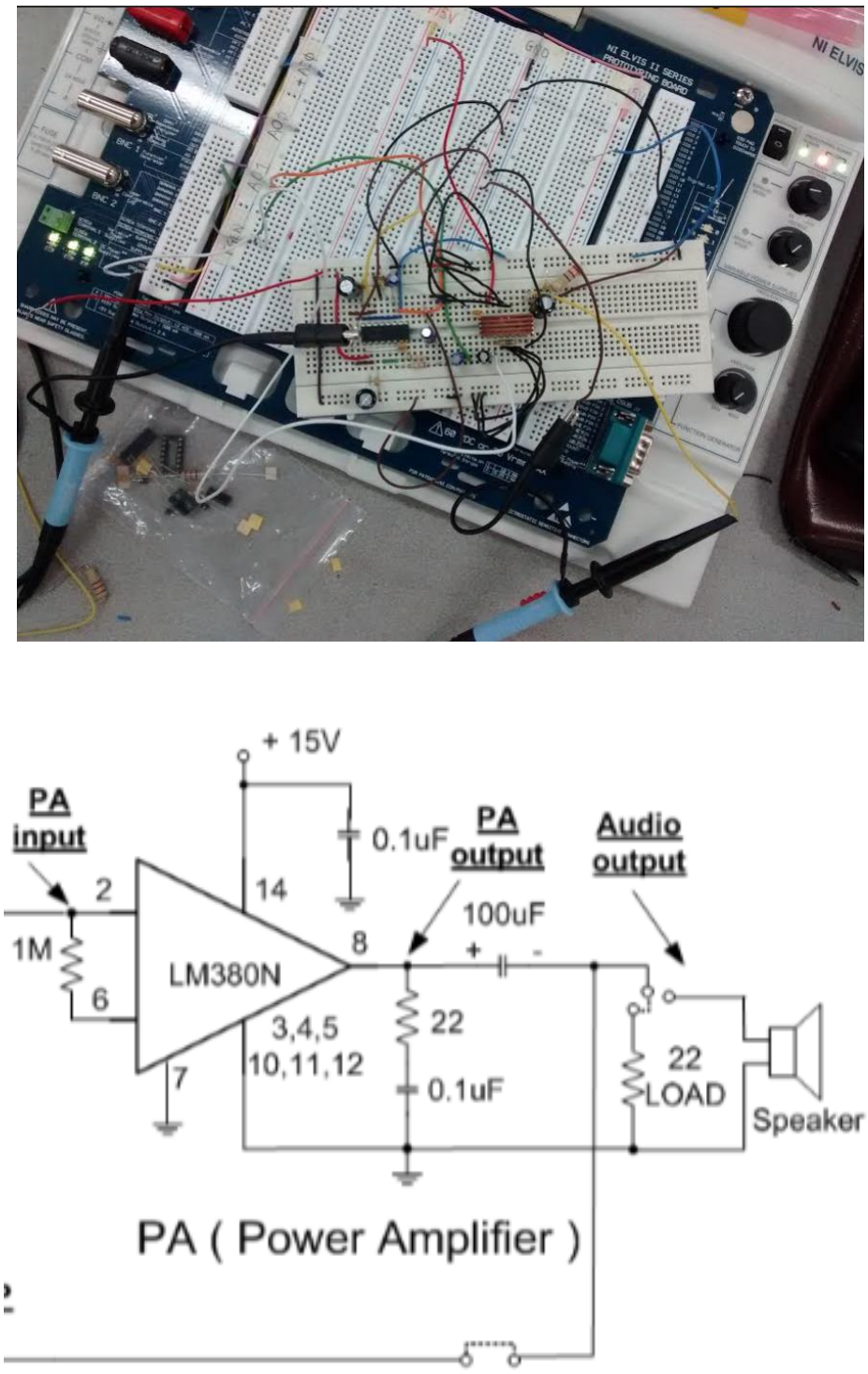


Figure 3.1 Breadboard connection and circuit schematic of PA

3.1 First set of result with a 1kHz sinusoidal input

Connecting Channel 0 to PA input and CH1 to the PA output, setting and use the function generator setting of:

- Sinusoidal wave
- 1k Hz
- 0.002 Vpp
- DC offset: 0v
- Step frequency: 1k Hz
- Step interval: 1000 ms

and we could get a clear graph of the signals at the two nodes as shown in figure 3.2.

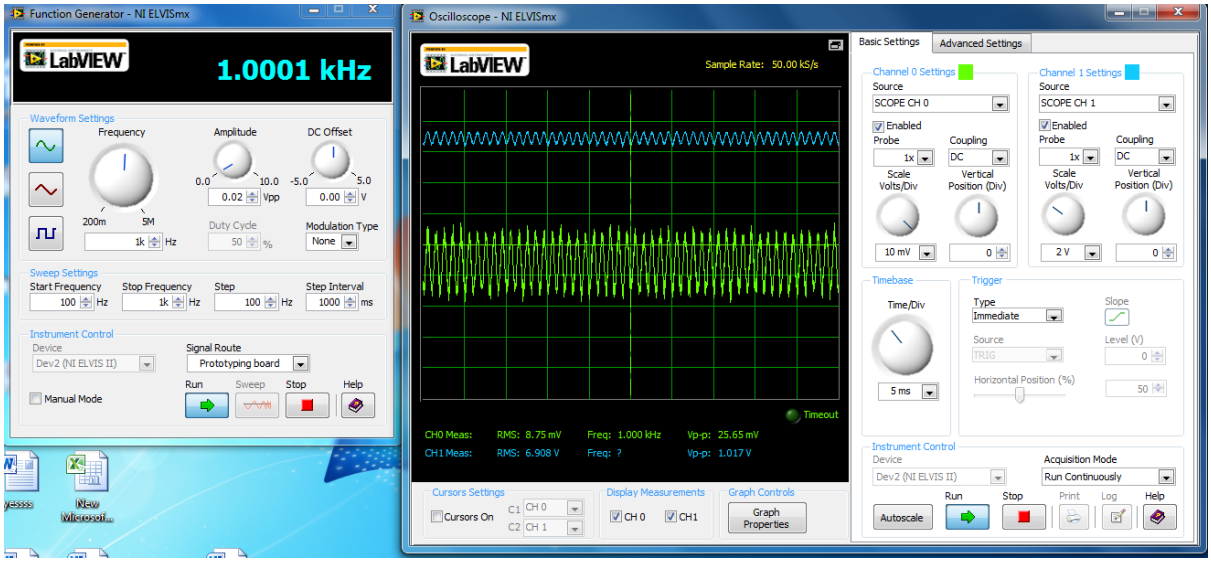


Figure3.2 Graph of PA input and output using a set of input

From the graph above:

$$\textbf{calculated gain} = 20log10\left(\frac{Vout}{Vin}\right) = 20log10\left(\frac{1.017v}{25.65mv}\right) = 32\text{dB},$$

Which is close to the expected value of 34dB within a reasonable range of error, which may be due to environmental factors such as temperature heat up of chipsets.

3.2 Testing and capture the bode Plot with a Start frequency of 100Hz, stop frequency of 200KHz, Steps as 20 per decade and Vpp=0.01V.

We have captured the bode graph as shown in figure 3.3.

Figure 3.3 Another set of Bode plots for PA

Discussion: is this the frequency response what we expect?

The Gain at low frequency = 32.5dB, cutoff frequency = 32.5 -3 = 29.5dB

The value is very close to what we expected within a reasonable range of experimental error.

3.3 Capture Bode Analyzer Windows with matriculation card numbers(U1122747F):

Vp(V)	Bode analyser window capture of the PA gain and phase response

0.02	 Bode Analyzer - NI ELVISmx LabVIEW Connections: SCOPE CH 0 - FGEN SCOPE CH 1 - Signal Gain (dB) Frequency (Hz) Phase (deg) Frequency (Hz) Frequency (Hz) 199526.1 Phase (deg) -17.35 Gain 27.65 Gain (dB) 28.83 Measurement Settings Stimulus Channel SCOPE CH 0 Response Channel SCOPE CH 1 Start Frequency 100.00 Hz Stop Frequency 200.00k Hz Steps 20 (per decade) Peak Amplitude 0.02 Op-Amp Signal Polarity Normal Graph Settings Mapping Logarithmic Autoscale Cursor Settings Cursors On Cursor (Real) Position Left Right Instrument Control Device Dev2 (NI ELVIS II) Run Stop Print Log Help
0.01	 Bode Analyzer - NI ELVISmx LabVIEW Connections: SCOPE CH 0 - FGEN SCOPE CH 1 - Signal Gain (dB) Frequency (Hz) Phase (deg) Frequency (Hz) Frequency (Hz) 199526.1 Phase (deg) -14.31 Gain 28.32 Gain (dB) 29.04 Measurement Settings Stimulus Channel SCOPE CH 0 Response Channel SCOPE CH 1 Start Frequency 100.00 Hz Stop Frequency 200.00k Hz Steps 20 (per decade) Peak Amplitude 0.01 Op-Amp Signal Polarity Normal Graph Settings Mapping Logarithmic Autoscale Cursor Settings Cursors On Cursor (Real) Position Left Right Instrument Control Device Dev2 (NI ELVIS II) Run Stop Print Log Help

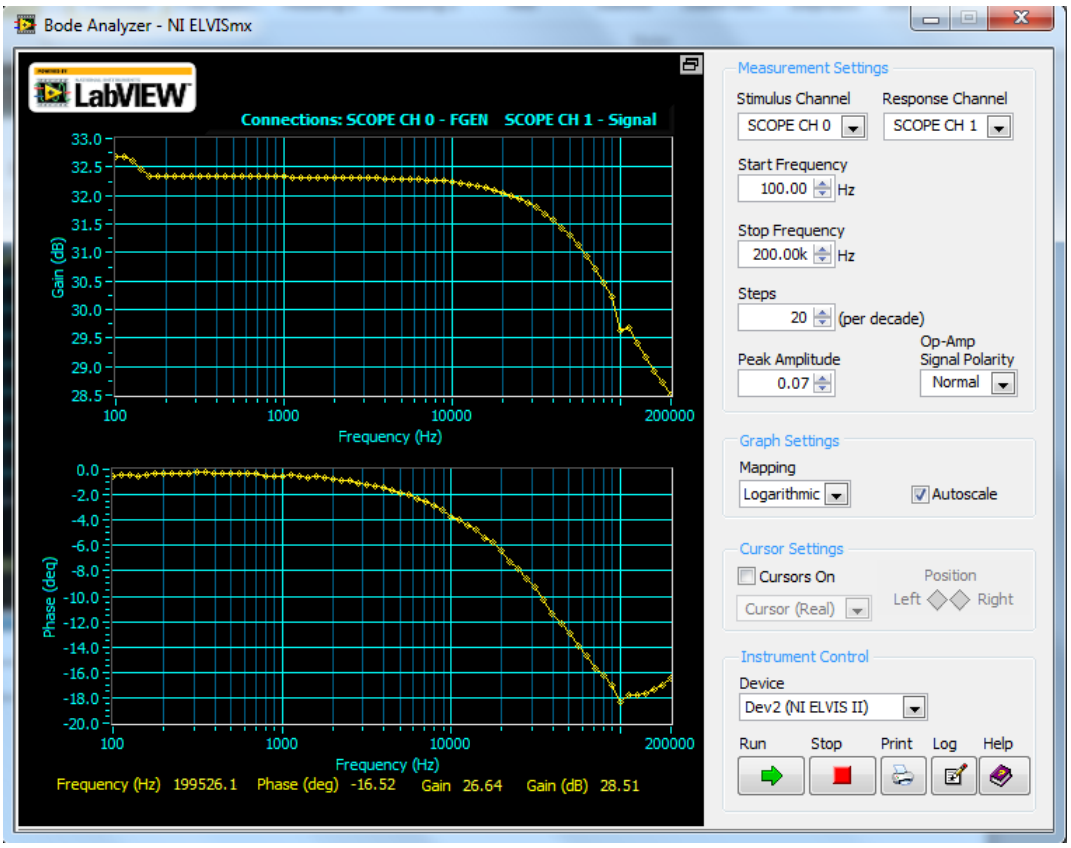
0.07	 Bode Analyzer - NI ELVISmx LabVIEW Connections: SCOPE CH 0 - FGEN SCOPE CH 1 - Signal Gain (dB) Frequency (Hz) Phase (deg) Frequency (Hz) 199526.1 Phase (deg) -16.52 Gain 26.64 Gain (dB) 28.51 Measurement Settings Stimulus Channel SCOPE CH 0 Response Channel SCOPE CH 1 Start Frequency 100.00 Hz Stop Frequency 200.00k Hz Steps 20 (per decade) Peak Amplitude 0.07 Op-Amp Signal Polarity Normal Graph Settings Mapping Logarithmic Autoscale Cursor Settings Cursors On Cursor (Real) Position Left Right Instrument Control Device Dev2 (NI ELVIS II) Run Stop Print Log Help
0.04	 Bode Analyzer - NI ELVISmx LabVIEW Connections: SCOPE CH 0 - FGEN SCOPE CH 1 - Signal Gain (dB) Frequency (Hz) Phase (deg) Frequency (Hz) 199526.1 Phase (deg) -16.15 Gain 26.88 Gain (dB) 28.59 Measurement Settings Stimulus Channel SCOPE CH 0 Response Channel SCOPE CH 1 Start Frequency 100.00 Hz Stop Frequency 200.00k Hz Steps 20 (per decade) Peak Amplitude 0.04 Op-Amp Signal Polarity Normal Graph Settings Mapping Logarithmic Autoscale Cursor Settings Cursors On Cursor (Real) Position Left Right Instrument Control Device Dev2 (NI ELVIS II) Run Stop Print Log Help

Table 3.1 Bode plots of gain and phase response graph

3.4 Additional observations and discussions

a) If Vpp = 0.01V, 0.02V, 0.04V, 0.07V, the measured gain approximate to 32.4dB at frequency range of 100Hz to 10000Hz. This is extremely close to the expected gain of 34dB.

b) We have observed a different level of distortion for all the above graph. There is no significant distortion for the values we used during the experiments. However, we expect the see very large distortion when Vpp exceeds 0.6V. This is because the gain of the PA is approximately 34dB or 50V/V, and when Vpp exceeds 0.6V, the range for the output will exceed 30V. Since the output will always be bounded by the power supply (-15, +15), any value beyond the range will not attainable.

Chapter 4 Volume Unit Meter

VU Meter acts as a sensor or output level detector for the PA output signal. Its output could then again used as a feedback node back to the VCA through node Vc. The breadboard is connected according to its circuit schematic as shown in figure 4.1.

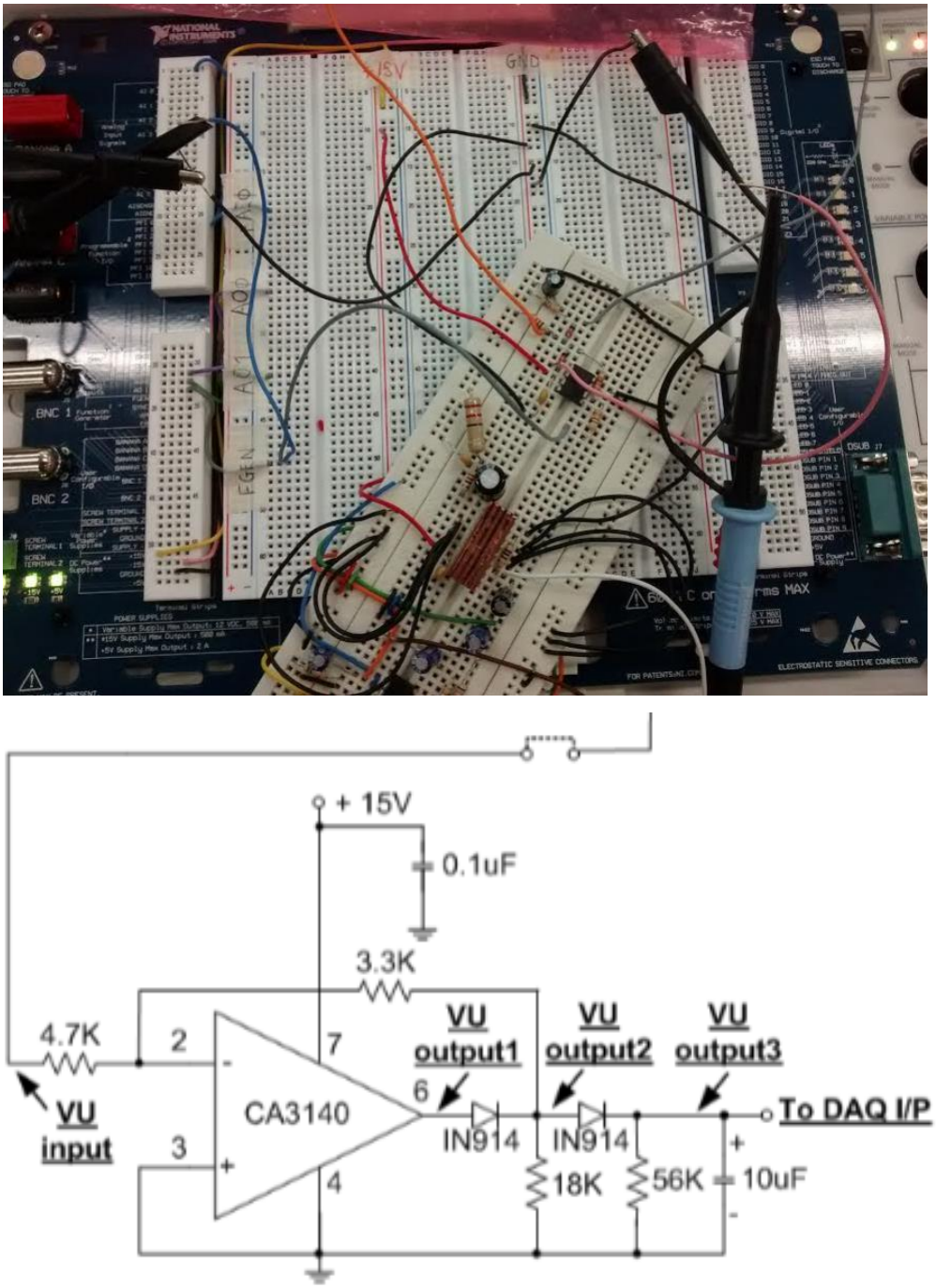


Figure4.1 Breadboard connection and Circuit schematic for VU

4.1 Testing of the first set of value

This section is simply to show an example of configuring the function generator and oscilloscope. Initial configurations for the testing:

- 1kHz input signal frequency, Vpp=5v, in the function generator
- CH0 connected to VUinput, CH1 to VUouput1,2,3 respectively.

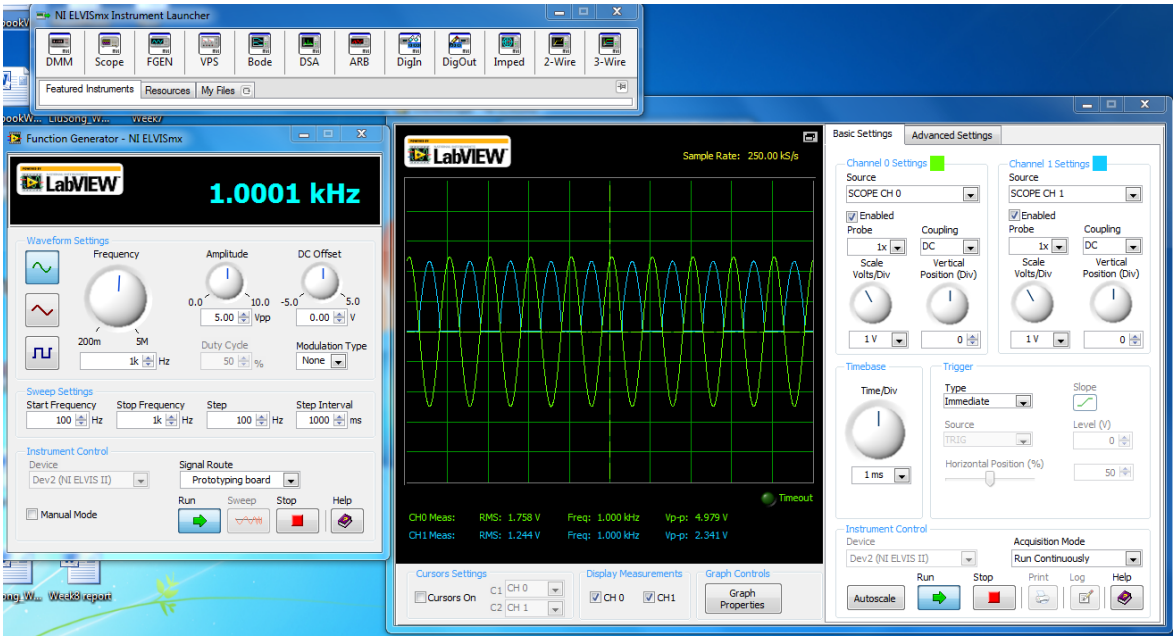


Figure 4.2 Function generator setting and oscilloscope output sample

4.2 Testing and calculate the measured gain based on my matric card number (U1122747F)

Many more tests have been carried out using the general settings in section 4.1. The VUinput used was according to my matric card number. The values used and measured gains are shown in Table 4.1:

VUinput (Vpp)	VUoutput1 (Vpk)	VUoutput2 (Vpk)	VUoutput3 (Vpk)	Measured Gain = 2 VUoutput2 / VUinput
5	2.34	1.716	0.00322	0.6864000
9.1	3.812	3.095	0.00596	0.6802198
4.51	2.162	1.543	0.0029	0.6842572

3.52	1.801	1.228	0.00226	0.6977273
2.52	1.430	0.880	0.00193	0.6984127
1.57	1.068	0.540	0.00161	0.6878981
0.54	0.66	0.196	0.00145	0.7259259
0.27	0.532	0.100	0.00129	0.7407407

Table 4.1 VU testing values and resutls

1.3 Plot of the measured gain VS VUinput

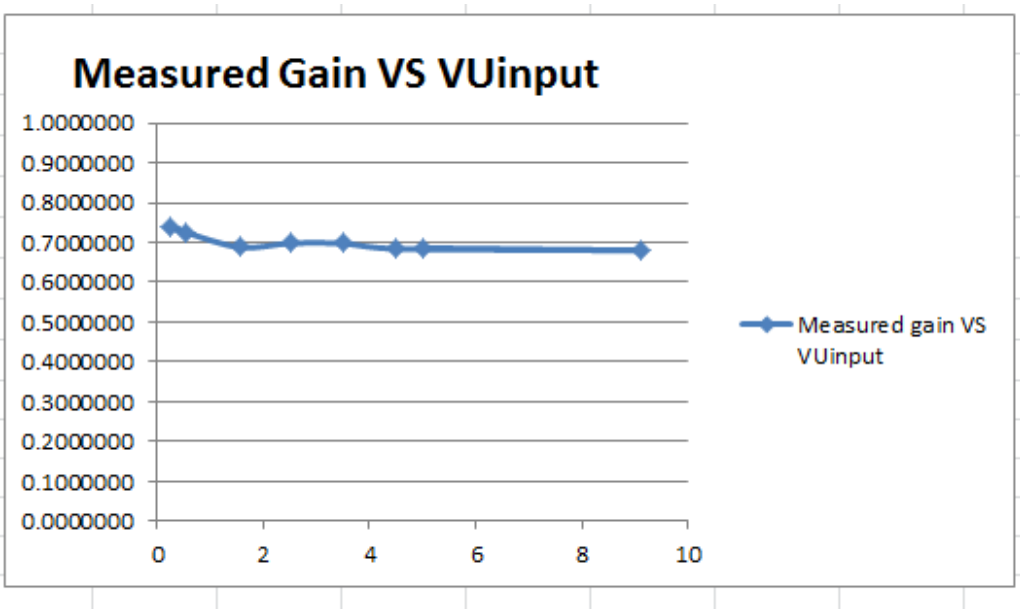


Figure 4.4 Measured Gain VS VUinput for VU meter

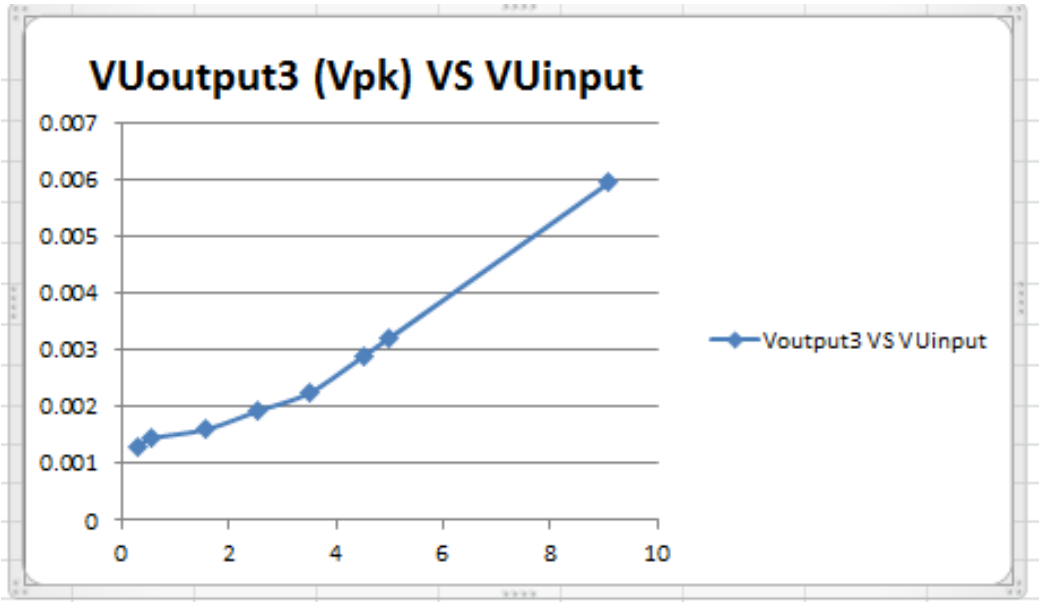


Figure 4.5 Voutput3 VS VUinput for VU meter

Additional Discussion:

$\boldsymbol{Theoretical\ Gain} = -\frac{\boldsymbol{R_2}}{\boldsymbol{R_1}} = \mathbf{-0.7021}$. From figure 4.4, it could be seen that our measured gain ranges from 0.6802198 to 0.7407407, which is very close to our theoretical value given by: $-R_2/R_1$=-3.3K/4.7K=-0.702.

Since the functionality of VU meter is the measure the output signal amplitude form the PA subsystem. From the above graph, we could conclude that the functionality of it is met and we could further see that the VUouput 3 changes almost linearly with VUinput.

Chapter 5 Integration of VCA, PA and VU

After successfully building and testing three individual circuit blocks, namely VCA, PA and VU, it is time to integrate them into one. Before a real closed feedback path is connected, we used a manually set Vc(from DAQ O/P) for the testing of the audio output level. Both a PCB and a breadboard had been built for this week as shown in Figure 5.1:

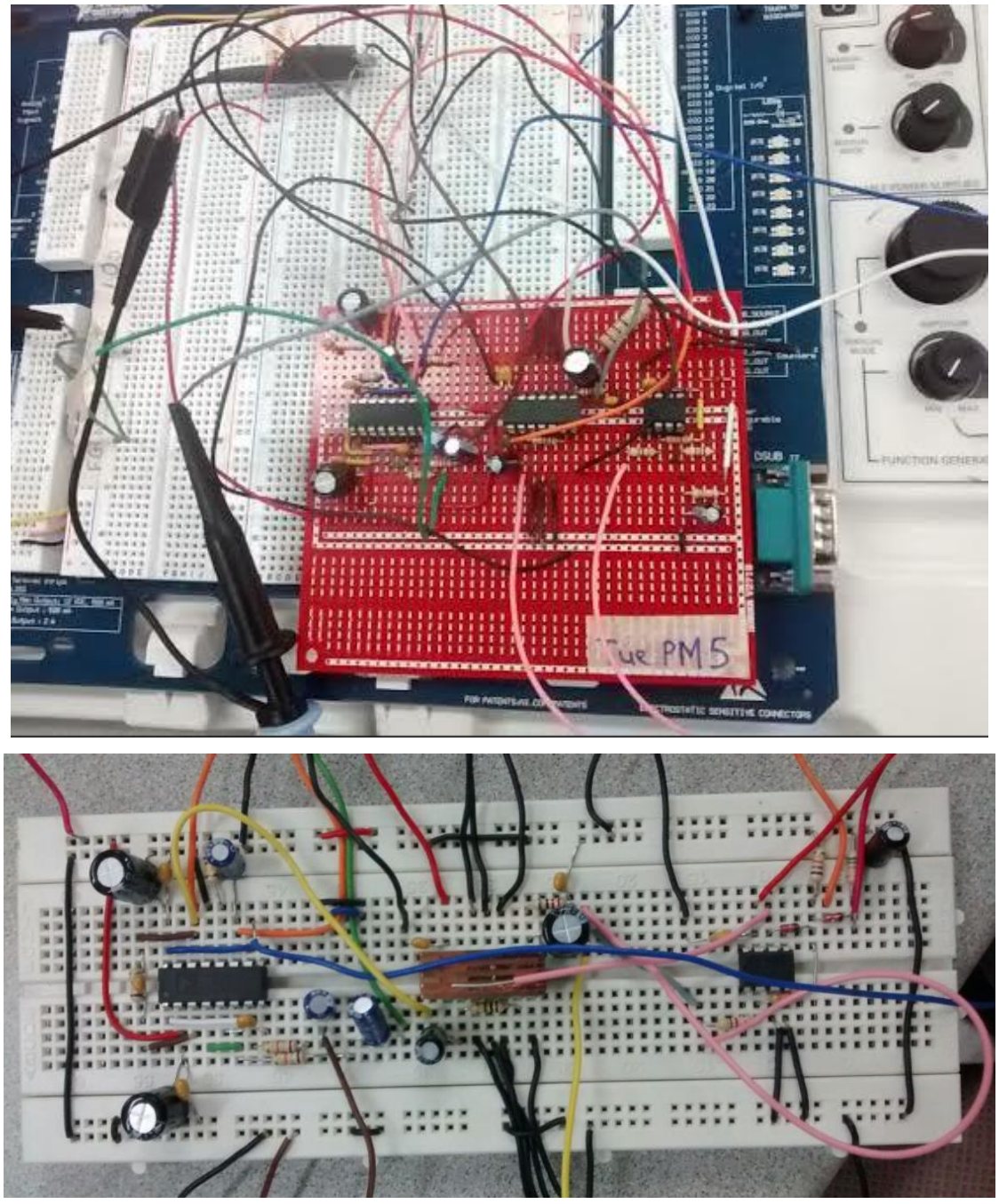


Figure 5.1 PCB and breadboard of the initially integrated system

5.1 Testing the system using values from my matric card number (U1122747F)

Sinusoidal waveform with frequency of 300Hz in FGEN was configured for a thorough testing of the system. The testing values and results are shown in table 5.1.

Audio input	Vc	Audio output	Gain (dB)
1.1	1.5	0.17	-16.2189
1.2	1	1.124	-0.5683
1.2	0.5	7.5	15.9176
1.0	0.25	13	22.27887
0.08	0	4.1	34.19388
0.14	-0.25	9.1	36.25827
0.15	-0.5	9.0	35.56303

Table 5.1 Testing values and audio outputs to test the initial integrated system

5.2 Plot Gain(dB) VS Vc

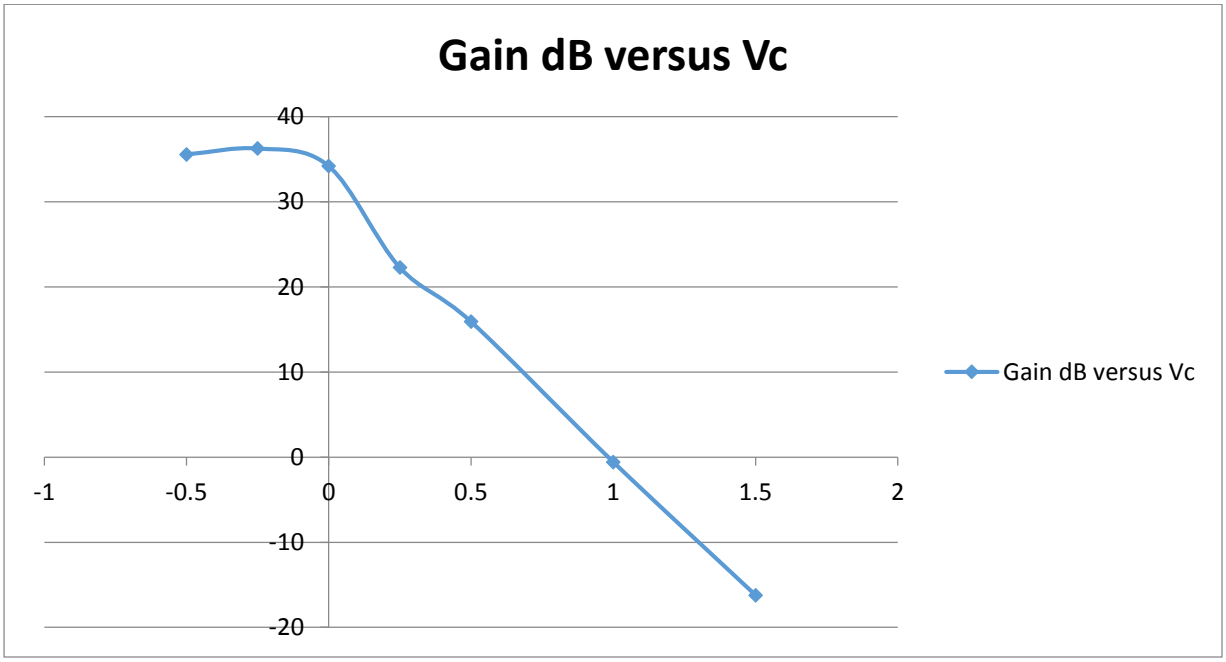


Figure 5.2 Gain VS Vc

Additional discussion:

1) The desired design is reasonably met. When Vc is negative, gain maintains very high at a value around 35dB. When Vc is in the positive domain, gain becomes smaller and decreases almost linearly. When Vc reduces to around 1V, gain turns negative and volume also reduce.
2) When frequency increases above 100kHz, the output is distorted a lot even though it can still be distinguished as a periodic function.

Chapter 6: Manual Volume Control

Before adding an automatic feedback control circuit, it is necessary to test the data acquisition circuit setup. Hence a manual value control signal Vc is applied to VCA by the operator manually to observe the output of the system. Notice that the manual control should work in accordance with the VCA(actuator) and VU(sensor). At this stage, the entire system is still an open loop circuit. According to the block diagram of the open loop system as shown in Figure 6.1, the breadboard is connected as shown in figure 6.2. Notice that the resistor was replaced by a speaker.

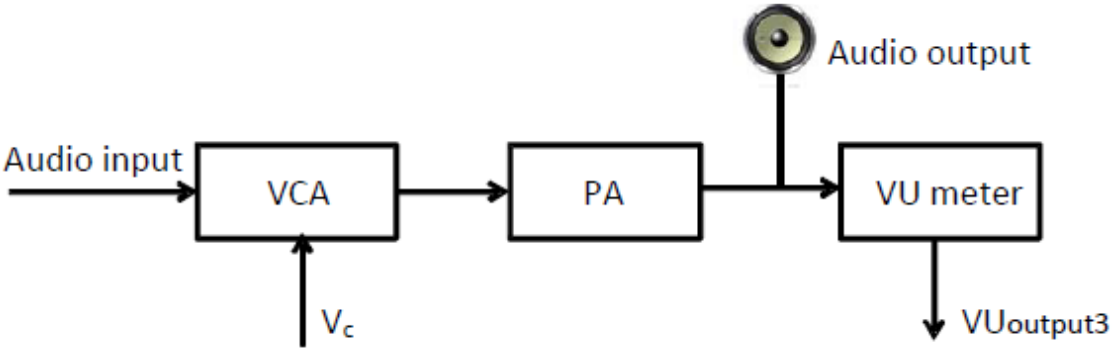
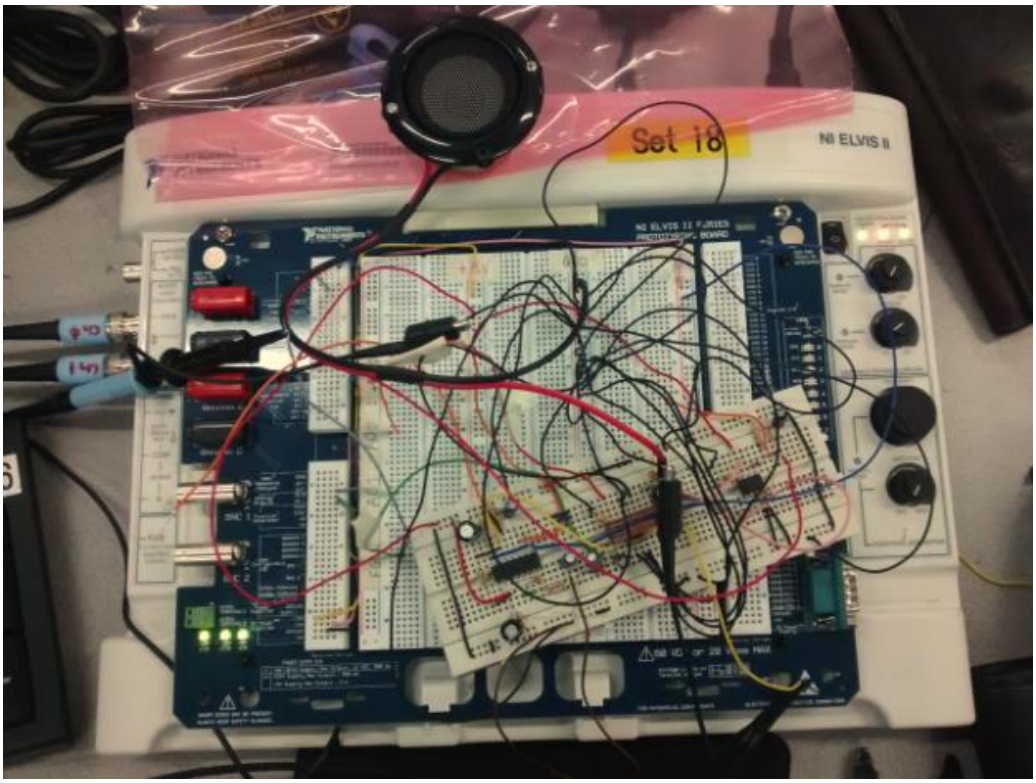


Figure 6.1 Block diagram of the open loop system



Fgiure 6.2 Bread connection of the open loop circuit

The manual control circuitry is drawn in LabView and its block diagram is shown in Figure 6.3.

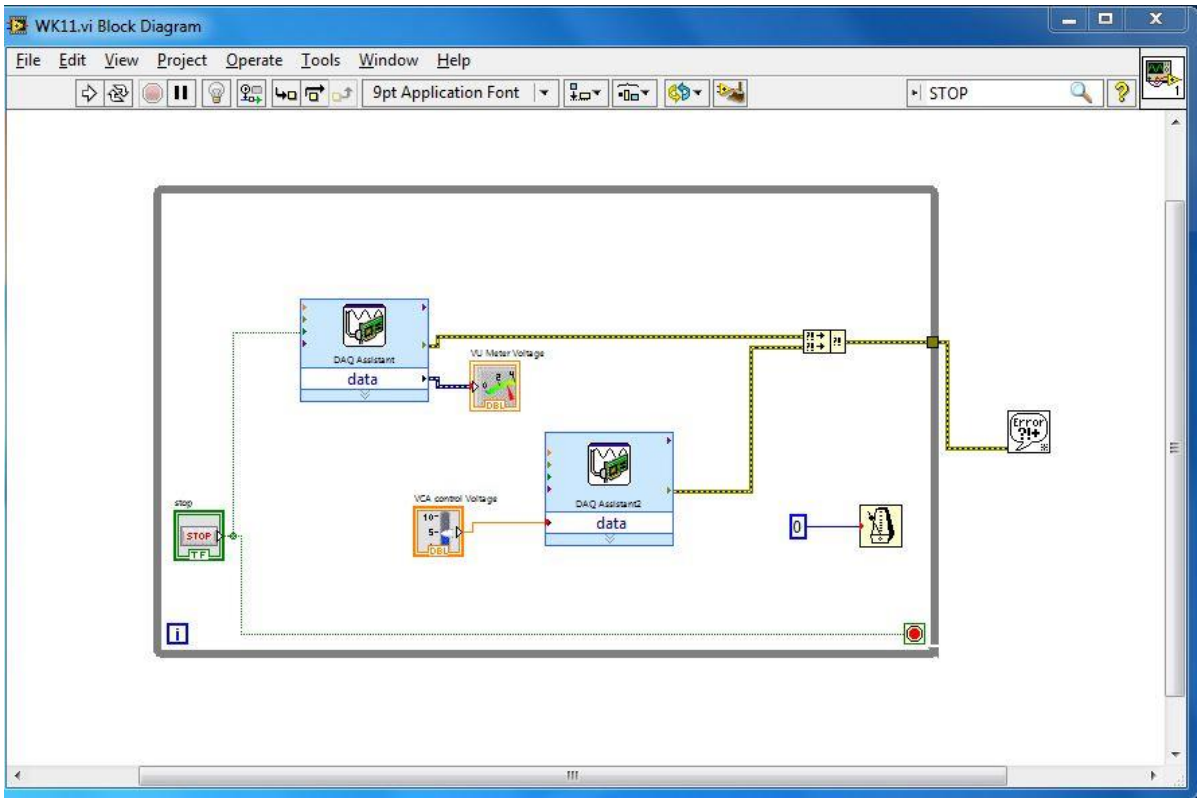
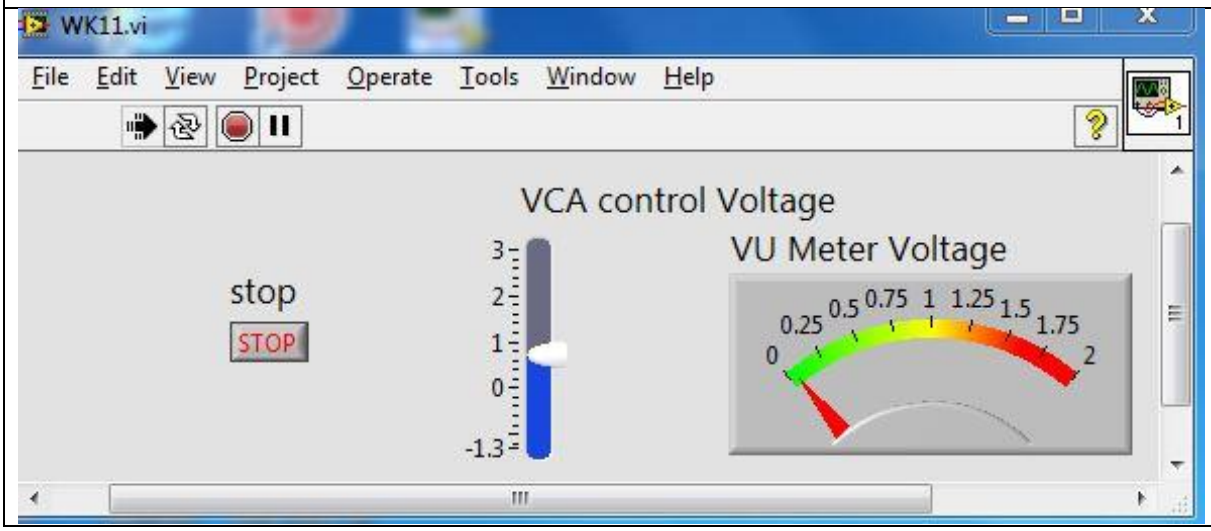
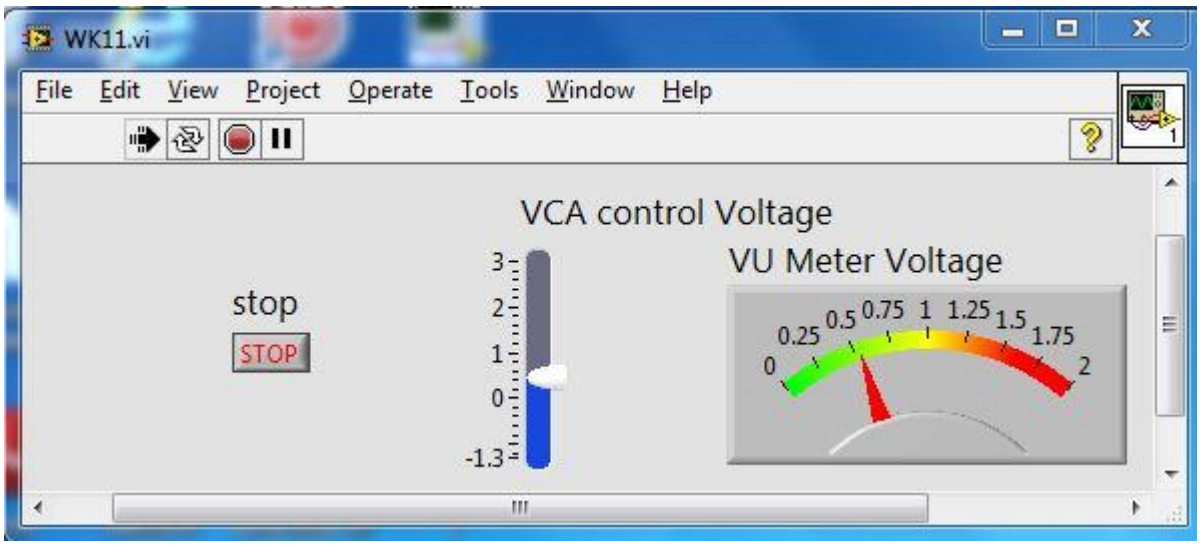


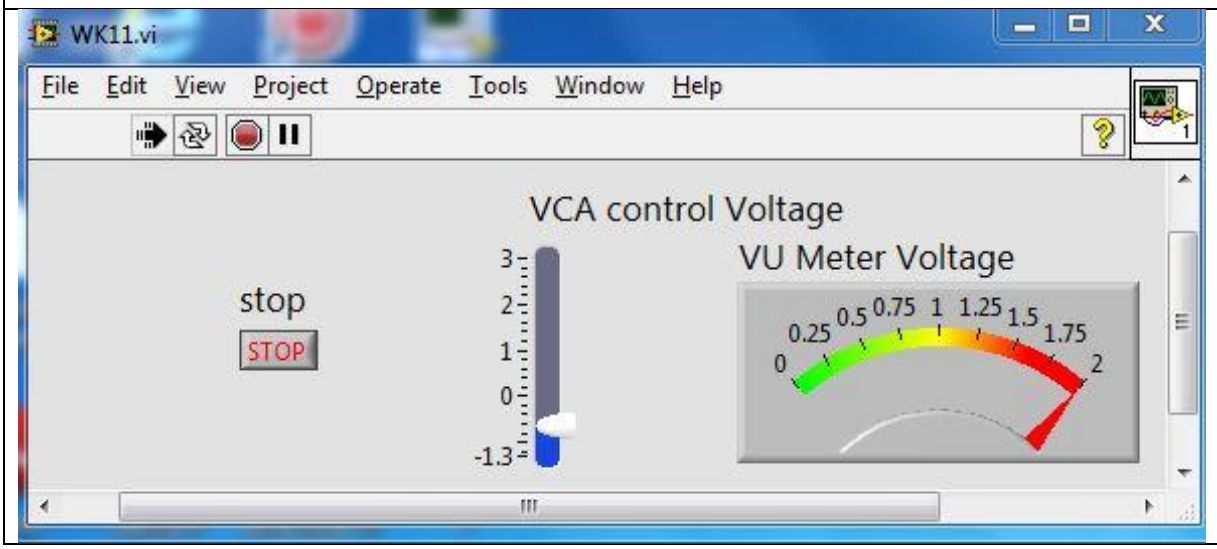
Figure 6.3 LabView block diagram for the open loop system

Different values of VCA control voltages have been tested for the circuits and the front panel displays are shown in table 6.1:

Table 6.1 Front panel displays with different VCA control voltage







Additional discussion:

We observed that when the VU meter display changes with VCA control voltage. In addition, as the control voltage Vc goes up, the VU display goes down. This is observation is expected because Vc is a negative feedback signal.

Also as we changed the input signal frequency, we could hear the speaker generating higher tones with higher frequencies.

Chapter 7 Automatic Volume Control (complete system)

At the final stage, we implemented a close loop circuitry to automate the process of volume control. The block diagram of the entire system is shown in figure 7.1. The VU acts like a sensor for the audio output level, the VCA acts as the actuator for the audio input amplification. The close loop circuit feedback the signal form the VU meter to the VCA, and it is developed in LabVIEW/ELVIS.

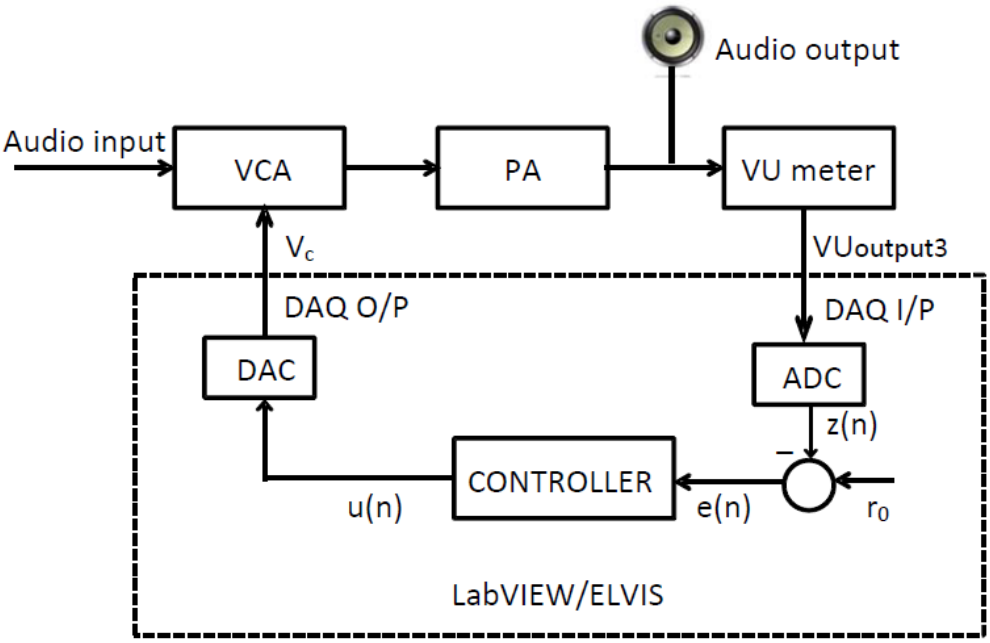


Figure 7.1 Block diagram for the closed loop system

The feedback circuit's working mechanism is shown below. When the VU meter output is bigger than the setpoint value, it will be reduced by a step size until it equals to the setpoint. When the VU meter output is smaller than the setpoint value, it will be enlarged by a step size until it equals to the setpoint.

Step-Up-Down Controller:

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

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

where

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 setpoint value.

The bread is connected to the NI ELVIS II as in figure 7.2, and the LabView block diagram is drawn as in figure 7.3.

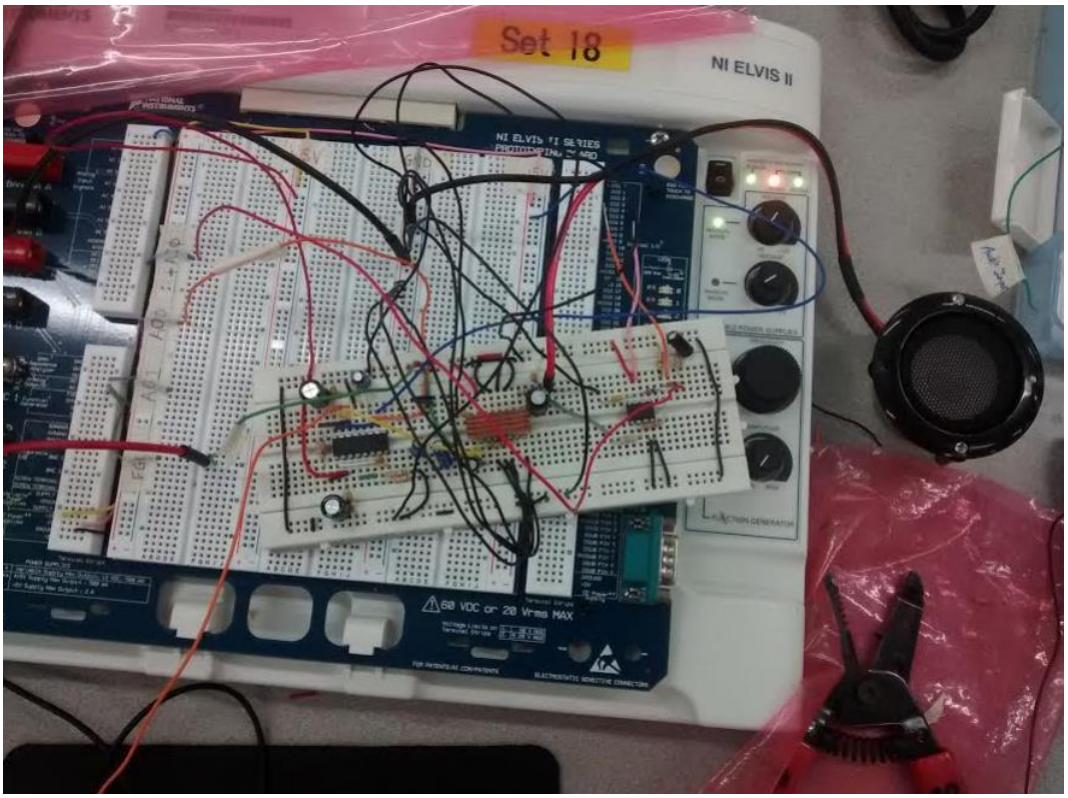


Figure 7.2 Breadboard connection for the closed loop system

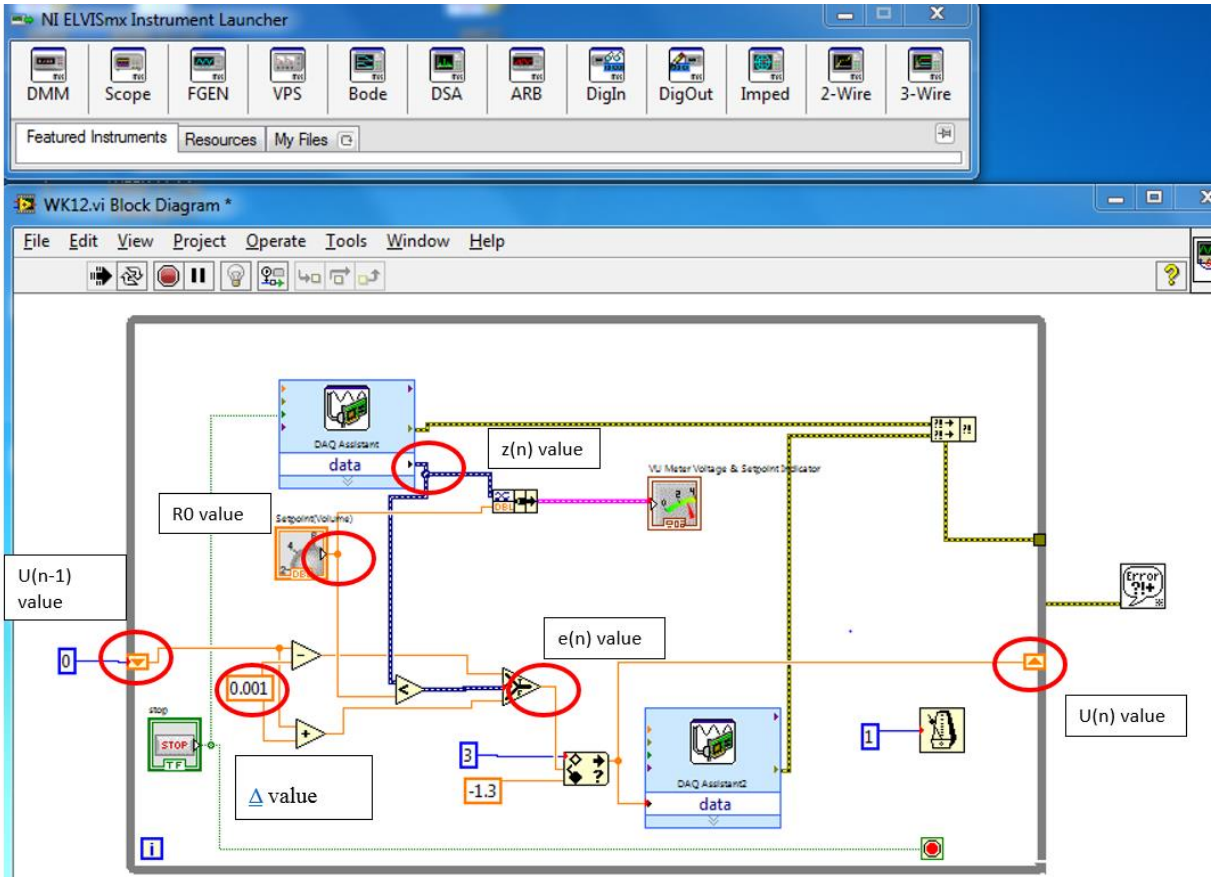


Figure 7.3 LabView block diagram for the closed loop system

The front panel is shown in figure 7.4. The RED needle indicates the actual or real-time oupt value from the VU meter. The black needle points to the value set by the setpoint knob.

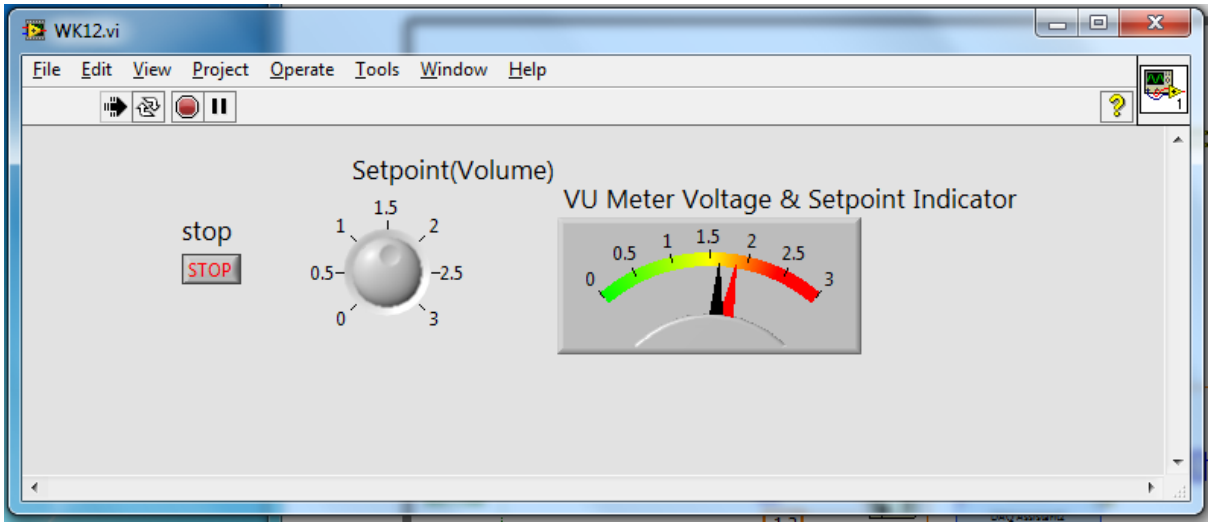
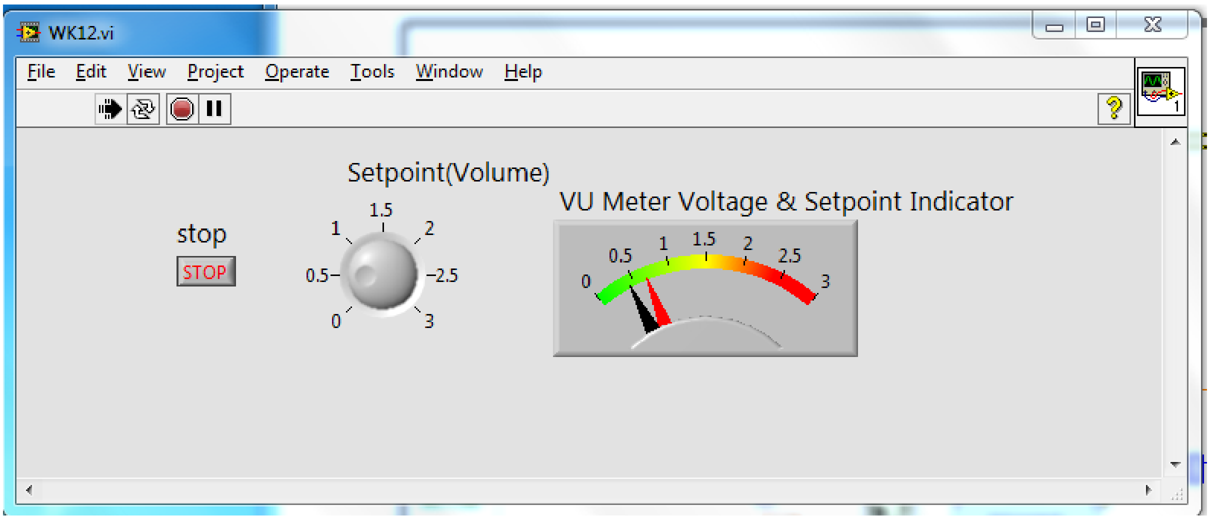
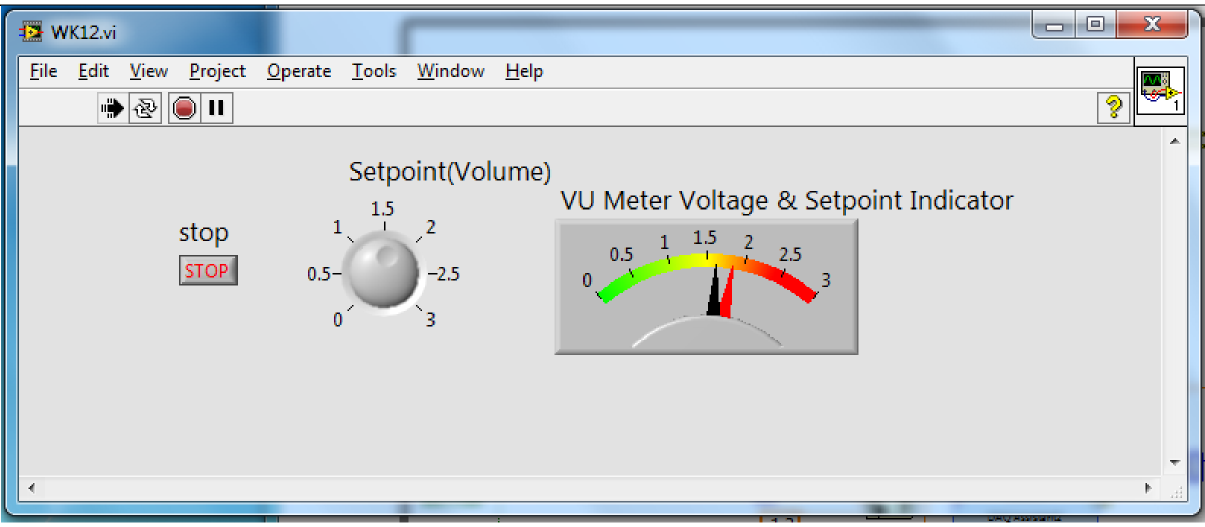


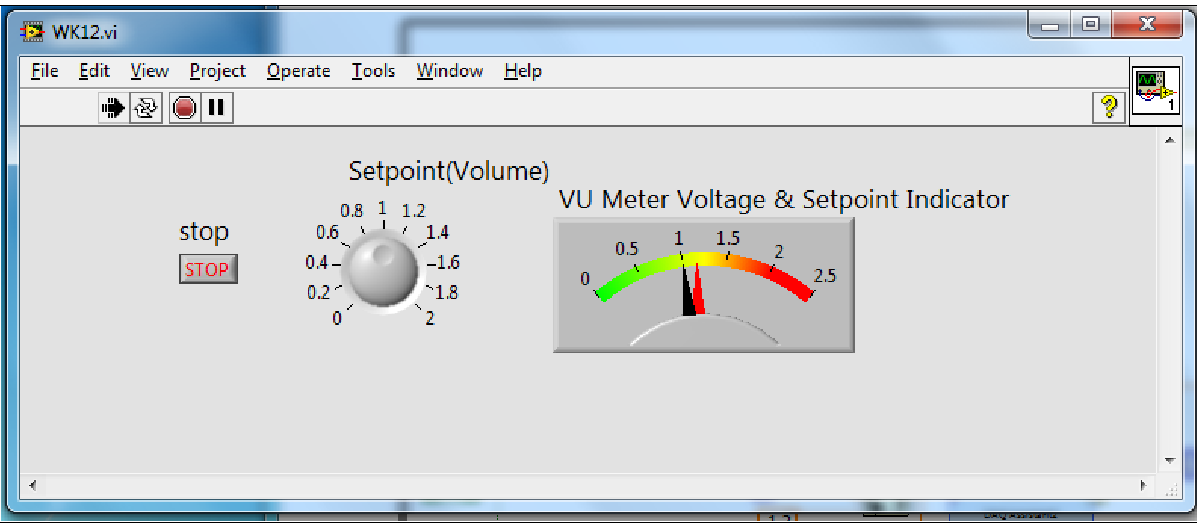
Figure 7.4 front panel of the closed loop system

Next, the system are tested while changing the setpoint value, the results are shown in table 7.1 below.

Table 7.1 The front panel display while changing the setpoint value







Additional discussion:

1. In the idea case, the black needle should overlap with the red needle, meaning that the volume controller should output a constant output audio level. However, there is a certain “response time” of the system. Hence we observed that the red needle oscillate around the black needle within a small range when the audio input changes abruptly, but will get close to the black needle swiftly. The “response time” could be further improved by increasing the step size delta (controller parameter variable). However increasing the delta would decrease the system performance because the step size is not small enough for a precise fine tune of the audio signal.

2. When testing using a speaker and computer audio output, we observed that our system was generally successfully realised the function of controlling the final speaker volume to a fixed value set by the “setpoint”. Further testing is done by inputting a music signal from a PC, it was also observed that the red indicator oscillates around the black within a reasonable range.

Conclusion

This project aims to develop an automatic volume control system as a way to prepare students for the EEE design and innovation projects. The first part of the system is a voltage controlled amplifier circuit, which receives audio input signal and plays the role of an actuator, whose gain are set by a feedback signal Vc. The second part is an power amplifier which is the central item that provides most of the gain and power for the audio output through a speaker. The final part is a volume unit meter used to sense the output signal level and feedback to the control circuit.

In developing the entire system, we have adopted a divide-and-conquer approach. The entire system is divided into three subsystems, namely the voltage controlled amplifier, the power amplifier and the volume unit meter. Each subsystem was implemented and tested individually before integrated together. After the initial integration was done and before adding a closed loop circuit as a final step, we tested the system using a manual feedback signal Vc. Hence we avoided a lot practical problems and the need to debug the entire system from head to toe.

The overall the performance of our system is satisfactory from a customer's point of view. Audio music input from a PC was used to replace to function generator signal, and the sound quality and volume control function was quite impressive. Hence we conclude that we have successfully finished the project.

Recommendations for next batches

1. Future batches of students are advised to have an overall picture of the entire system before rushing to complete each subsystem. Having a clear understanding of the underlying mechanism would be very helpful in preparing the weekly log and debugging.
2. Many noises when using the breadboard comes from loose connections of wires. Extra attention should be paid into managing the wires in a tidy manner.
3. Double check your PCB connections before rushing to solder them. Debugging a PCB could be very troublesome and time consuming.

References

[1]Sedra.A, Smith.K, “Microelectronic circuits”, 6ed, Oxford University Press, 2009

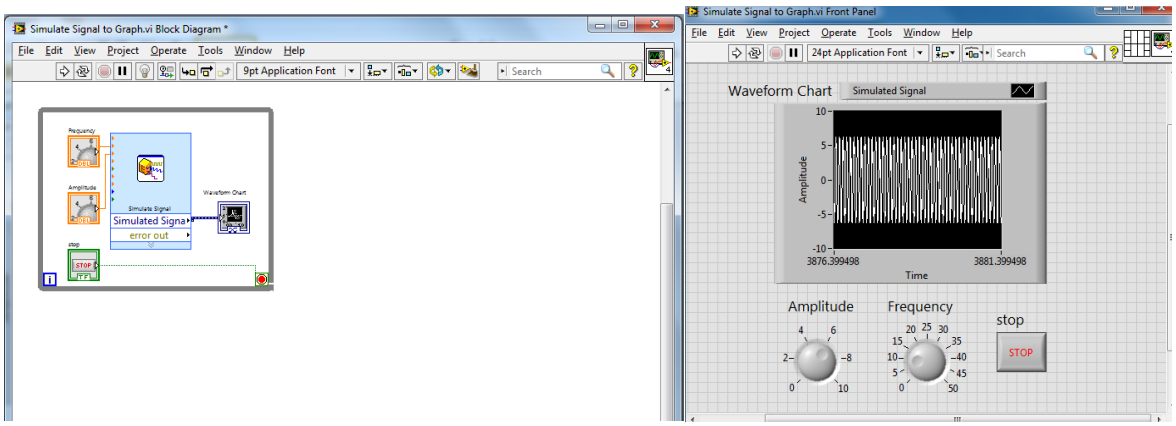
[2] D.H.Horrocks, “Feedback Circuits and Operational Amplifiers”, Van Nost. Reinhold, 1990

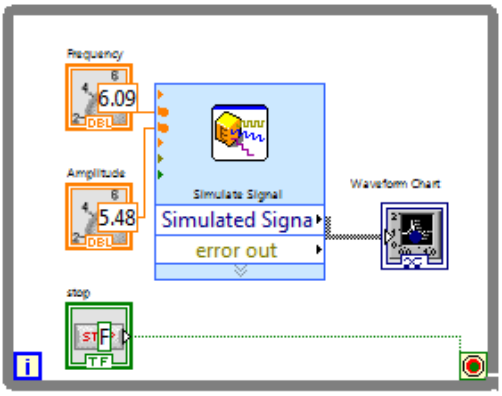
[3] Franco.S, “Design With Operational Amplifiers and Analog Integrated Circuits”, 3ed, Mcgraw-Hill College, 2002

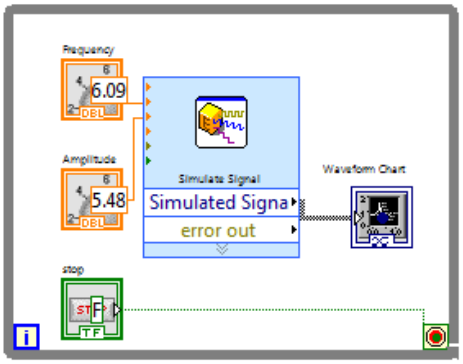
[4] Theodore.F, “Introduction to Digital Circuits: Lab Manual”, McGraw-Hill Inc., 1992

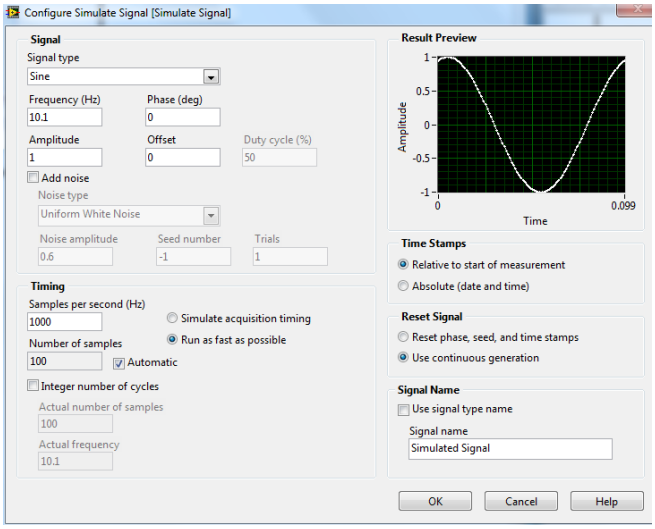
Appendix

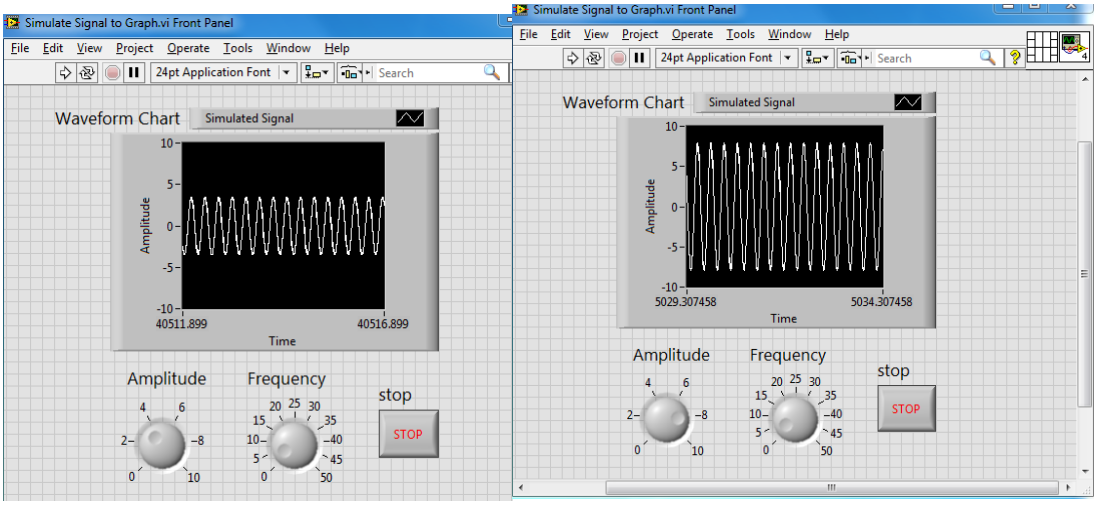
Week3







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Time
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40516.899
Amplitude
Frequency
stop
STOP
Simulate Signal to Graph.vi Front Panel
File Edit View Project Operate Tools Window Help
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Frequency
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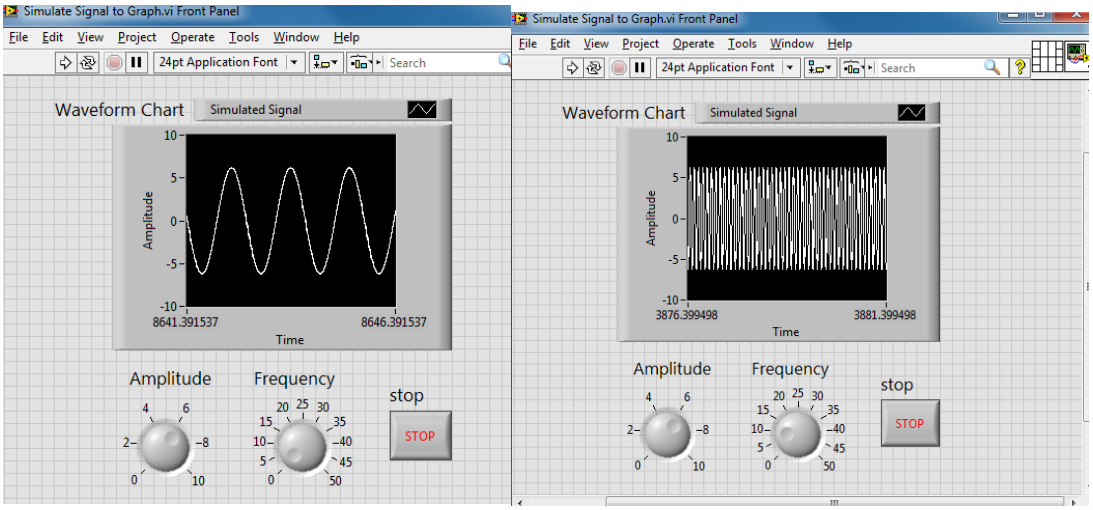
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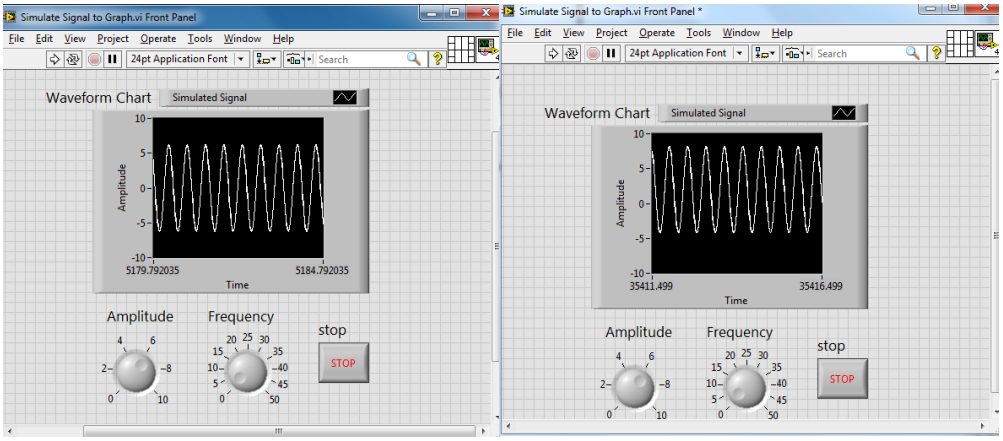
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Frequency
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Frequency
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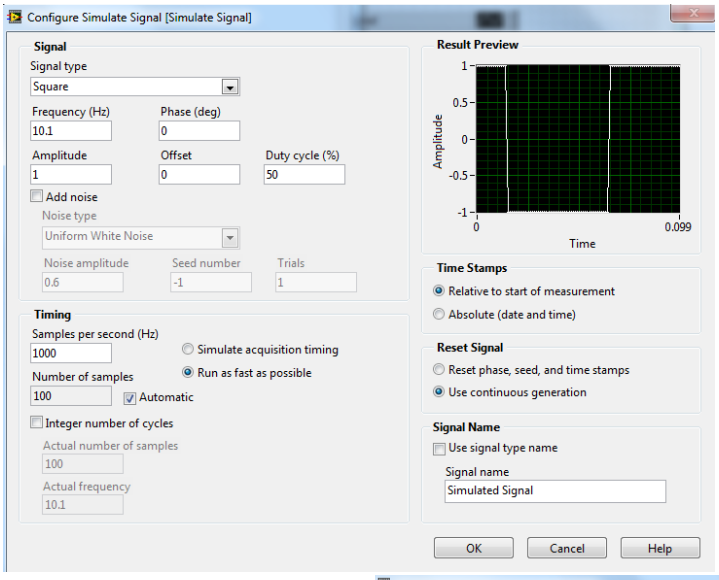
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Noise type
Uniform White Noise
Noise amplitude
0.6
Seed number
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Trials
1
Timing
Samples per second (Hz)
1000
Simulate acquisition timing
Run as fast as possible
Number of samples
100
Automatic
Integer number of cycles
Actual number of samples
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Actual frequency
10.1
Result Preview
Amplitude
Time
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Time Stamps
Relative to start of measurement
Absolute (date and time)
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Signal Name
Use signal type name
Signal name
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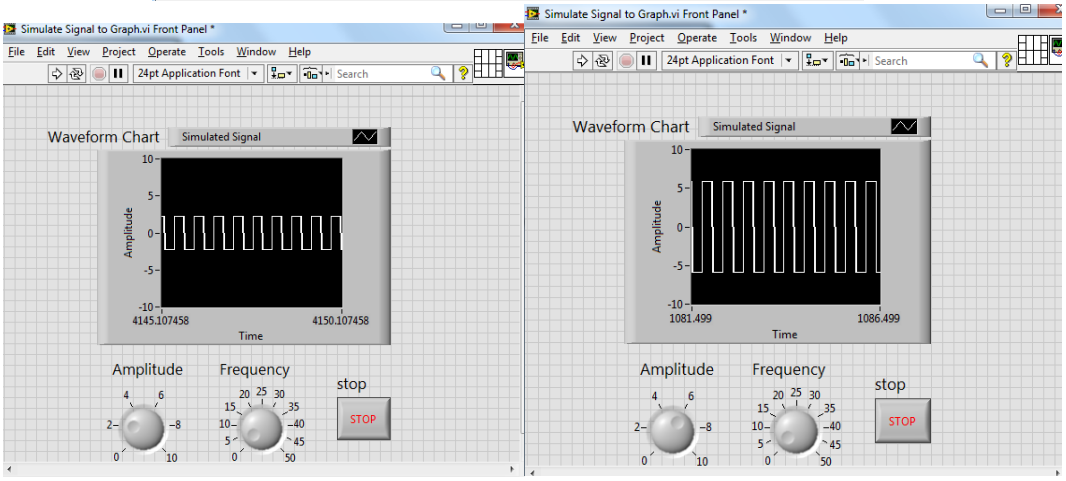
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Frequency
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Frequency
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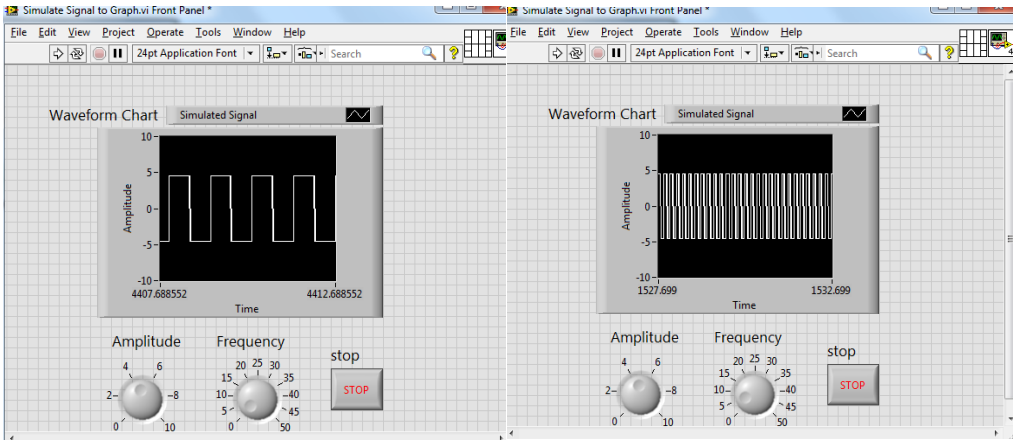
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Frequency
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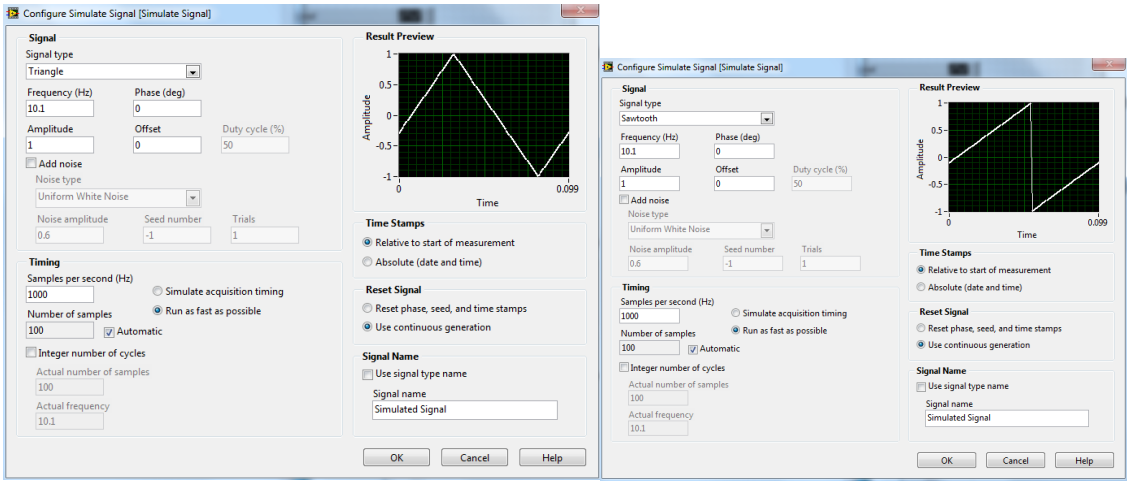
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Duty cycle (%)
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Noise type
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Noise amplitude
0.6
Seed number
-1
Trials
1
Timing
Samples per second (Hz)
1000
Simulate acquisition timing
Number of samples
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Run as fast as possible
Automatic
Integer number of cycles
Actual number of samples
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Actual frequency
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Result Preview
Amplitude
Time
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Time Stamps
Relative to start of measurement
Absolute (date and time)
Reset Signal
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Signal Name
Use signal type name
Signal name
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OK
Cancel
Help
Configure Simulate Signal [Simulate Signal]
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Signal type
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Frequency (Hz)
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Trials
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Timing
Samples per second (Hz)
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Run as fast as possible
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Actual frequency
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Result Preview
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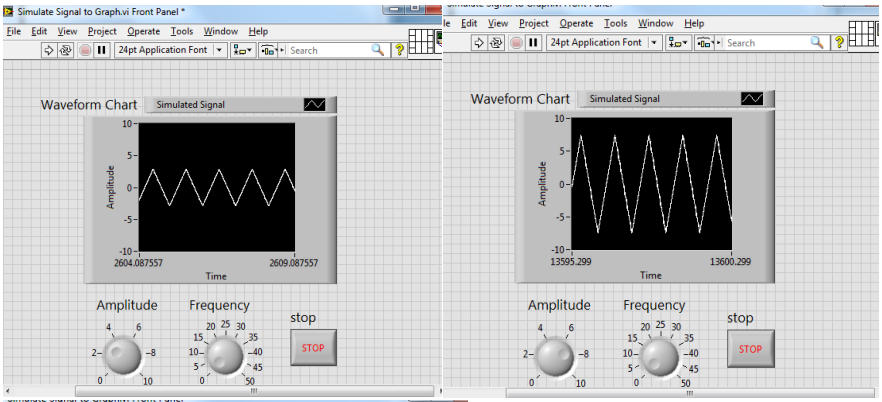
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Amplitude
Frequency
stop
STOP
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Frequency
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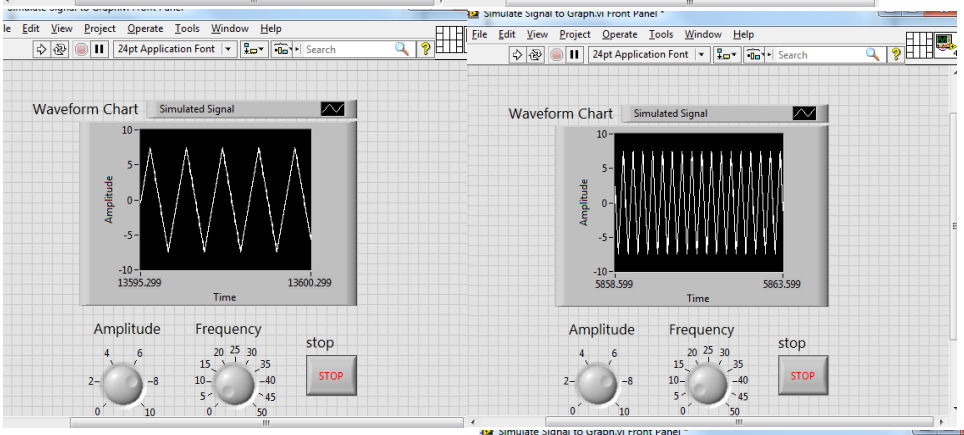
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Amplitude
Frequency
stop
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Amplitude
Frequency
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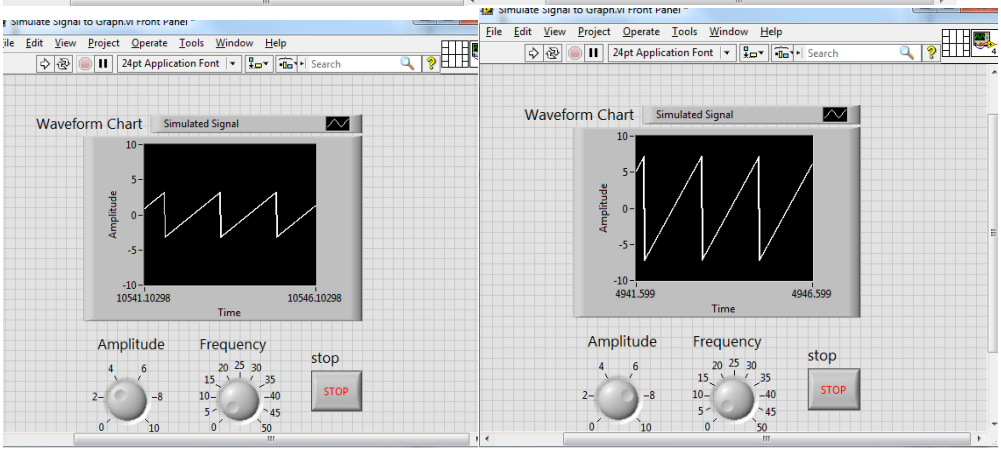
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Time
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Amplitude
Frequency
stop
STOP
Simulate Signal to Graph.vi Front Panel *
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Frequency
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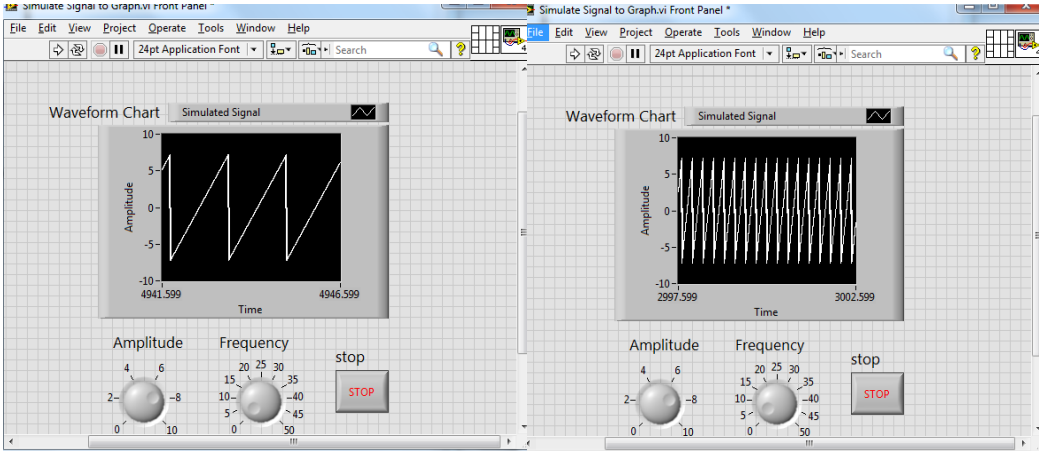
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Frequency
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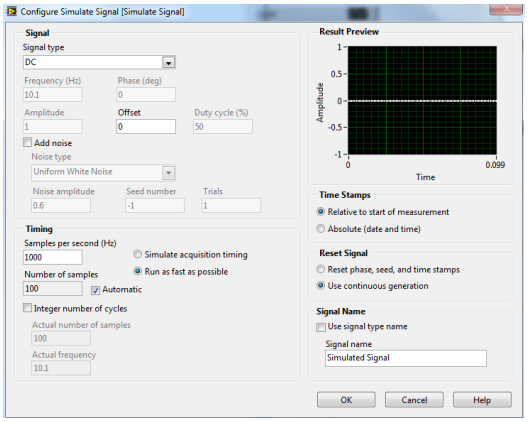
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Signal type
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Frequency (Hz)
Phase (deg)
Amplitude
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Duty cycle (%)
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Noise type
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Noise amplitude
Seed number
Trials
Timing
Samples per second (Hz)
Simulate acquisition timing
Number of samples
Run as fast as possible
Automatic
Integer number of cycles
Actual number of samples
Actual frequency
Result Preview
Time Stamps
Relative to start of measurement
Absolute (date and time)
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Signal name
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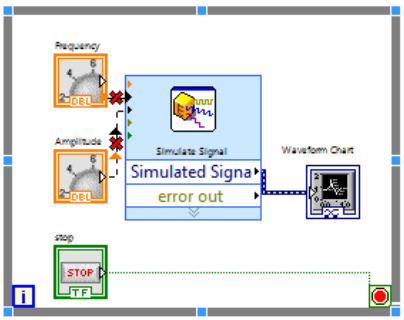
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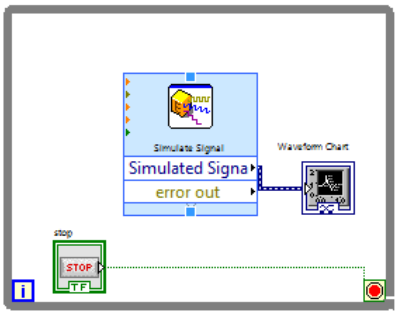
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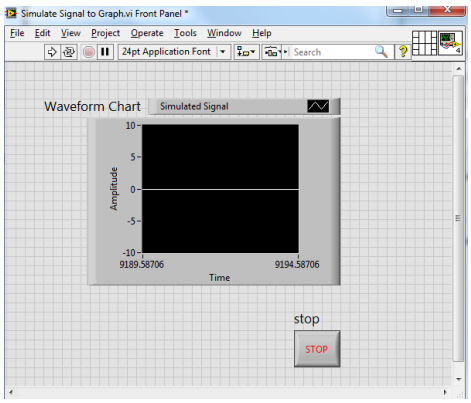
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Time
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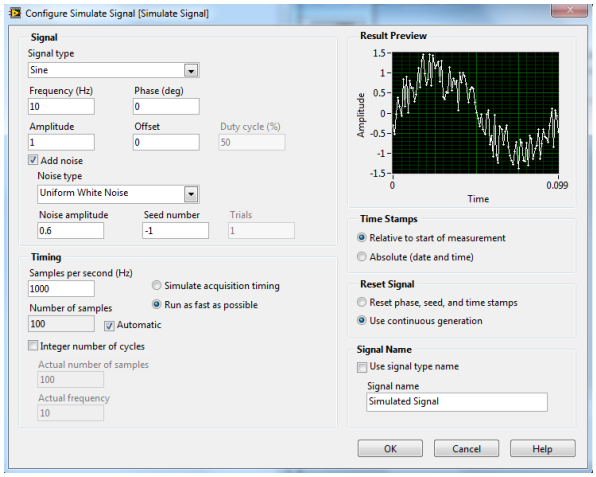
STOP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Noise amplitude
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Trials
1
Timing
Samples per second (Hz)
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Simulate acquisition timing
Run as fast as possible
Number of samples
100
Automatic
Integer number of cycles
Actual number of samples
100
Actual frequency
10
Result Preview
Amplitude
Time
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Time Stamps
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Use continuous generation
Signal Name
Use signal type name
Signal name
Simulated Signal
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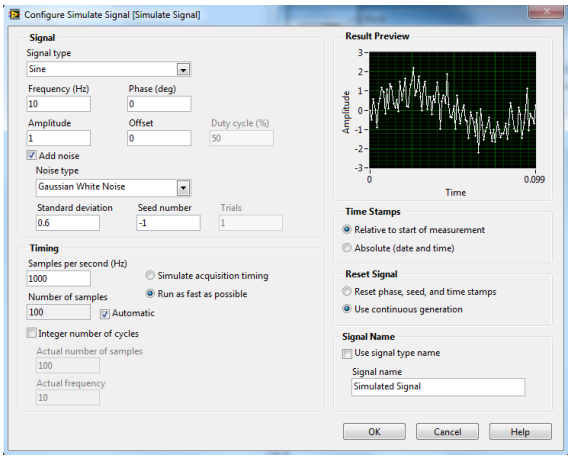
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Offset
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Standard deviation
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Seed number
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Trials
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Timing
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Simulate acquisition timing
Run as fast as possible
Number of samples
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Actual frequency
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Result Preview
Amplitude
Time
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Time Stamps
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Absolute (date and time)
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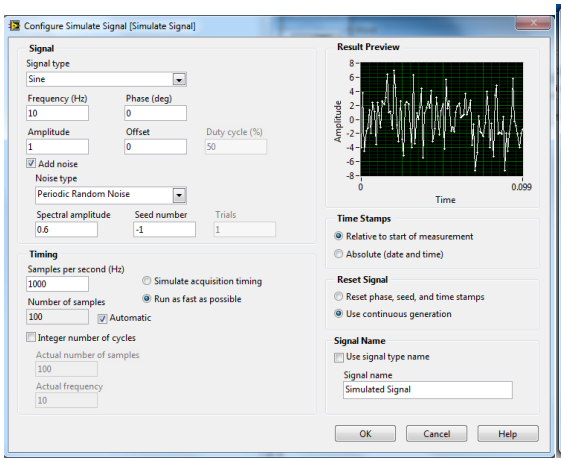
Signal Name
Use signal type name
Signal name
Simulated Signal
OK
Cancel
Help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Frequency (Hz)
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Phase (deg)
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Amplitude
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Offset
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Duty cycle (%)
50
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Noise type
Periodic Random Noise
Spectral amplitude
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Seed number
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Trials
1
Timing
Samples per second (Hz)
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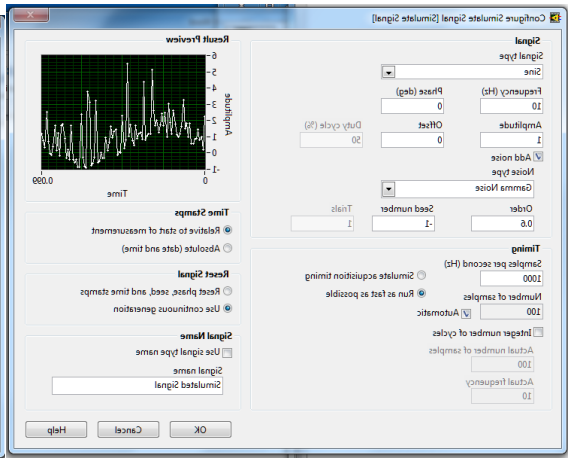
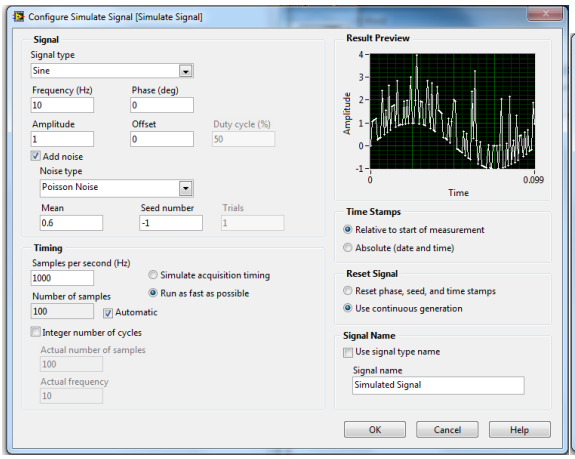
Simulate acquisition timing
Run as fast as possible
Number of samples
100
Automatic
Integer number of cycles
Actual number of samples
100
Actual frequency
10
Result Preview
Amplitude
Time
0.099
Time Stamps
Relative to start of measurement
Absolute (date and time)
Reset Signal
Reset phase, seed, and time stamps
Use continuous generation
Signal Name
Use signal type name
Signal name
Simulated Signal
OK
Cancel
Help




Configure Simulate Signal [Simulate Signal]
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Signal type
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Phase (deg)
0
Amplitude
1
Offset
0
Duty cycle (%)
50
Add noise
Noise type
Poisson Noise
Mean
0.6
Seed number
-1
Trials
1
Timing
Samples per second (Hz)
1000
Simulate acquisition timing
Run as fast as possible
Number of samples
100
Automatic
Integer number of cycles
Actual number of samples
100
Actual frequency
10
Result Preview
Amplitude
Time
0.099
Time Stamps
Relative to start of measurement
Absolute (date and time)
Reset Signal
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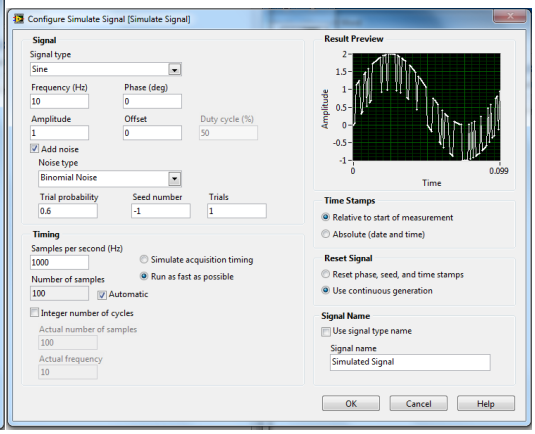
Use continuous generation
Signal Name
Use signal type name
Signal name
Simulated Signal
OK
Cancel
Help


Configure Simulate Signal [Simulate Signal]
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Frequency (Hz)
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Phase (deg)
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Amplitude
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Offset
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Duty cycle (%)
50
Add noise
Noise type
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Trial probability
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Seed number
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Trials
1
Timing
Samples per second (Hz)
1000
Simulate acquisition timing
Run as fast as possible
Number of samples
100
Automatic
Integer number of cycles
Actual number of samples
100
Actual frequency
10
Result Preview
Amplitude
Time
0.099
Time Stamps
Relative to start of measurement
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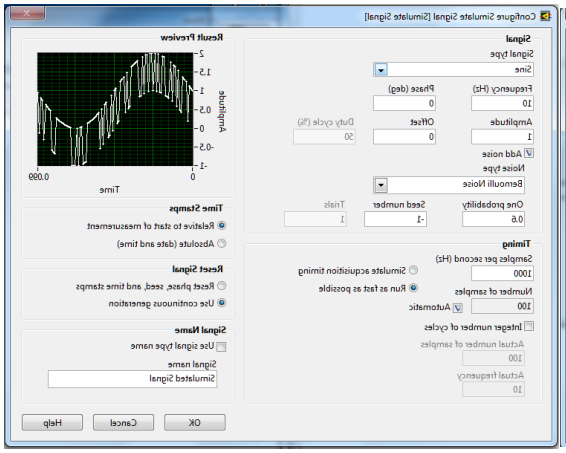
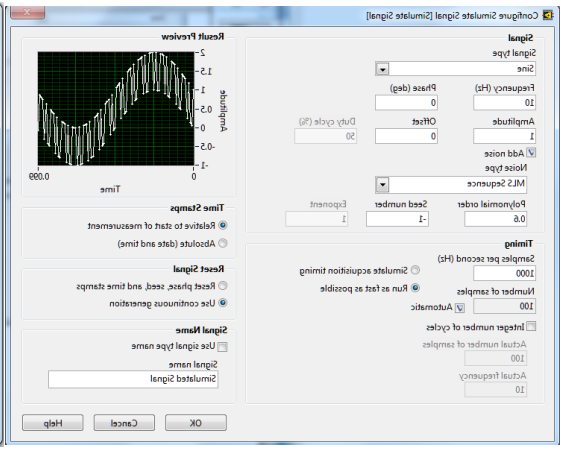
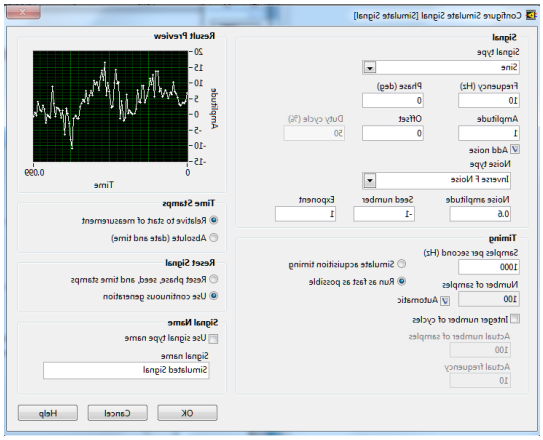
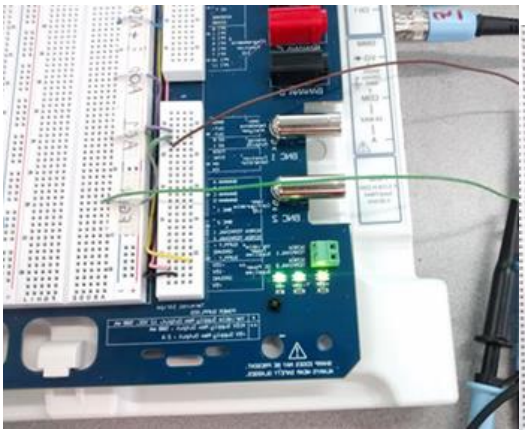
Reset Signal
Reset phase, seed, and time stamps
Use continuous generation
Signal Name
Use signal type name
Signal name
Simulated Signal
OK
Cancel
Help

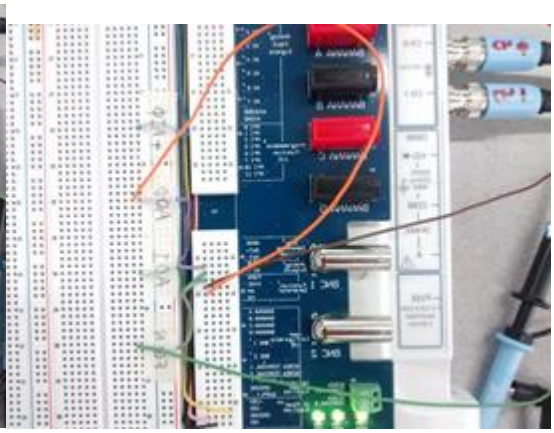


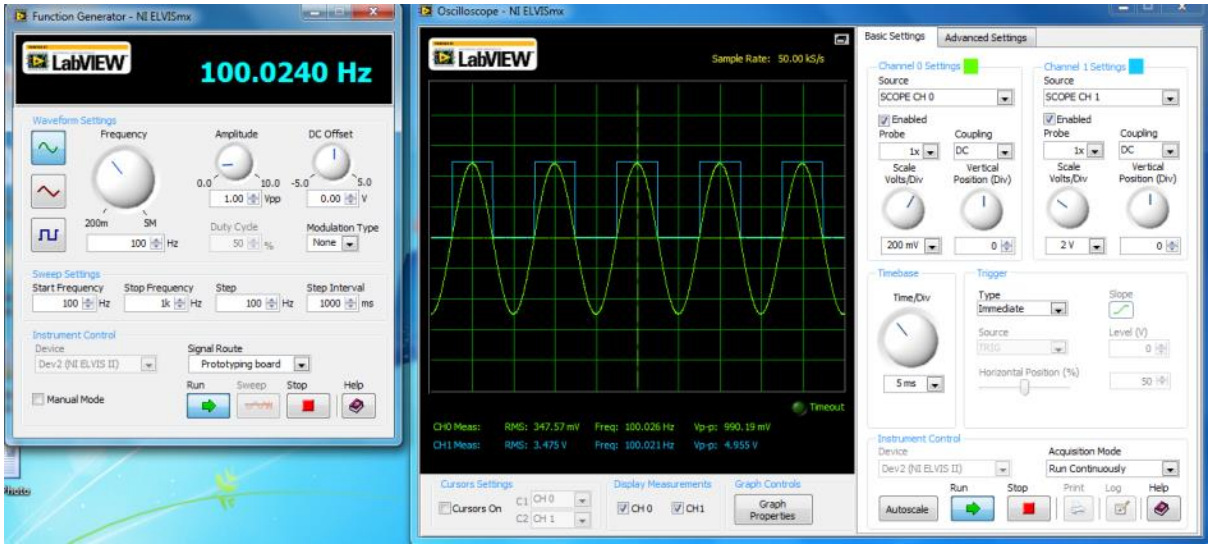


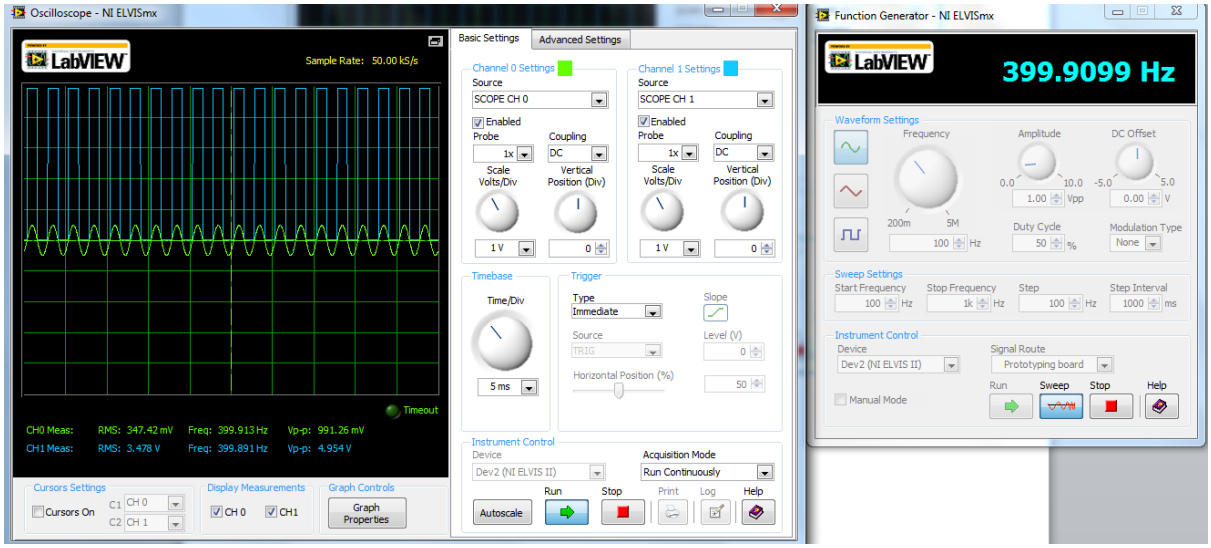


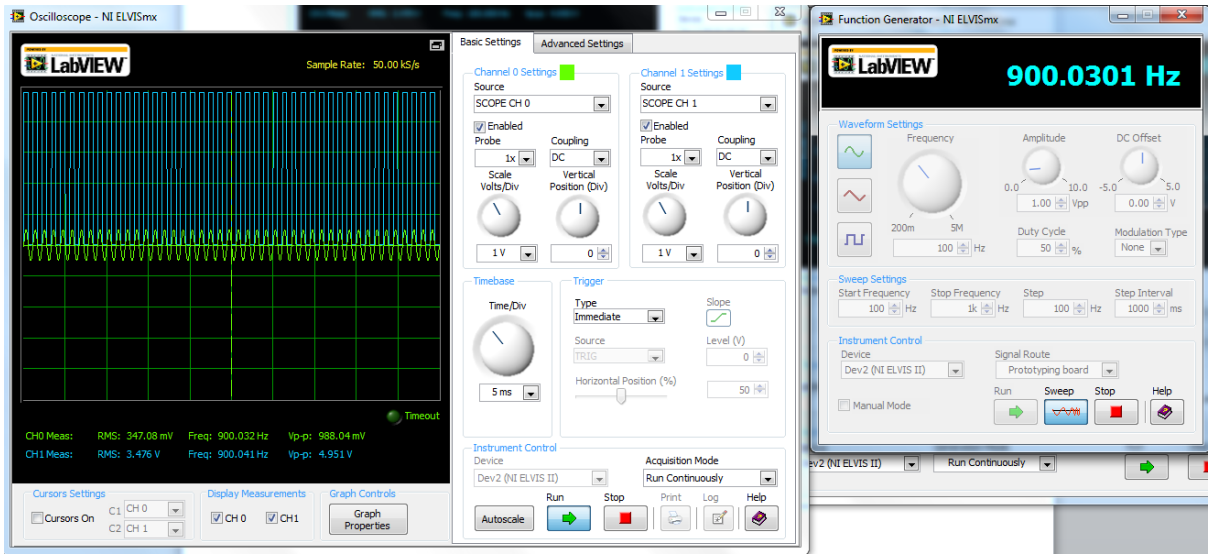
Week 4

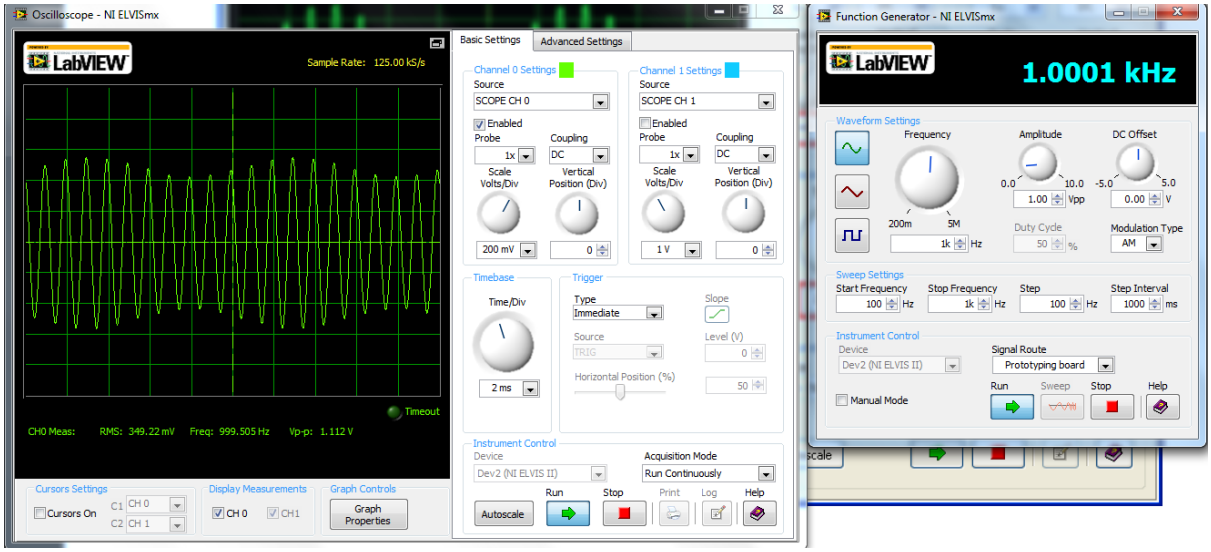





Function Generator - NI ELVISmx
LabVIEW
100.0240 Hz
Waveform Settings
Frequency
Amplitude
DC Offset
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
Instrument Control
Device
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help
Oscilloscope - NI ELVISmx
Sample Rate: 50.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Enabled
Probe
Coupling
Scale Volts/Div
Vertical Position (Div)
Timebase
Time/Div
Trigger
Type
Immediate
Source
Slope
Level (V)
Horizontal Position (%)
Acquisition Mode
Run Continuously
Autoscale
Print
Log
Timeout
CH0 Meas: RMS: 347.57 mV Freq: 100.026 Hz Vp-p: 990.19 mV
CH1 Meas: RMS: 3.475 V Freq: 100.021 Hz Vp-p: 4.955 V
Cursors Settings
Cursors On
Display Measurements
Graph Controls
Graph Properties

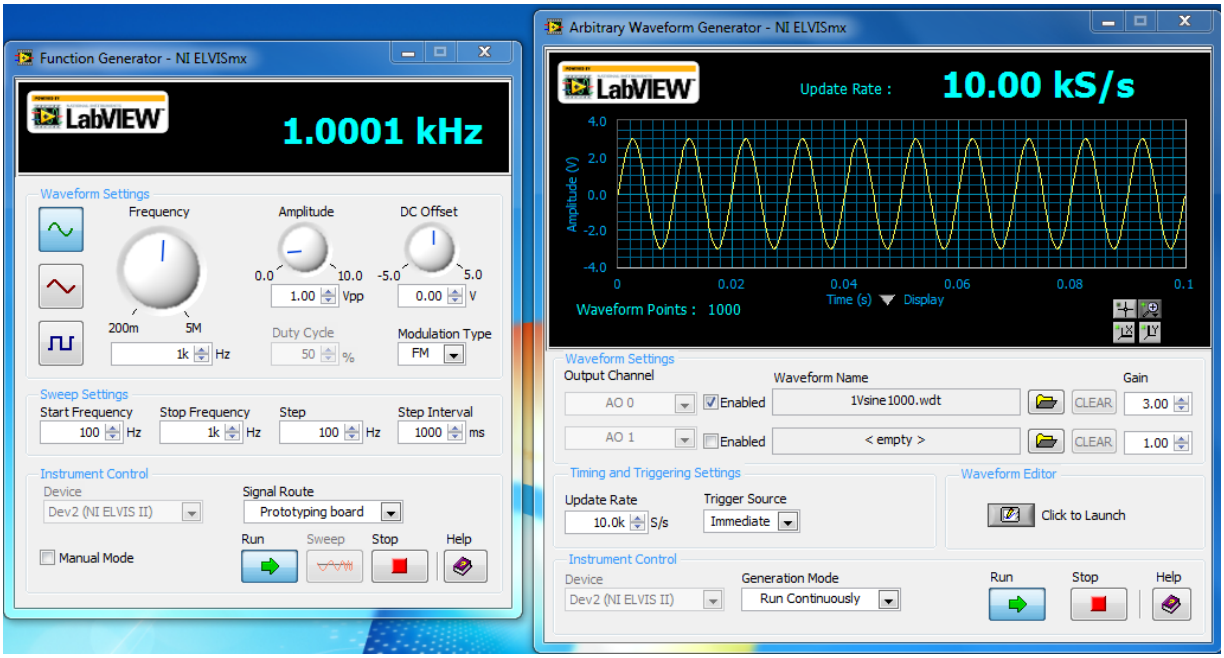

Oscilloscope - NI ELVISmx
Function Generator - NI ELVISmx
LabVIEW
Sample Rate: 50.00 kS/s
399.9099 Hz
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Timebase
Trigger
Instrument Control
Acquisition Mode
Run Continuously
Autoscale
Timeout
CH0 Meas: RMS: 347.42 mV Freq: 399.913 Hz Vp-p: 991.26 mV
CH1 Meas: RMS: 3.478 V Freq: 399.891 Hz Vp-p: 4.954 V
Cursors Settings
Display Measurements
Graph Controls
Graph Properties
Waveform Settings
Sweep Settings
Manual Mode

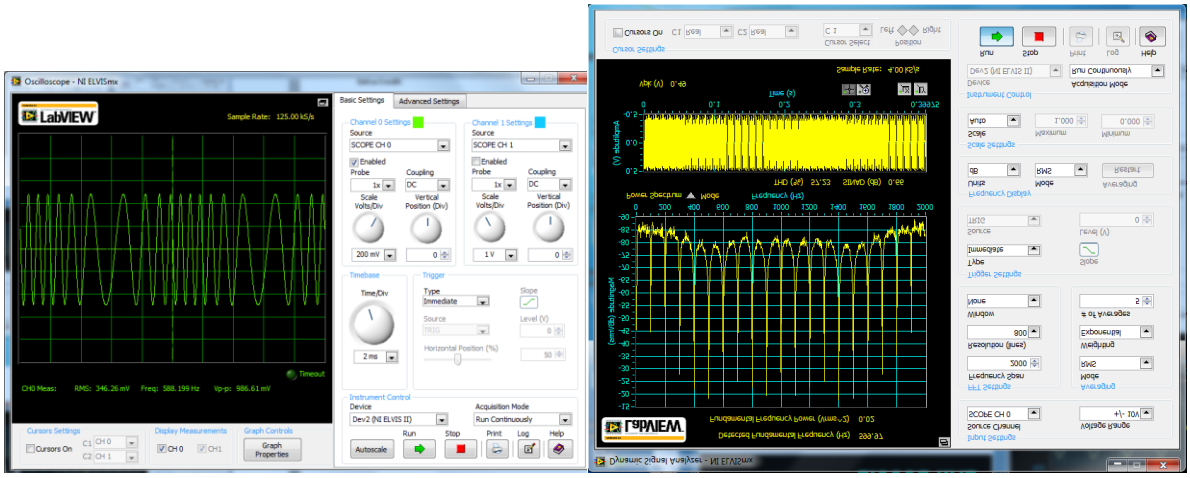

Oscilloscope - NI ELVISmx
Function Generator - NI ELVISmx
LabVIEW
Sample Rate: 50.00 kS/s
900.0301 Hz
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Timebase
Trigger
Instrument Control
Acquisition Mode
Run Continuously
Autoscale
Timeout
CH0 Meas: RMS: 347.08 mV Freq: 900.032 Hz Vp-p: 988.04 mV
CH1 Meas: RMS: 3.476 V Freq: 900.041 Hz Vp-p: 4.951 V
Cursors Settings
Display Measurements
Graph Controls
Graph Properties
Waveform Settings
Sweep Settings
Manual Mode

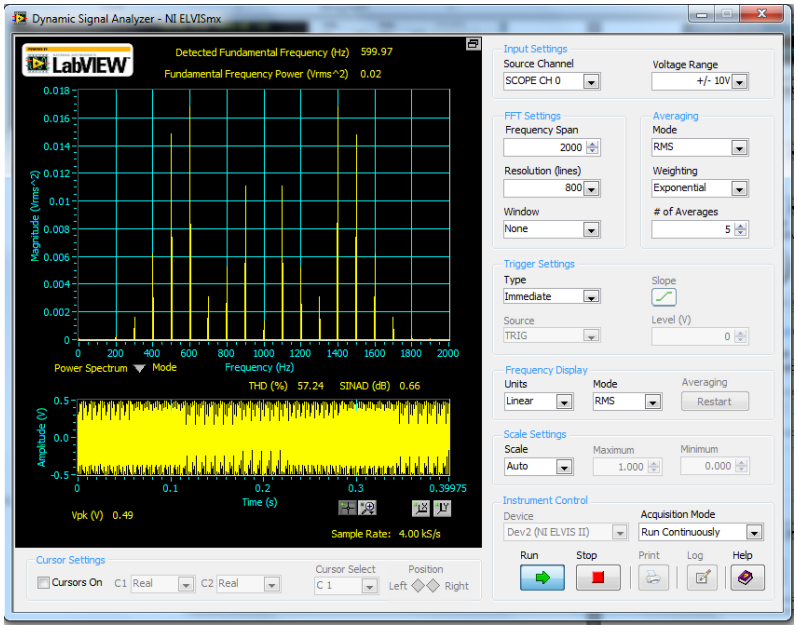

Oscilloscope - NI ELVISmx
Sample Rate: 125.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Timeout
CH0 Meas: RMS: 349.22 mV Freq: 999.505 Hz Vp-p: 1.112 V
Function Generator - NI ELVISmx
1.0001 kHz
Waveform Settings
Frequency
Amplitude
DC Offset
Sweep Settings
Instrument Control
Signal Route
Prototyping board
Manual Mode

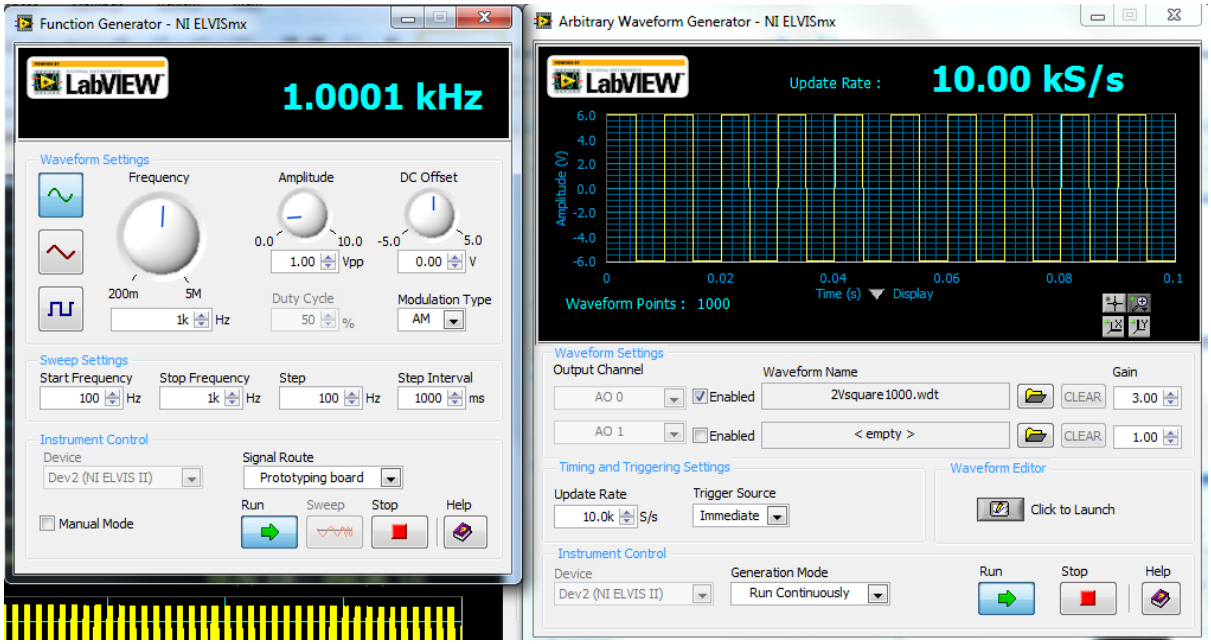

Arbitrary Waveform Generator - NI ELVISmx
Update Rate : 10.00 kS/s
Waveform Points : 1000
Dynamic Signal Analyzer - NI ELVISmx
Detected Fundamental Frequency (Hz) 1000.06
Fundamental Frequency Power (Vrms^2) 12.52
Power Spectrum
THD (%) 0.00 SINAD (dB) 23.07
Sample Rate: 4.00 kS/s

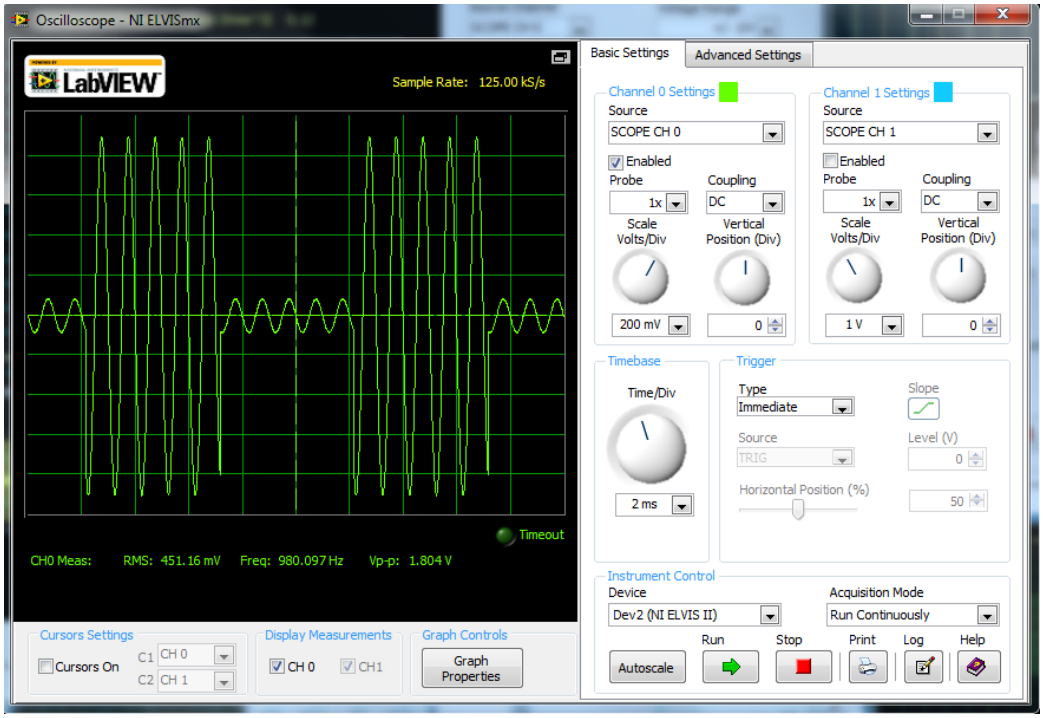

Arbitrary Waveform Generator - NI ELVISmx
Update Rate : 10.00 kS/s
Waveform Points : 1000
Dynamic Signal Analyzer - NI ELVISmx
Detected Fundamental Frequency (Hz) 1000.06
Fundamental Frequency Power (Vrms^2) 12.52
Power Spectrum
THD (%) 0.00 SINAD (dB) 23.06
Sample Rate: 4.00 kS/s

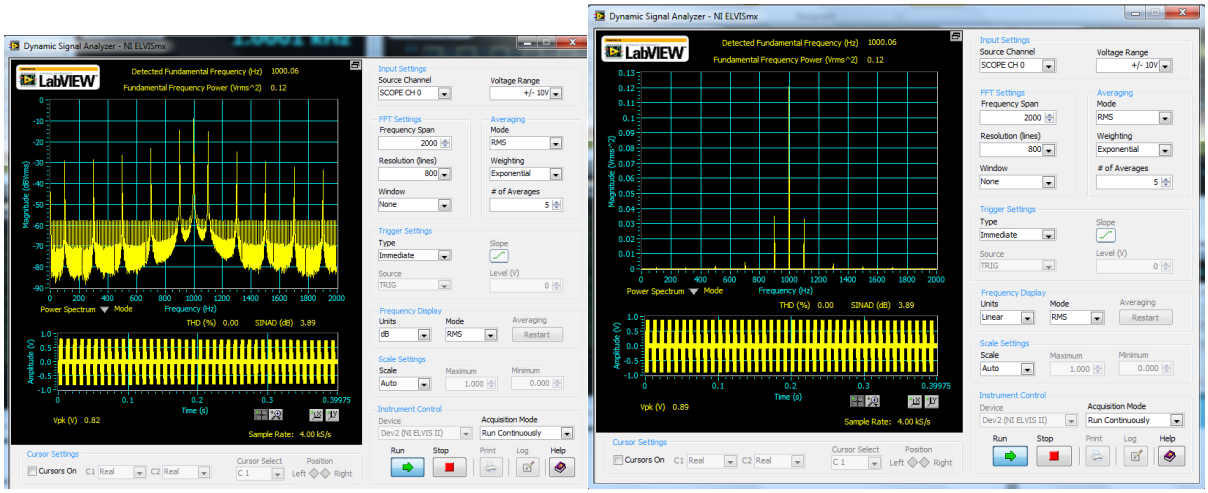

Function Generator - NI ELVISmx
LabVIEW
1.0001 kHz
Waveform Settings
Frequency
Amplitude
DC Offset
1.00 Vpp
0.00 V
1k Hz
Duty Cycle
50 %
Modulation Type
FM
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
100 Hz
1k Hz
100 Hz
1000 ms
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help
Arbitrary Waveform Generator - NI ELVISmx
LabVIEW
Update Rate :
10.00 kS/s
Amplitude (V)
Time (s)
Display
Waveform Points : 1000
Waveform Settings
Output Channel
Waveform Name
Gain
AO 0
Enabled
1Vsine1000.wdt
CLEAR
3.00
AO 1
Enabled
< empty >
CLEAR
1.00
Timing and Triggering Settings
Update Rate
10.0k S/s
Trigger Source
Immediate
Waveform Editor
Click to Launch
Instrument Control
Device
Dev2 (NI ELVIS II)
Generation Mode
Run Continuously
Run
Stop
Help

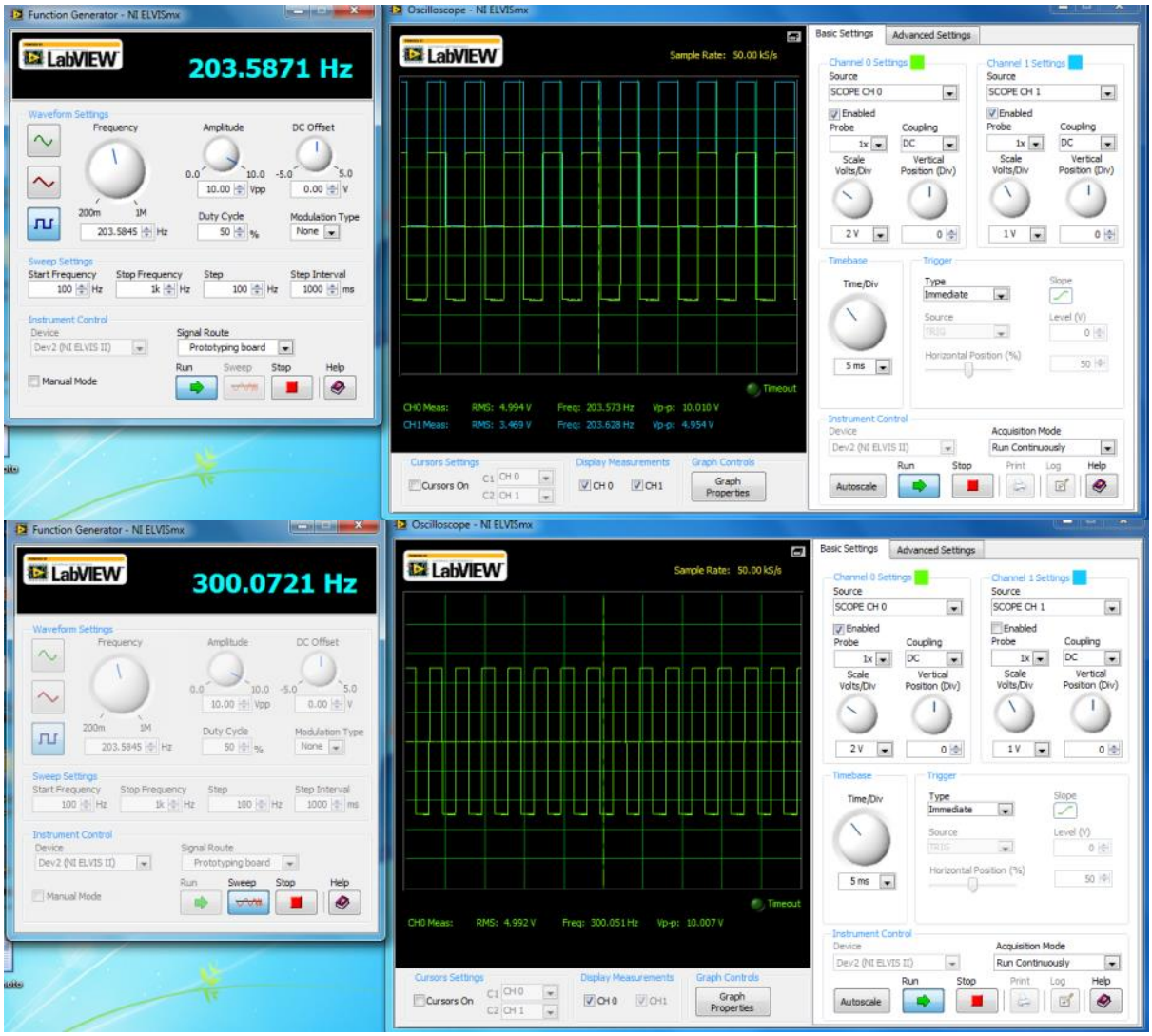

Oscilloscope - NI ELVISmx
LabVIEW
Basic Settings
Advanced Settings
Dynamic Signal Analyzer - NI ELVISmx

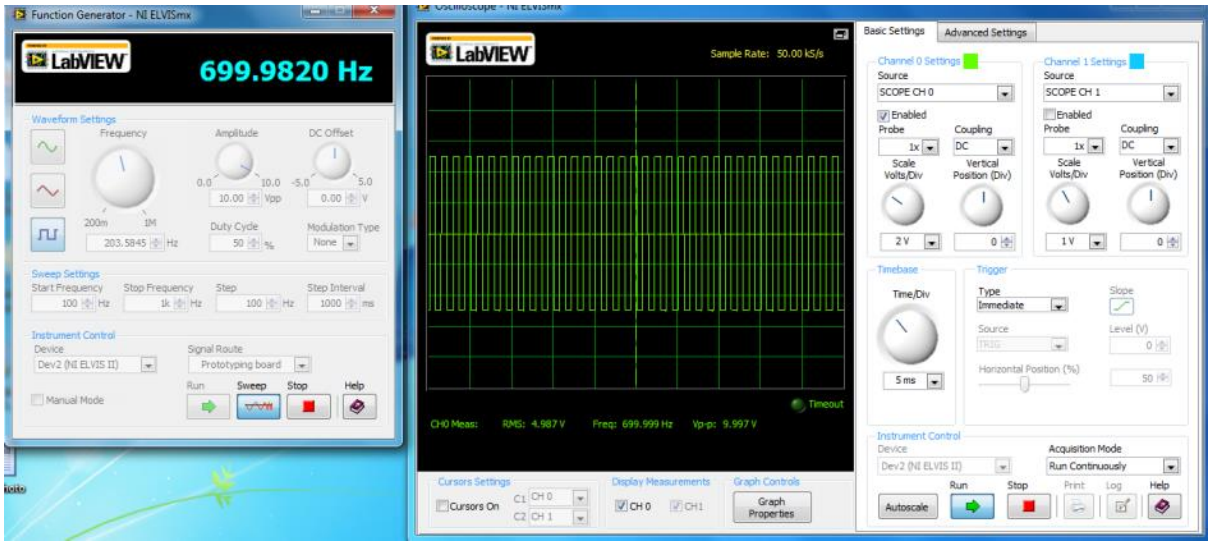

Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 599.97
Fundamental Frequency Power (Vrms^2) 0.02
Power Spectrum
Mode
Frequency (Hz)
THD (%) 57.24
SINAD (dB) 0.66
Amplitude (V)
Time (s)
Vpk (V) 0.49
Sample Rate: 4.00 kS/s
Input Settings
Source Channel
SCOPE CH 0
Voltage Range
+/- 10V
FFT Settings
Frequency Span
2000
Resolution (lines)
800
Window
None
Averaging
Mode
RMS
Weighting
Exponential
# of Averages
5
Trigger Settings
Type
Immediate
Source
TRIG
Slope
Level (V)
Frequency Display
Units
Linear
Mode
RMS
Averaging
Restart
Scale Settings
Scale
Auto
Maximum
1.000
Minimum
0.000
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Run
Stop
Print
Log
Help
Cursor Settings
Cursors On
C1 Real
C2 Real
Cursor Select
C 1
Position
Left
Right

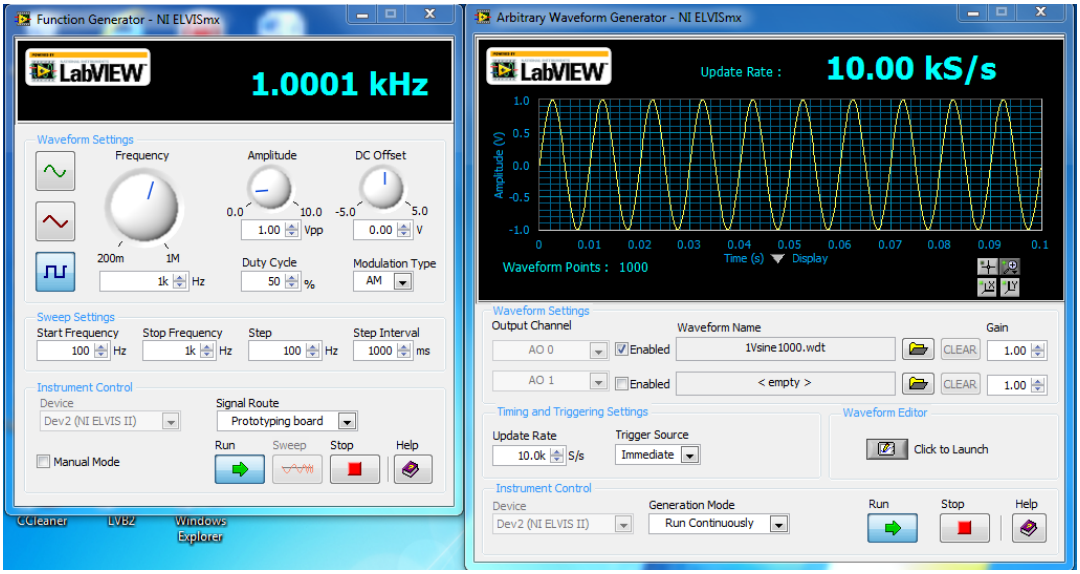

Function Generator - NI ELVISmx
LabVIEW
1.0001 kHz
Waveform Settings
Frequency
Amplitude
DC Offset
200m
5M
1k Hz
0.0
10.0
1.00 Vpp
-5.0
5.0
0.00 V
Duty Cycle
50 %
Modulation Type
AM
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
100 Hz
1k Hz
100 Hz
1000 ms
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help
Arbitrary Waveform Generator - NI ELVISmx
LabVIEW
Update Rate :
10.00 kS/s
Amplitude (V)
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
0
0.02
0.04
0.06
0.08
0.1
Time (s)
Display
Waveform Points : 1000
Waveform Settings
Output Channel
Waveform Name
Gain
AO 0
Enabled
2Vsquare1000.wdt
CLEAR
3.00
AO 1
Enabled
< empty >
CLEAR
1.00
Timing and Triggering Settings
Update Rate
10.0k S/s
Trigger Source
Immediate
Waveform Editor
Click to Launch
Instrument Control
Device
Dev2 (NI ELVIS II)
Generation Mode
Run Continuously
Run
Stop
Help

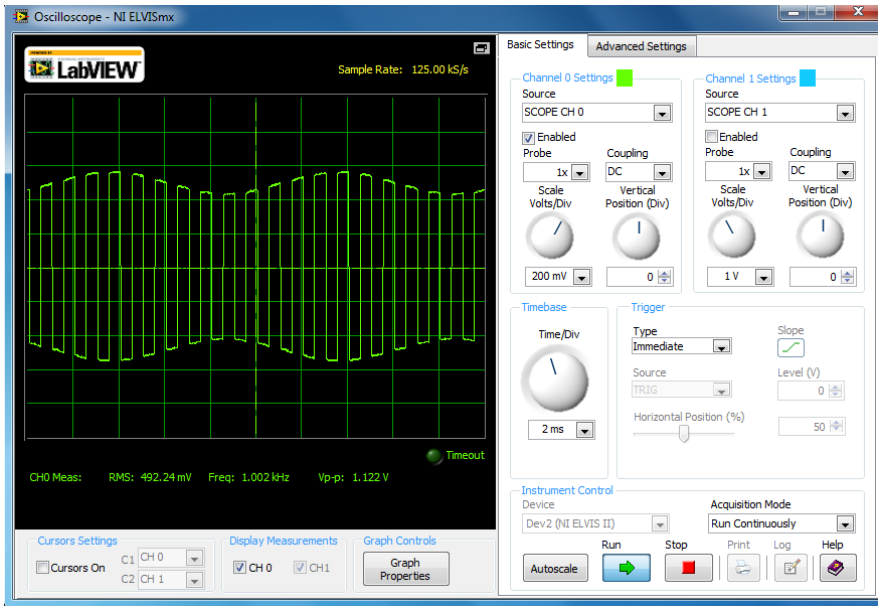

Oscilloscope - NI ELVISmx
LabVIEW
Sample Rate: 125.00 kS/s
Timeout
CH0 Meas:
RMS: 451.16 mV
Freq: 980.097 Hz
Vp-p: 1.804 V
Basic Settings
Advanced Settings
Channel 0 Settings
Source
SCOPE CH 0
Enabled
Probe
Coupling
1x
DC
Scale Volts/Div
Vertical Position (Div)
200 mV
0
Channel 1 Settings
Source
SCOPE CH 1
Enabled
Probe
Coupling
1x
DC
Scale Volts/Div
Vertical Position (Div)
1 V
0
Timebase
Time/Div
2 ms
Trigger
Type
Immediate
Slope
Source
TRIG
Level (V)
0
Horizontal Position (%)
50
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Autoscale
Run
Stop
Print
Log
Help
Cursors Settings
Cursors On
C1 CH 0
C2 CH 1
Display Measurements
CH 0
CH1
Graph Controls
Graph Properties

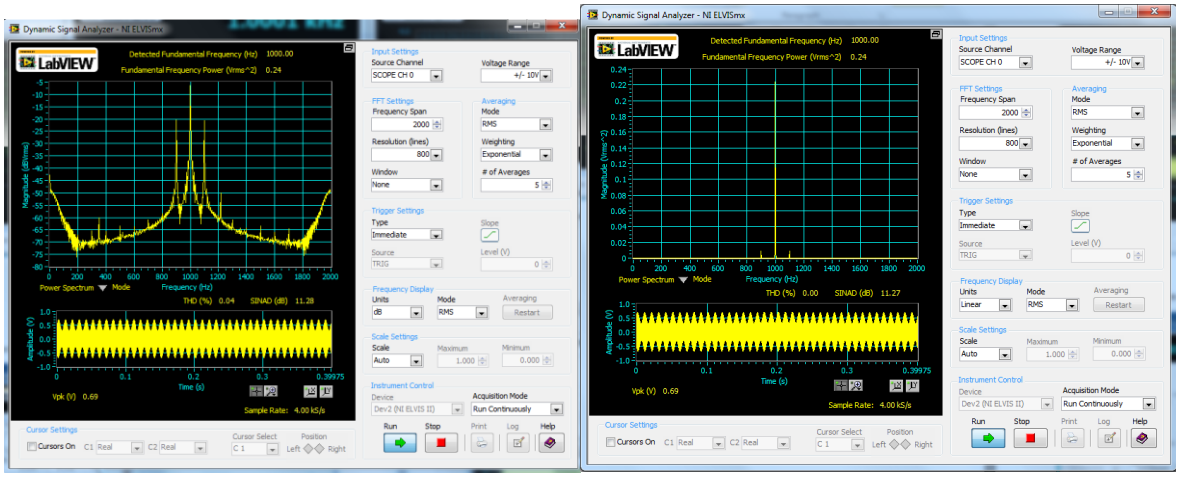

Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 1000.06
Fundamental Frequency Power (Vrms^2) 0.12
Power Spectrum
Frequency (Hz)
THD (%) 0.00
SINAD (dB) 3.89
Time (s)
Sample Rate: 4.00 kS/s
Input Settings
Source Channel
SCOPE CH 0
Voltage Range
+/- 10V
FFT Settings
Frequency Span
2000
Resolution (lines)
800
Window
None
Averaging
Mode
RMS
Weighting
Exponential
# of Averages
5
Trigger Settings
Type
Immediate
Source
TRIG
Slope
Level (V)
Frequency Display
Units
dB
Mode
RMS
Averaging
Restart
Scale Settings
Scale
Auto
Maximum
1.000
Minimum
0.000
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Run
Stop
Print
Log
Help
Cursor Settings
Cursors On
C1 Real
C2 Real
Cursor Select
Position
Left
Right

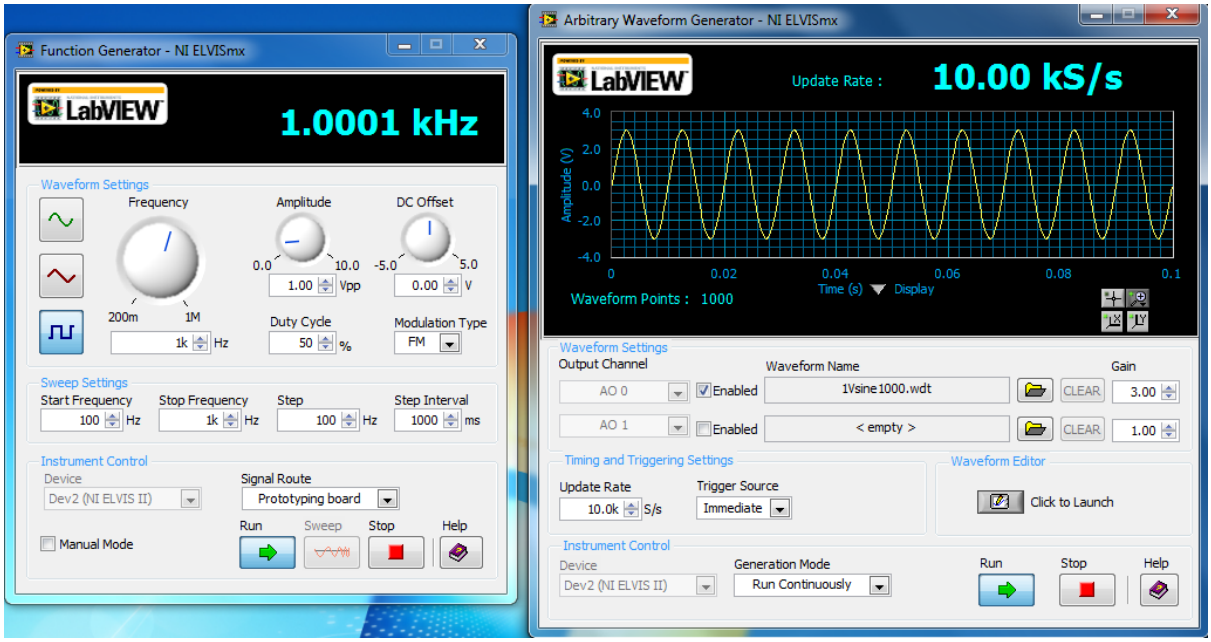

Function Generator - NI ELVISmx
LabVIEW
203.5871 Hz
Waveform Settings
Frequency
Amplitude
DC Offset
10.00 Vpp
0.00 V
203.5845 Hz
Duty Cycle
50 %
Modulation Type
None
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
100 Hz
1k Hz
100 Hz
1000 ms
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help
Oscilloscope - NI ELVISmx
Sample Rate: 50.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
Source
SCOPE CH 0
SCOPE CH 1
Enabled
Probe
Coupling
DC
Scale Volts/Div
Vertical Position (Div)
2 V
1 V
Timebase
Time/Div
5 ms
Trigger
Type
Immediate
Slope
Level (V)
Horizontal Position (%)
Timeout
CH0 Meas: RMS: 4.994 V Freq: 203.573 Hz Vp-p: 10.010 V
CH1 Meas: RMS: 3.469 V Freq: 203.628 Hz Vp-p: 4.954 V
Cursors Settings
Cursors On
Display Measurements
Graph Controls
Graph Properties
Autoscale
Function Generator - NI ELVISmx
300.0721 Hz
Oscilloscope - NI ELVISmx
CH0 Meas: RMS: 4.992 V Freq: 300.051 Hz Vp-p: 10.007 V

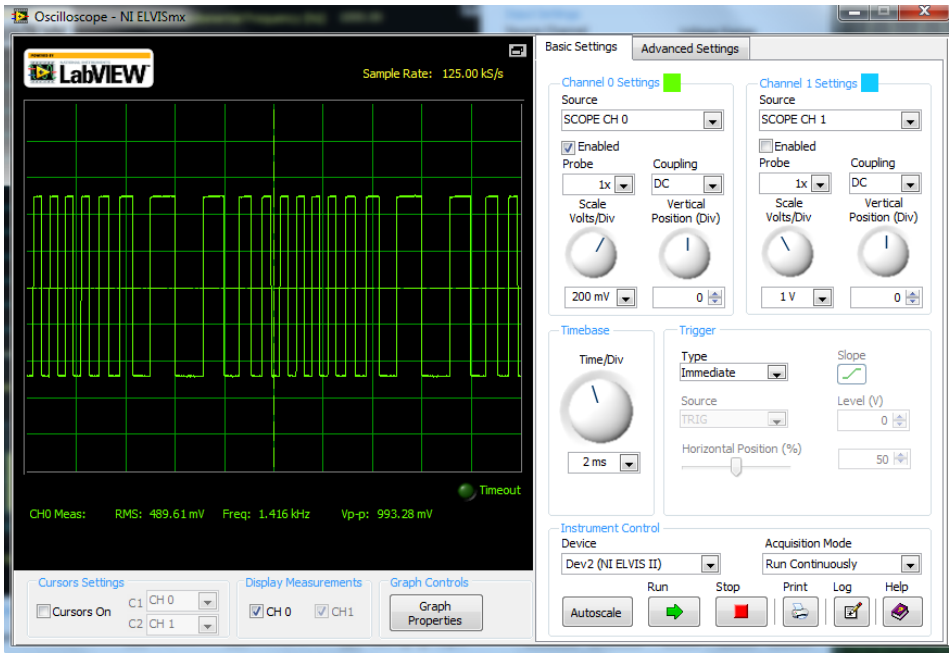

Function Generator - NI ELVISmx
LabVIEW
699.9820 Hz
Waveform Settings
Frequency
Amplitude
DC Offset
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
Instrument Control
Device
Signal Route
Prototyping board
Run
Sweep
Stop
Help
Manual Mode
Sample Rate: 50.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Enabled
Probe
Coupling
Scale Volts/Div
Vertical Position (Div)
Timebase
Time/Div
Trigger
Type
Immediate
Source
Level (V)
Horizontal Position (%)
Acquisition Mode
Run Continuously
Autoscale
Print
Log
Cursors Settings
Cursors On
Display Measurements
Graph Controls
Graph Properties
CH0 Meas:
RMS: 4.987 V
Freq: 699.999 Hz
Vp-p: 9.997 V
Timeout


Function Generator - NI ELVISmx
LabVIEW
1.0001 kHz
Waveform Settings
Frequency
Amplitude
DC Offset
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
Instrument Control
Device
Signal Route
Prototyping board
Run
Sweep
Stop
Help
Manual Mode
Arbitrary Waveform Generator - NI ELVISmx
Update Rate :
10.00 kS/s
Amplitude (V)
Time (s)
Display
Waveform Points : 1000
Output Channel
Waveform Name
Gain
AO 0
AO 1
Enabled
1Vsine1000.wdt
< empty >
CLEAR
Timing and Triggering Settings
Update Rate
Trigger Source
Immediate
Waveform Editor
Click to Launch
Generation Mode
Run Continuously

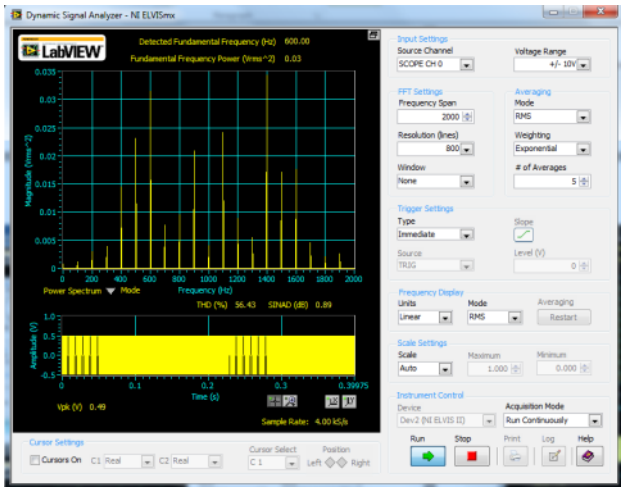

Oscilloscope - NI ELVISmx
LabVIEW
Sample Rate: 125.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Enabled
Probe
Coupling
Scale Volts/Div
Vertical Position (Div)
200 mV
1 V
Timebase
Time/Div
2 ms
Trigger
Type
Immediate
Source
Level (V)
Horizontal Position (%)
Instrument Control
Device
Acquisition Mode
Run Continuously
Autoscale
Run
Stop
Print
Log
Help
Timeout
CH0 Meas:
RMS: 492.24 mV
Freq: 1.002 kHz
Vp-p: 1.122 V
Cursors Settings
Cursors On
Display Measurements
Graph Controls
Graph Properties

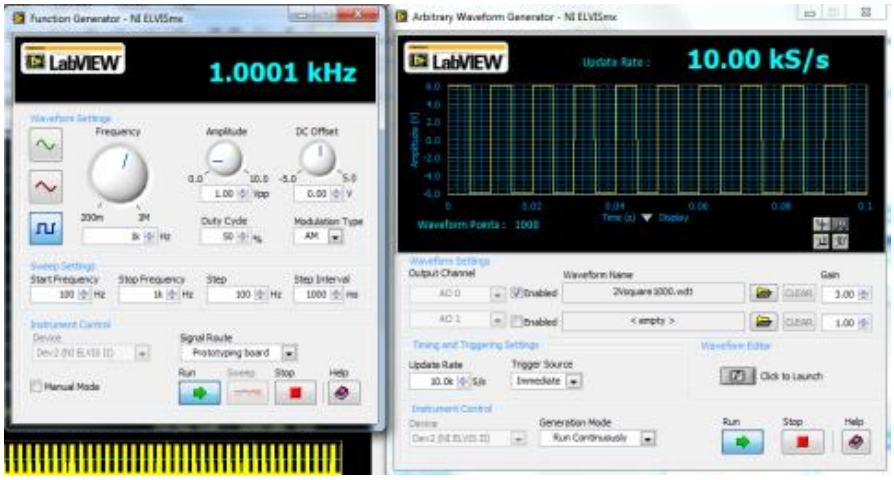

Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 1000.00
Fundamental Frequency Power (Vrms^2) 0.24
Power Spectrum
Frequency (Hz)
THD (%) 0.04
SINAD (dB) 11.28
Time (s)
Sample Rate: 4.00 kS/s
Input Settings
Source Channel
SCOPE CH 0
Voltage Range
+/- 10V
FFT Settings
Frequency Span
2000
Resolution (lines)
800
Window
None
Averaging
Mode
RMS
Weighting
Exponential
# of Averages
5
Trigger Settings
Type
Immediate
Source
TRIG
Slope
Level (V)
Frequency Display
Units
dB
Mode
RMS
Averaging
Restart
Scale Settings
Scale
Auto
Maximum
1.000
Minimum
0.000
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Run
Stop
Print
Log
Help
Cursor Settings
Cursors On
C1 Real
C2 Real
Cursor Select
Position
Left
Right

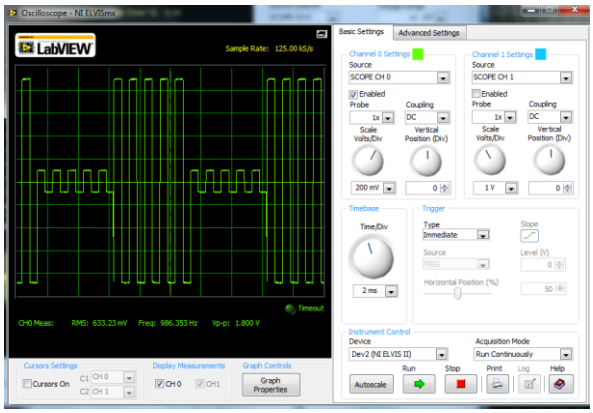

Function Generator - NI ELVISmx
LabVIEW
1.0001 kHz
Waveform Settings
Frequency
Amplitude
DC Offset
0.0
10.0
1.00 Vpp
-5.0
5.0
0.00 V
200m
1M
1k Hz
Duty Cycle
50 %
Modulation Type
FM
Sweep Settings
Start Frequency
100 Hz
Stop Frequency
1k Hz
Step
100 Hz
Step Interval
1000 ms
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help
Arbitrary Waveform Generator - NI ELVISmx
LabVIEW
Update Rate :
10.00 kS/s
Amplitude (V)
Time (s)
Display
Waveform Points : 1000
Waveform Settings
Output Channel
Waveform Name
Gain
AO 0
Enabled
1Vsine1000.wdt
CLEAR
3.00
AO 1
< empty >
1.00
Timing and Triggering Settings
Update Rate
10.0k S/s
Trigger Source
Immediate
Waveform Editor
Click to Launch
Instrument Control
Device
Dev2 (NI ELVIS II)
Generation Mode
Run Continuously
Run
Stop
Help

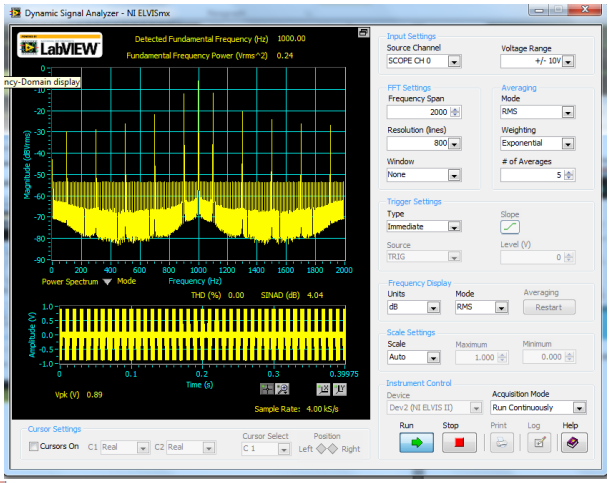

Oscilloscope - NI ELVISmx
LabVIEW
Sample Rate: 125.00 kS/s
Timeout
CH0 Meas:
RMS: 489.61 mV
Freq: 1.416 kHz
Vp-p: 993.28 mV
Basic Settings
Advanced Settings
Channel 0 Settings
Source
SCOPE CH 0
Enabled
Probe
1x
Coupling
DC
Scale Volts/Div
200 mV
Vertical Position (Div)
0
Channel 1 Settings
SCOPE CH 1
1 V
Timebase
Time/Div
2 ms
Trigger
Type
Immediate
Slope
Source
TRIG
Level (V)
Horizontal Position (%)
50
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Autoscale
Run
Stop
Print
Log
Help
Cursors Settings
Cursors On
C1 CH 0
C2 CH 1
Display Measurements
CH 0
CH1
Graph Controls
Graph Properties

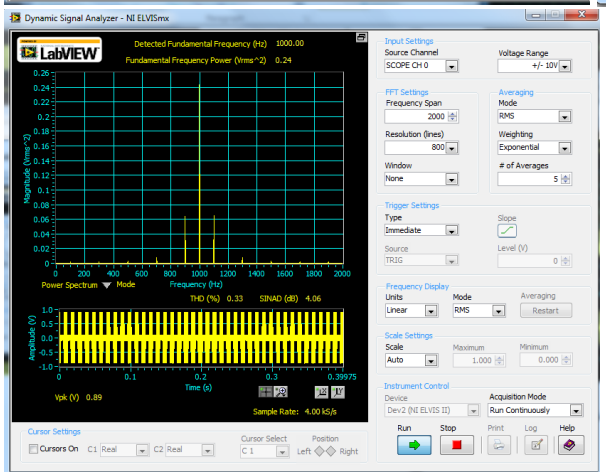

Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 499.96
Fundamental Frequency Power (Vrms^2) 0.04
Magnitude (dBVrms)
Power Spectrum
Mode
Frequency (Hz)
THD (%) 47.90
SINAD (dB) 1.01
Amplitude (V)
Time (s)
Vpk (V) 0.49
Sample Rate: 4.00 kS/s
Input Settings
Source Channel
SCOPE CH 0
Voltage Range
+/- 10V
FFT Settings
Frequency Span
2000
Resolution (lines)
800
Window
None
Averaging
Mode
RMS
Weighting
Exponential
# of Averages
5
Trigger Settings
Type
Immediate
Slope
Source
TRIG
Level (V)
Frequency Display
Units
dB
Mode
RMS
Averaging
Restart
Scale Settings
Scale
Auto
Maximum
1.000
Minimum
0.000
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Run
Stop
Print
Log
Help
Cursor Settings
Cursors On
C1 Real
C2 Real
Cursor Select
C 1
Position
Left
Right

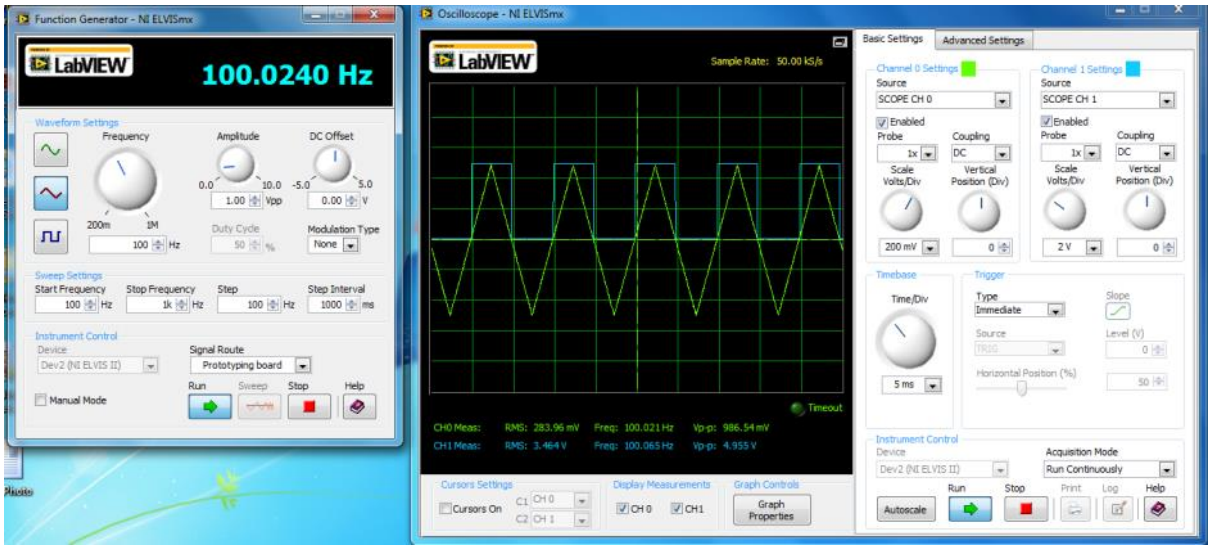


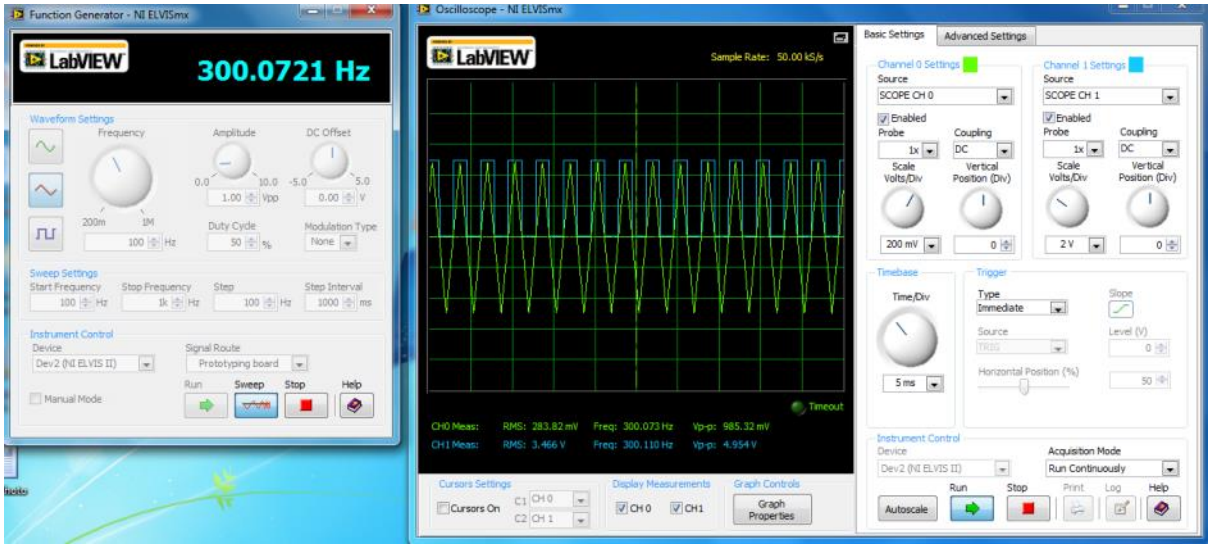

Function Generator - NI ELVISmx
LabVIEW
1.0001 kHz
Arbitrary Waveform Generator - NI ELVISmx
LabVIEW
Update Rate :
10.00 kS/s

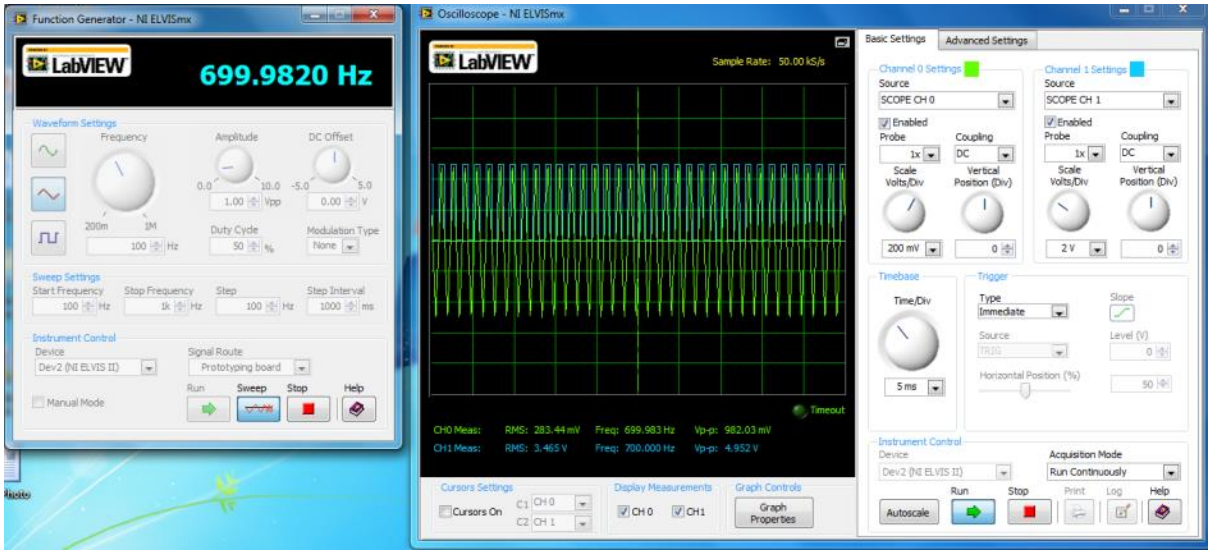

Oscilloscope - NI ELVISmx
LabVIEW
Sample Rate: 125.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Timebase
Trigger
Instrument Control
Autoscale
Run
Stop


Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 1000.00
Fundamental Frequency Power (Vrms^2) 0.24
Power Spectrum
Mode
Frequency (Hz)
THD (%) 0.00
SINAD (dB) 4.04
Time (s)
Vpk (V) 0.89
Sample Rate: 4.00 kS/s
Input Settings
FFT Settings
Averaging
Trigger Settings
Frequency Display
Scale Settings
Instrument Control
Run
Stop

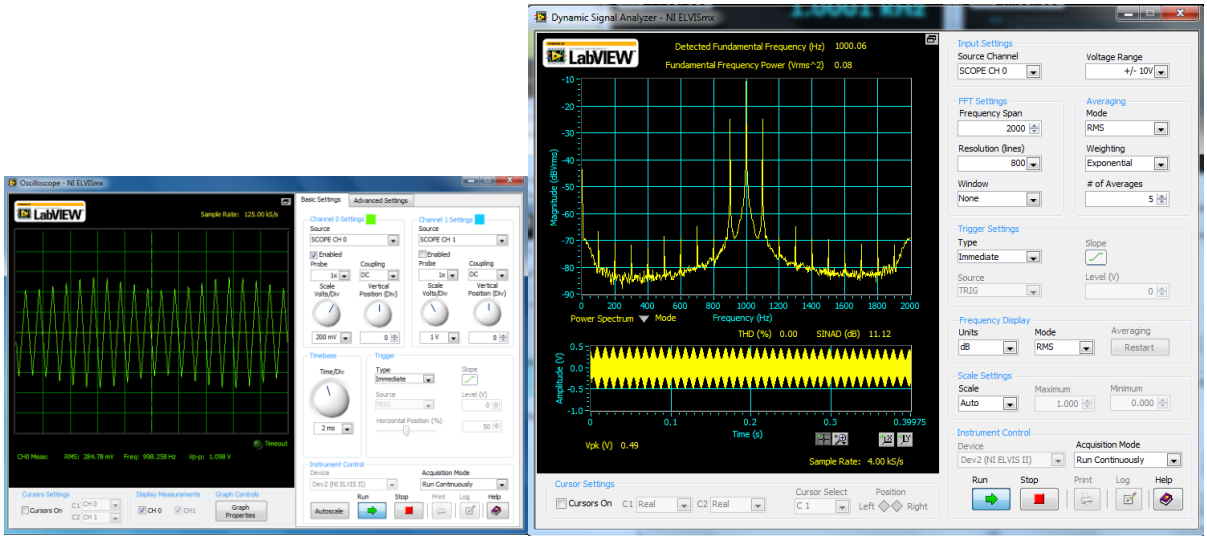

Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 1000.00
Fundamental Frequency Power (Vrms^2) 0.24
Power Spectrum
Mode
Frequency (Hz)
THD (%) 0.33
SINAD (dB) 4.06
Time (s)
Vpk (V) 0.89
Sample Rate: 4.00 kS/s
Input Settings
FFT Settings
Averaging
Trigger Settings
Frequency Display
Scale Settings
Instrument Control
Run
Stop

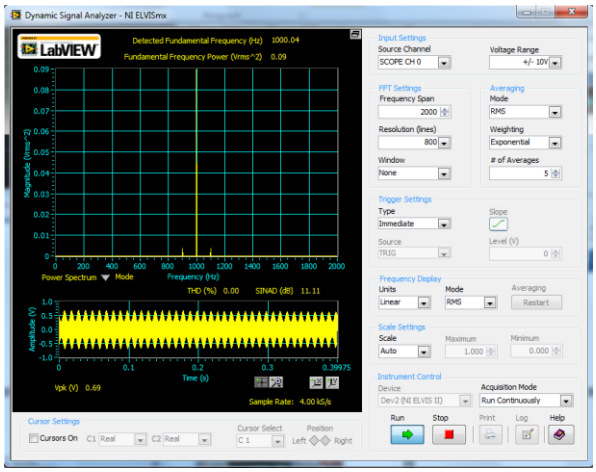

Function Generator - NI ELVISmx
LabVIEW
100.0240 Hz
Waveform Settings
Frequency
Amplitude
DC Offset
Modulation Type
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
Instrument Control
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help
Oscilloscope - NI ELVISmx
LabVIEW
Sample Rate: 50.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Timebase
Trigger
Instrument Control
Autoscale
Run
Stop

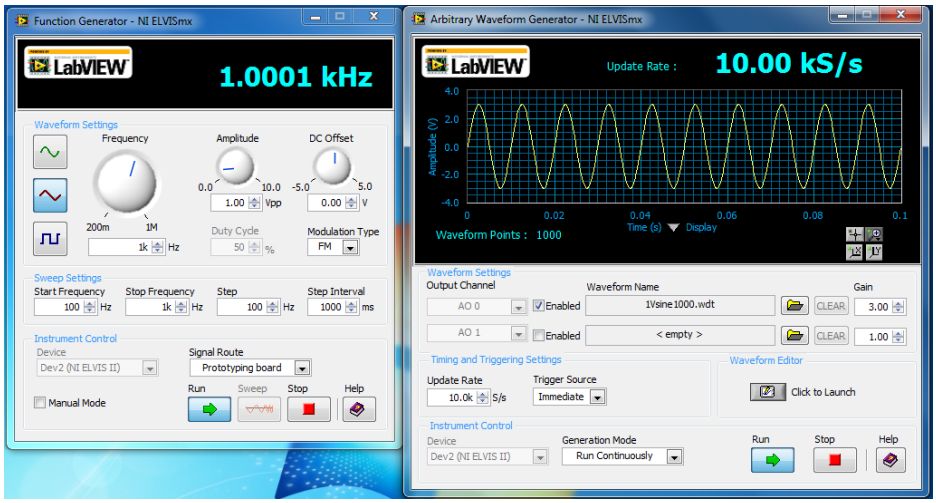

Function Generator - NI ELVISmx
LabVIEW
300.0721 Hz
Waveform Settings
Frequency
Amplitude
DC Offset
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help
Oscilloscope - NI ELVISmx
Sample Rate: 50.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Enabled
Probe
Coupling
Scale Volts/Div
Vertical Position (Div)
Timebase
Time/Div
Trigger
Type
Immediate
Source
Level (V)
Horizontal Position (%)
Timeout
CH0 Meas: RMS: 283.82 mV Freq: 300.073 Hz Vp-p: 985.32 mV
CH1 Meas: RMS: 3.466 V Freq: 300.110 Hz Vp-p: 4.954 V
Cursors Settings
Cursors On
Display Measurements
Graph Controls
Graph Properties
Acquisition Mode
Run Continuously
Autoscale
Print
Log

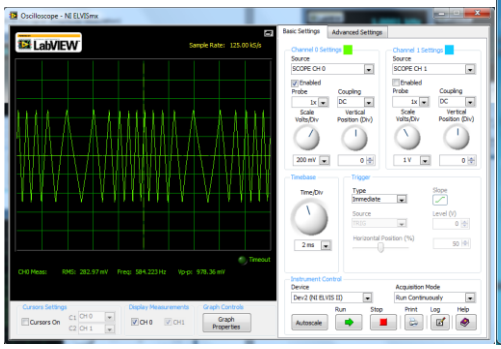

Function Generator - NI ELVISmx
LabVIEW
699.9820 Hz
Waveform Settings
Frequency
Amplitude
DC Offset
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help
Oscilloscope - NI ELVISmx
Sample Rate: 50.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Channel 1 Settings
SCOPE CH 0
SCOPE CH 1
Enabled
Probe
Coupling
Scale Volts/Div
Vertical Position (Div)
Timebase
Time/Div
Trigger
Type
Immediate
Source
Level (V)
Horizontal Position (%)
Timeout
CH0 Meas: RMS: 283.44 mV Freq: 699.983 Hz Vp-p: 982.03 mV
CH1 Meas: RMS: 3.465 V Freq: 700.000 Hz Vp-p: 4.952 V
Cursors Settings
Cursors On
Display Measurements
Graph Controls
Graph Properties
Acquisition Mode
Run Continuously
Autoscale
Print
Log

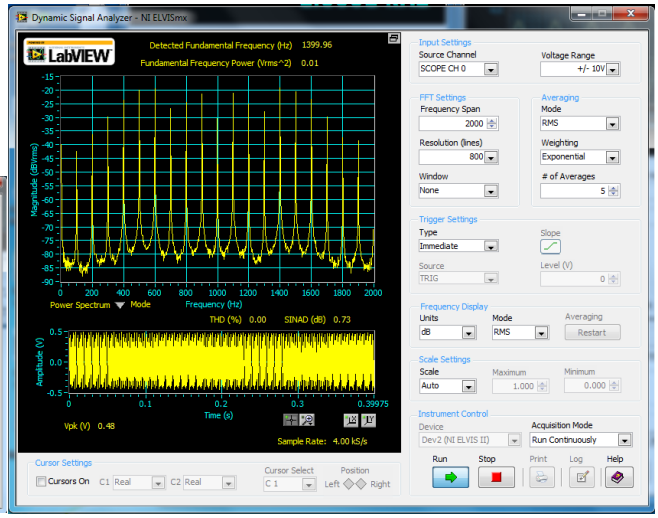

Arbitrary Waveform Generator - NI ELVISmx
LabVIEW
Update Rate :
10.00 kS/s
Amplitude (V)
Time (s)
Display
Waveform Points : 1000
Waveform Settings
Output Channel
Waveform Name
Gain
AO 0
Enabled
1Vsine1000.wdt
CLEAR
1.00
AO 1
< empty >
Timing and Triggering Settings
Update Rate
10.0k
S/s
Trigger Source
Immediate
Waveform Editor
Click to Launch
Instrument Control
Device
Dev2 (NI ELVIS II)
Generation Mode
Run Continuously
Run
Stop
Help
Function Generator - NI ELVISmx
LabVIEW
1.0001 kHz
Waveform Settings
Frequency
Amplitude
DC Offset
1.00
Vpp
0.00
V
200m
1M
1k
Hz
Duty Cycle
50
%
Modulation Type
AM
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
100
1k
100
1000
ms
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help

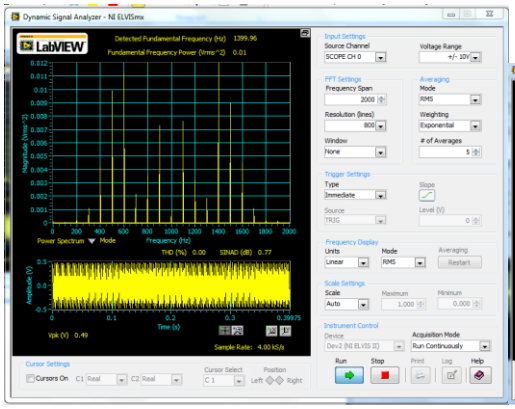

Oscilloscope - NI ELVISmx
Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 1000.06
Fundamental Frequency Power (Vrms^2) 0.08
Input Settings
Source Channel
SCOPE CH 0
Voltage Range
+/- 10V
FFT Settings
Frequency Span
2000
Resolution (lines)
800
Window
None
Averaging
Mode
RMS
Weighting
Exponential
# of Averages
5
Trigger Settings
Type
Immediate
Source
TRIG
Slope
Level (V)
Frequency Display
Units
dB
Mode
RMS
Averaging
Restart
Scale Settings
Scale
Auto
Maximum
1.000
Minimum
0.000
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Run
Stop
Print
Log
Help
Cursor Settings
Cursors On
Cursor Select
Position
Left
Right
Power Spectrum
Mode
Frequency (Hz)
THD (%) 0.00
SINAD (dB) 11.12
Time (s)
Vpk (V) 0.49
Sample Rate: 4.00 kS/s

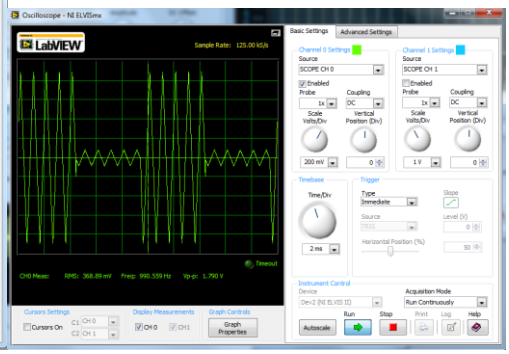

Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 1000.04
Fundamental Frequency Power (Vrms^2) 0.09
Input Settings
Source Channel
SCOPE CH 0
Voltage Range
+/- 10V
FFT Settings
Frequency Span
2000
Resolution (lines)
800
Window
None
Averaging
Mode
RMS
Weighting
Exponential
# of Averages
5
Trigger Settings
Type
Immediate
Source
TRIG
Slope
Level (V)
Frequency Display
Units
Linear
Mode
RMS
Averaging
Restart
Scale Settings
Scale
Auto
Maximum
1.000
Minimum
0.000
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Run
Stop
Print
Log
Help
Cursor Settings
Cursors On
Cursor Select
Position
Left
Right
Power Spectrum
Mode
Frequency (Hz)
THD (%) 0.00
SINAD (dB) 11.11
Time (s)
Vpk (V) 0.69
Sample Rate: 4.00 kS/s

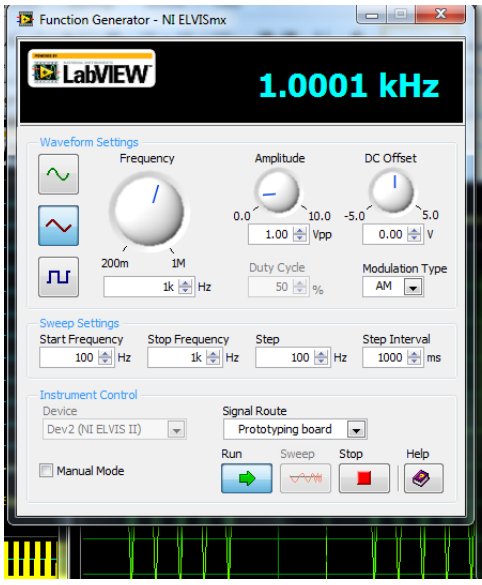

Function Generator - NI ELVISmx
LabVIEW
1.0001 kHz
Waveform Settings
Frequency
Amplitude
DC Offset
1.00 Vpp
0.00 V
Duty Cycle
50 %
Modulation Type
FM
1k Hz
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
100 Hz
1k Hz
100 Hz
1000 ms
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help
Arbitrary Waveform Generator - NI ELVISmx
LabVIEW
Update Rate :
10.00 kS/s
Amplitude (V)
Waveform Points : 1000
Time (s)
Display
Waveform Settings
Output Channel
Waveform Name
Gain
AO 0
Enabled
1Vsine1000.wdt
CLEAR
3.00
AO 1
Enabled
< empty >
CLEAR
1.00
Timing and Triggering Settings
Update Rate
10.0k S/s
Trigger Source
Immediate
Waveform Editor
Click to Launch
Instrument Control
Device
Dev2 (NI ELVIS II)
Generation Mode
Run Continuously
Run
Stop
Help

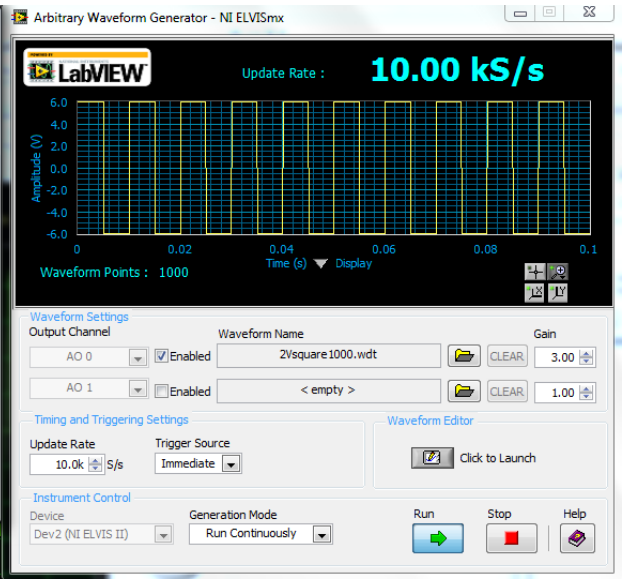


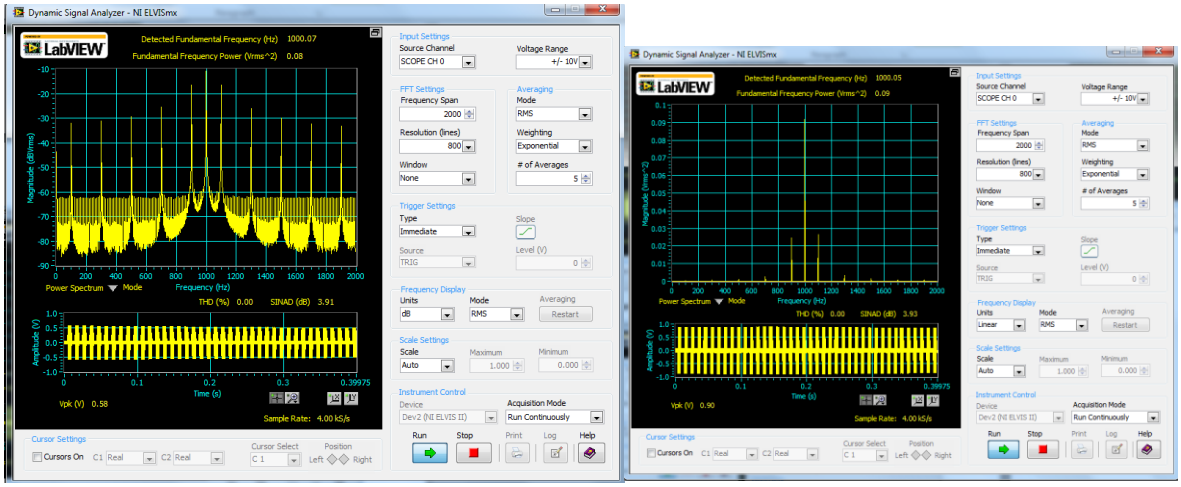

Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 1399.96
Fundamental Frequency Power (Vrms^2) 0.01
Input Settings
Source Channel
SCOPE CH 0
Voltage Range
+/- 10V
FFT Settings
Frequency Span
2000
Resolution (lines)
800
Window
None
Averaging
Mode
RMS
Weighting
Exponential
# of Averages
5
Trigger Settings
Type
Immediate
Source
TRIG
Slope
Level (V)
Frequency Display
Units
dB
Mode
RMS
Averaging
Restart
Scale Settings
Scale
Auto
Maximum
1.000
Minimum
0.000
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Run
Stop
Print
Log
Help
Power Spectrum
Mode
Frequency (Hz)
THD (%) 0.00
SINAD (dB) 0.73
Amplitude (V)
Time (s)
Vpk (V) 0.48
Sample Rate: 4.00 kS/s
Cursor Settings
Cursors On
C1 Real
C2 Real
Cursor Select
Position
Left
Right



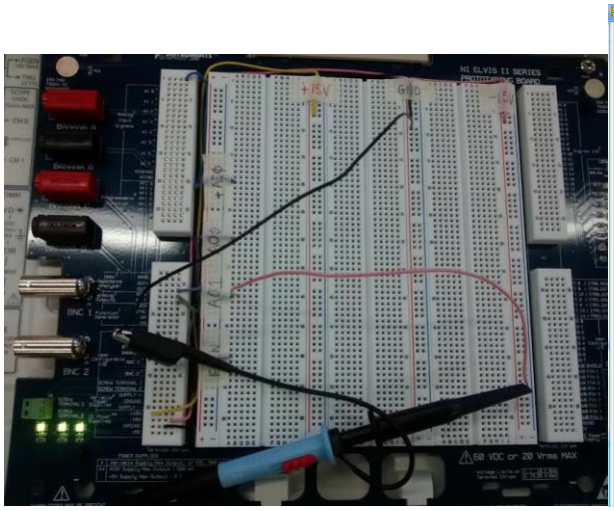


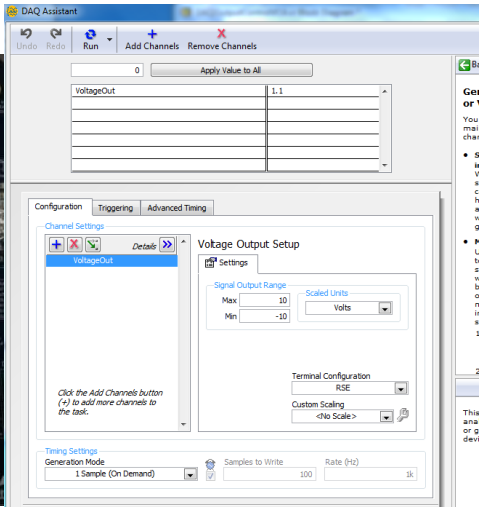

Function Generator - NI ELVISmx
LabVIEW
1.0001 kHz
Waveform Settings
Frequency
Amplitude
DC Offset
0.0
10.0
1.00
Vpp
-5.0
5.0
0.00
V
200m
1M
1k
Hz
Duty Cycle
50
%
Modulation Type
AM
Sweep Settings
Start Frequency
100
Hz
Stop Frequency
1k
Hz
Step
100
Hz
Step Interval
1000
ms
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Manual Mode
Run
Sweep
Stop
Help

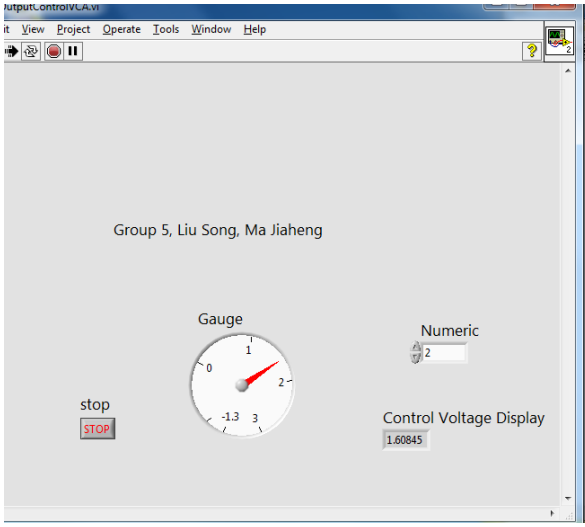

Arbitrary Waveform Generator - NI ELVISmx
LabVIEW
Update Rate :
10.00 kS/s
Amplitude (V)
Time (s)
Display
Waveform Points : 1000
Waveform Settings
Output Channel
Waveform Name
Gain
AO 0
Enabled
2Vsquare1000.wdt
CLEAR
3.00
AO 1
Enabled
< empty >
CLEAR
1.00
Timing and Triggering Settings
Update Rate
10.0k
S/s
Trigger Source
Immediate
Waveform Editor
Click to Launch
Instrument Control
Device
Dev2 (NI ELVIS II)
Generation Mode
Run Continuously
Run
Stop
Help

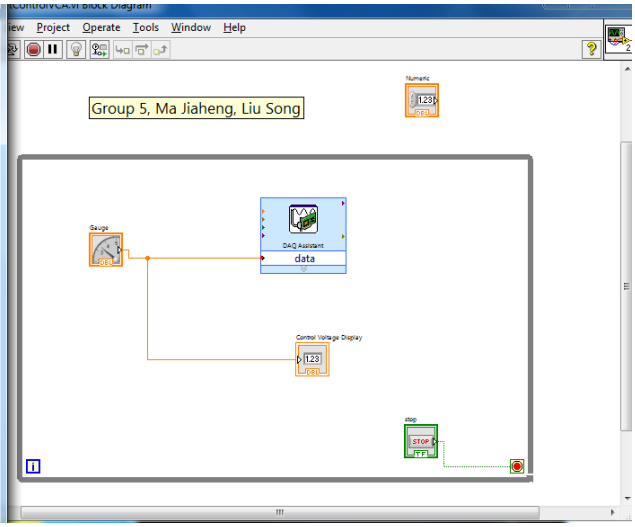

Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 1000.07
Fundamental Frequency Power (Vrms^2) 0.08
Input Settings
Source Channel
SCOPE CH 0
Voltage Range
+/- 10V
FFT Settings
Frequency Span
2000
Resolution (lines)
800
Window
None
Averaging
Mode
RMS
Weighting
Exponential
# of Averages
5
Trigger Settings
Type
Immediate
Slope
Source
TRIG
Level (V)
Frequency Display
Units
dB
Mode
RMS
Averaging
Restart
Scale Settings
Scale
Auto
Maximum
1.000
Minimum
0.000
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Run
Stop
Print
Log
Help
Cursor Settings
Cursors On
Cursor Select
Position
Left
Right
Power Spectrum
Mode
Frequency (Hz)
THD (%) 0.00
SINAD (dB) 3.91
Time (s)
Vpk (V) 0.58
Sample Rate: 4.00 kS/s
Dynamic Signal Analyzer - NI ELVISmx
LabVIEW
Detected Fundamental Frequency (Hz) 1000.05
Fundamental Frequency Power (Vrms^2) 0.09
Power Spectrum
Mode
Frequency (Hz)
THD (%) 0.00
SINAD (dB) 3.93
Time (s)
Vpk (V) 0.90
Sample Rate: 4.00 kS/s

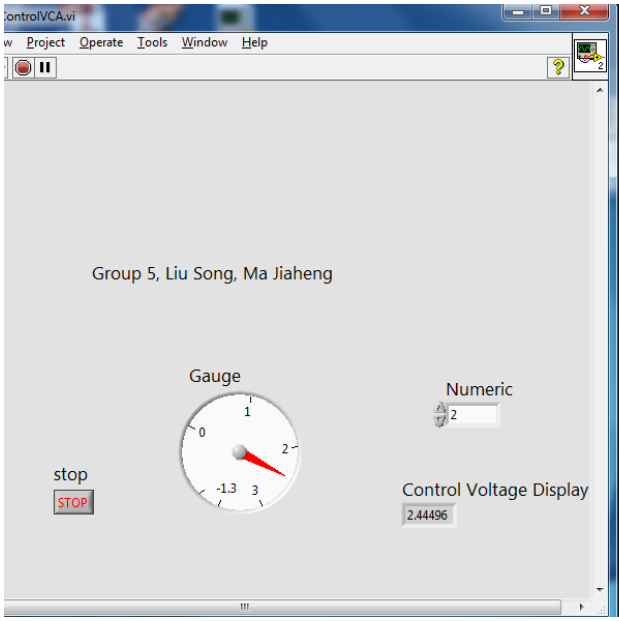
Week 5

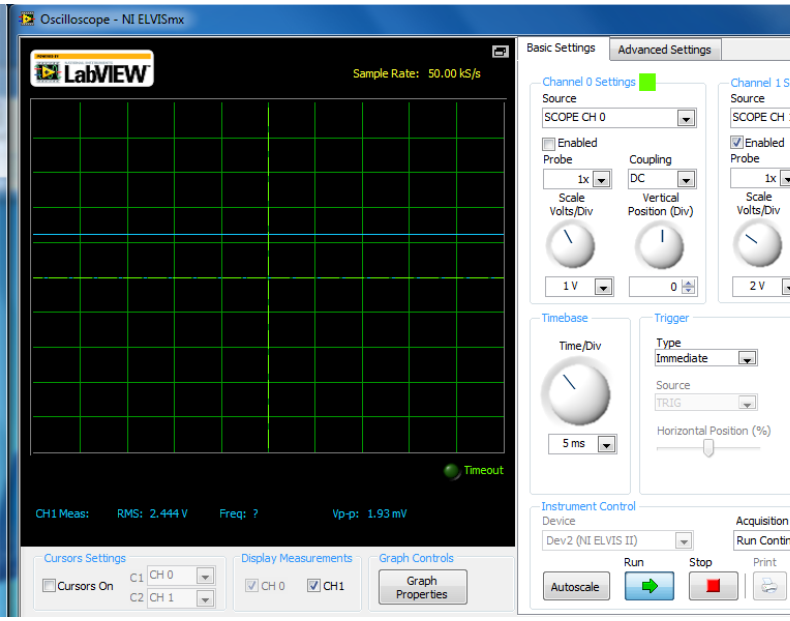


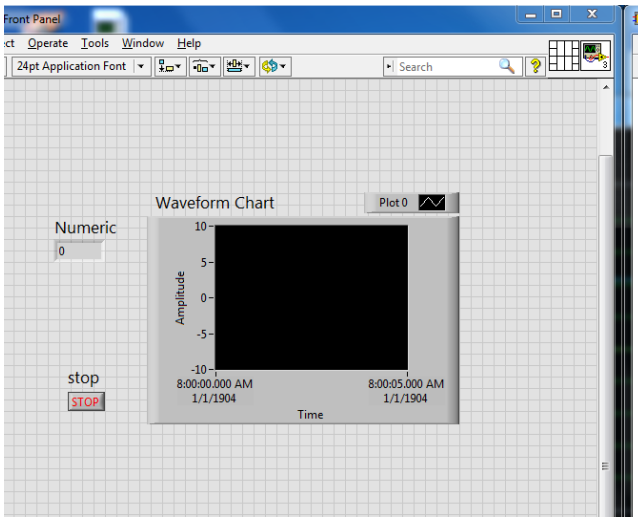

DAQ Assistant
Undo
Redo
Run
Add Channels
Remove Channels
Apply Value to All
VoltageOut
Configuration
Triggering
Advanced Timing
Channel Settings
Details
VoltageOut
Voltage Output Setup
Settings
Signal Output Range
Max
10
Min
-10
Scaled Units
Volts
Terminal Configuration
RSE
Custom Scaling
<No Scale>
Click the Add Channels button (+) to add more channels to the task.
Timing Settings
Generation Mode
1 Sample (On Demand)
Samples to Write
100
Rate (Hz)
1k

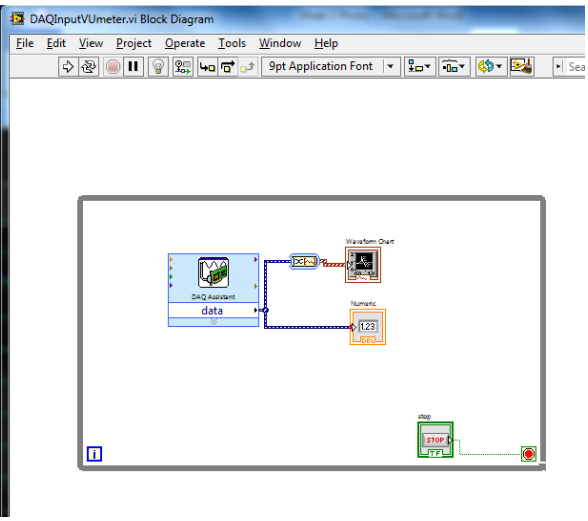

View
Project
Operate
Tools
Window
Help
Group 5, Liu Song, Ma Jiaheng
Gauge
Numeric
stop
STOP
Control Voltage Display
1.60845

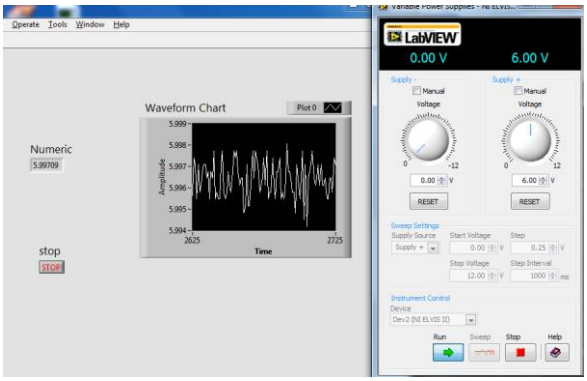

Project
Operate
Tools
Window
Help
Group 5, Ma Jiaheng, Liu Song
Numeric
Gauge
DAQ Assistant
data
Control Voltage Display
stop
STOP


ControlVCA.vi
Project Operate Tools Window Help
Group 5, Liu Song, Ma Jiaheng
Gauge
Numeric
stop
STOP
Control Voltage Display
2.44496

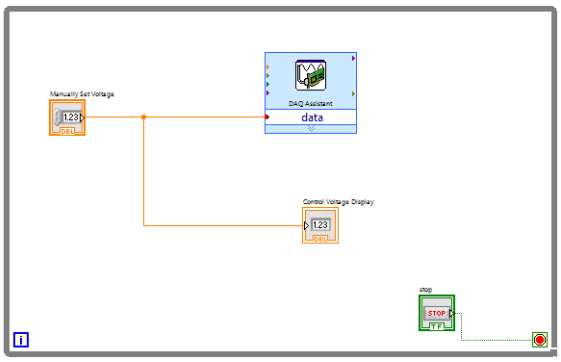

Oscilloscope - NI ELVISmx
LabVIEW
Sample Rate: 50.00 kS/s
Basic Settings
Advanced Settings
Channel 0 Settings
Source
SCOPE CH 0
Enabled
Probe
Coupling
DC
Scale Volts/Div
Vertical Position (Div)
1 V
0
Timebase
Time/Div
5 ms
Trigger
Type
Immediate
Source
Horizontal Position (%)
Timeout
CH1 Meas:
RMS: 2.444 V
Freq: ?
Vp-p: 1.93 mV
Cursors Settings
Cursors On
Display Measurements
CH 0
CH1
Graph Controls
Graph Properties
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition
Run Contin
Run
Stop
Print
Autoscale

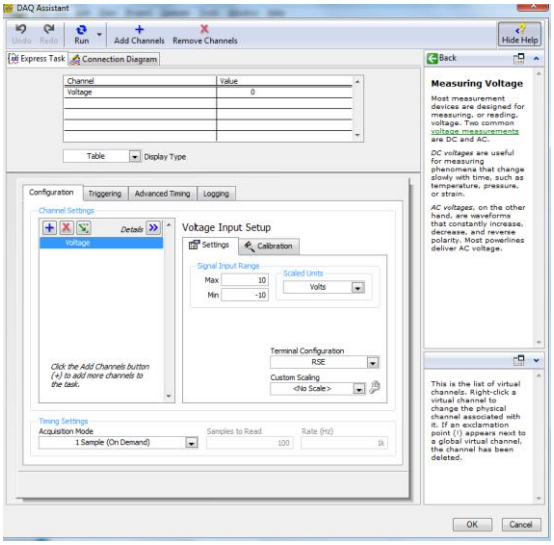

Front Panel
Operate Tools Window Help
24pt Application Font
Search
Waveform Chart
Plot 0
Numeric
stop
STOP
Amplitude
Time
8:00:00.000 AM
1/1/1904
8:00:05.000 AM
1/1/1904

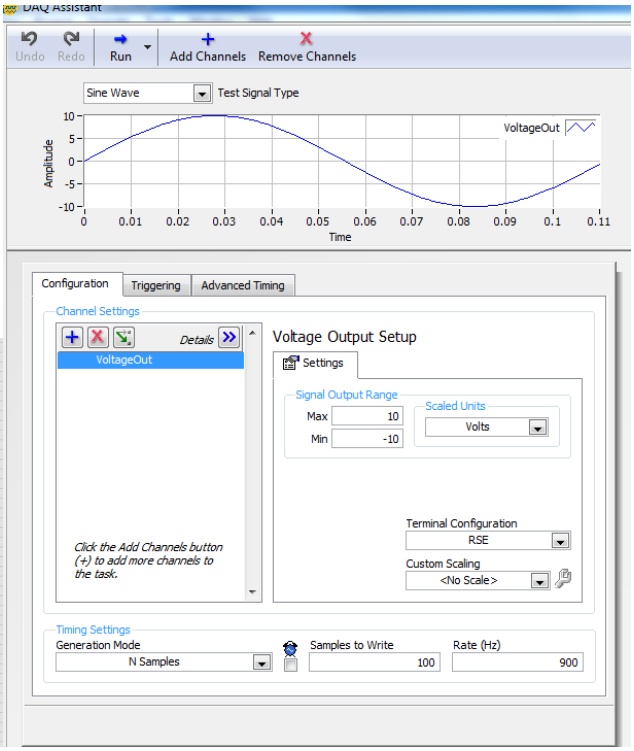

DAQInputVUmeter.vi Block Diagram
File Edit View Project Operate Tools Window Help
9pt Application Font
DAQ Assistant
data
Waveform Chart
Numeric
stop
STOP

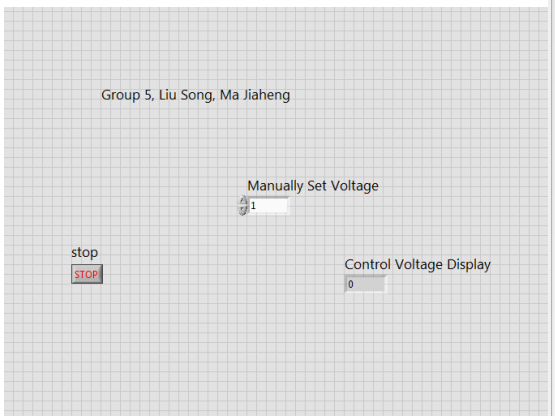

Operate Tools Window Help
Waveform Chart
Plot 0
Numeric
stop
STOP
Amplitude
Time
LabVIEW
0.00 V
6.00 V
RESET
Run
Stop
Help

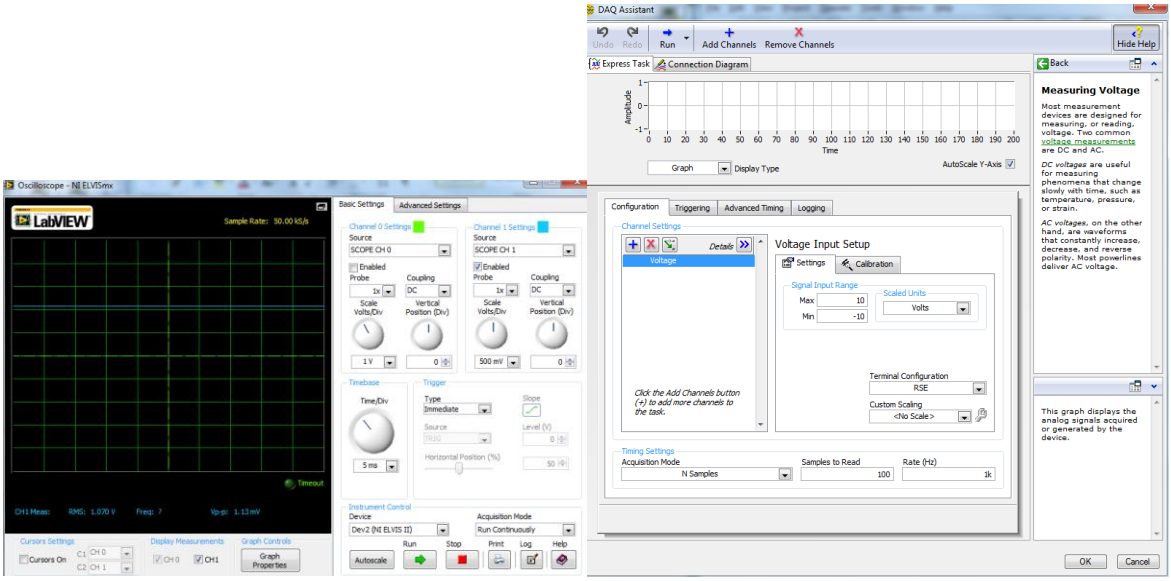
Group 5, Ma Jiaheng, Liu Song

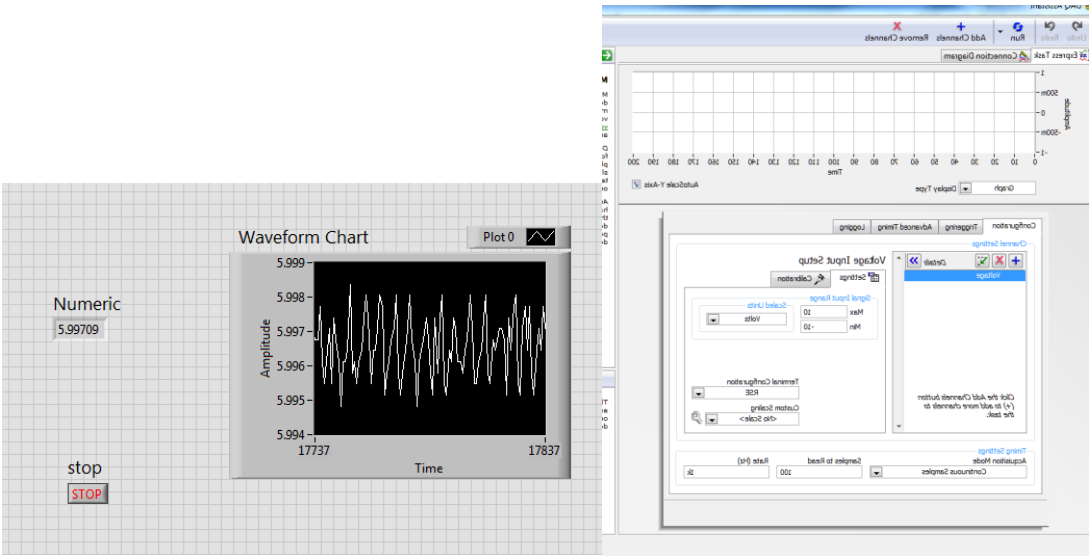


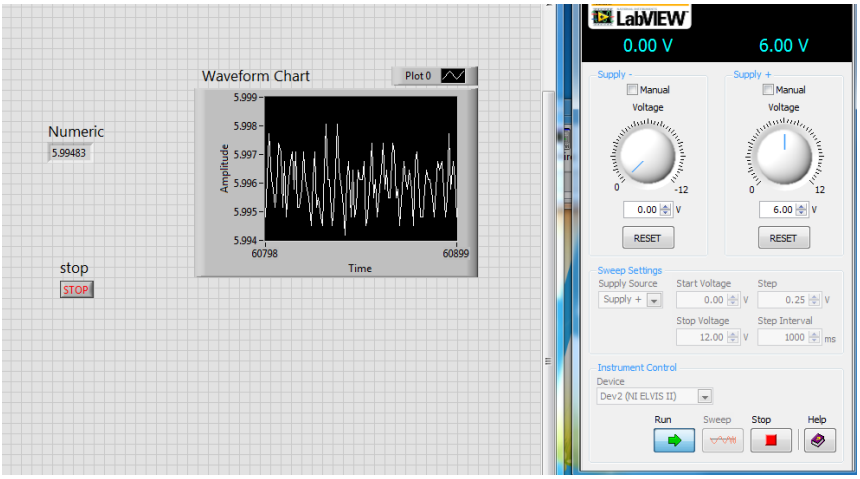




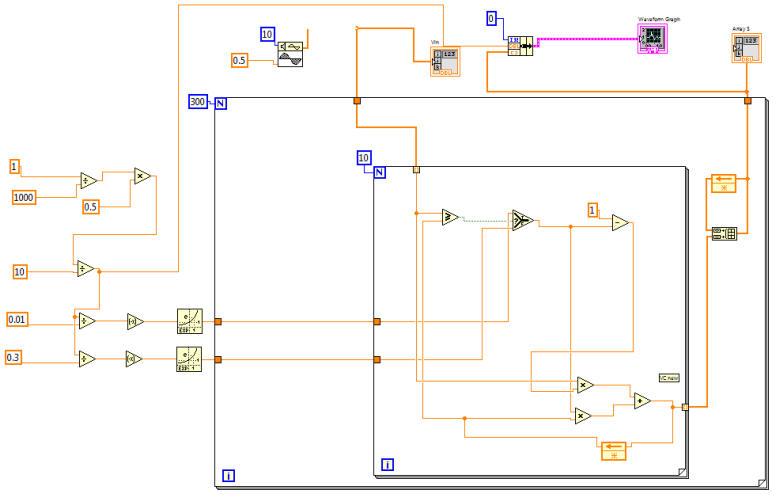


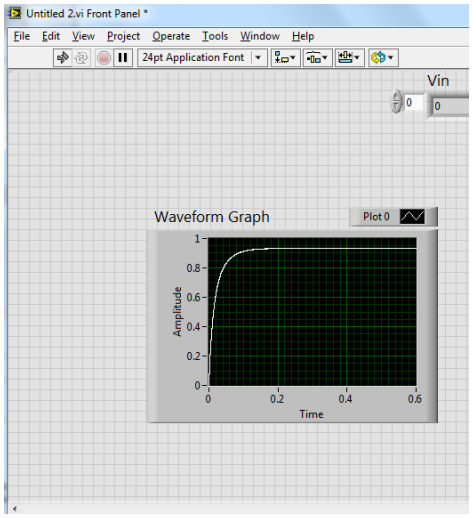

DAQ Assistant
Undo
Redo
Run
Add Channels
Remove Channels
Hide Help
Express Task
Connection Diagram
Back
Measuring Voltage
Most measurement devices are designed for measuring, or reading, voltage. Two common voltage measurements are DC and AC.
DC voltages are useful for measuring phenomena that change slowly with time, such as temperature, pressure, or strain.
AC voltages, on the other hand, are waveforms that constantly increase, decrease, and reverse polarity. Most powerlines deliver AC voltage.
Graph
Display Type
AutoScale Y-Axis
Configuration
Triggering
Advanced Timing
Logging
Channel Settings
Voltage Input Setup
Settings
Calibration
Signal Input Range
Max
Min
Scaled Units
Volts
Terminal Configuration
RSE
Custom Scaling
<No Scale>
Click the Add Channels button (+) to add more channels to the task.
Timing Settings
Acquisition Mode
N Samples
Samples to Read
Rate (Hz)
This graph displays the analog signals acquired or generated by the device.
OK
Cancel
Oscilloscope - NI ELVISmx
LabVIEW
Sample Rate: 50.00 kS/s
Basic Settings
Advanced Settings
Timeout
Instrument Control
Device
Dev2 (NI ELVIS II)
Acquisition Mode
Run Continuously
Autoscale
Run
Stop
Print
Log
Help

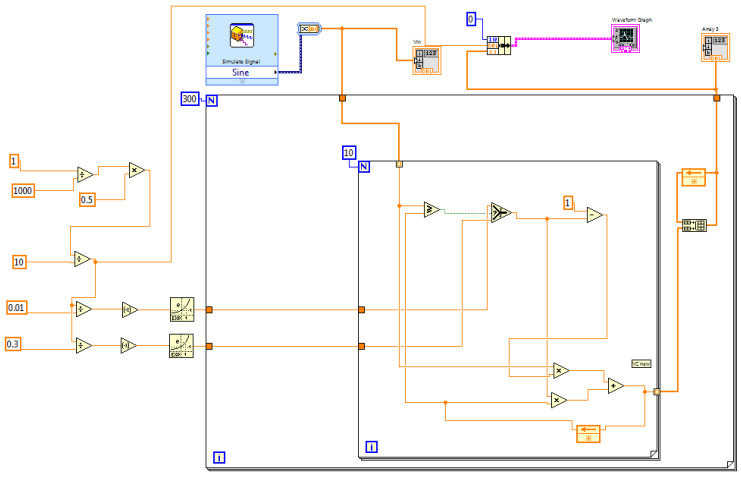

Waveform Chart
Plot 0
Numeric
5.99709
Amplitude
5.999
5.998
5.997
5.996
5.995
5.994
17737
17837
Time
stop
STOP

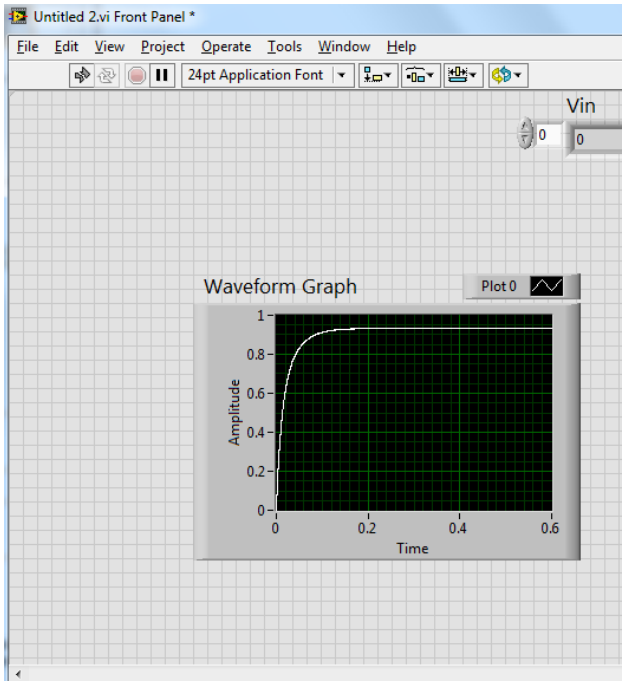

Waveform Chart
Plot 0
Numeric
5.99483
Amplitude
5.999
5.998
5.997
5.996
5.995
5.994
60798
60899
Time
stop
STOP
LabVIEW
0.00 V
6.00 V
Supply -
Supply +
Manual
Voltage
0.00 V
6.00 V
RESET
Sweep Settings
Supply Source
Start Voltage
Step
Stop Voltage
Step Interval
Instrument Control
Device
Dev2 (NI ELVIS II)
Run
Sweep
Stop
Help

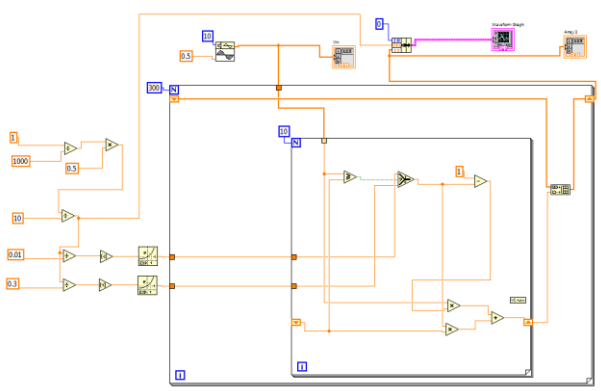
Week6

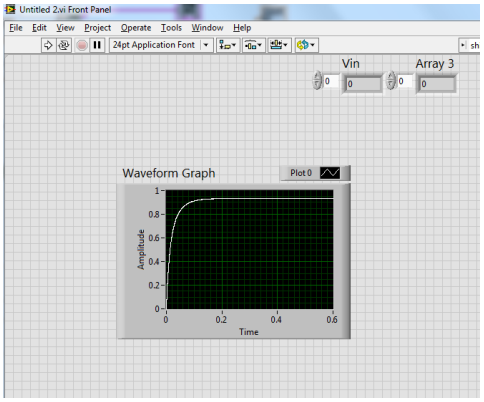


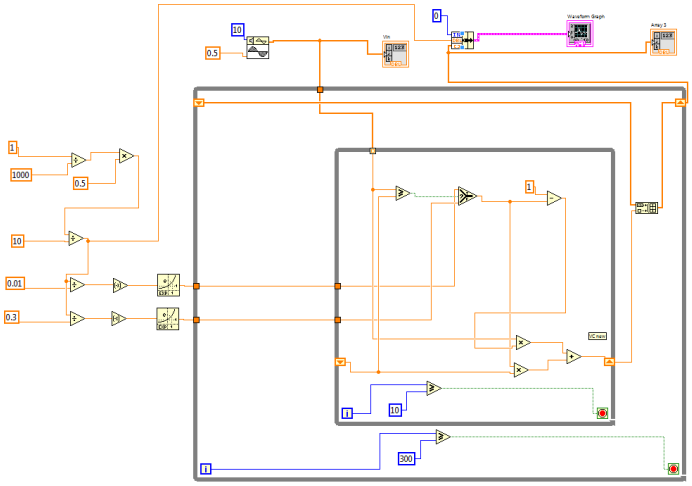

Untitled 2.vi Front Panel *
File Edit View Project Operate Tools Window Help
24pt Application Font
Vin
Waveform Graph
Plot 0
Amplitude
Time

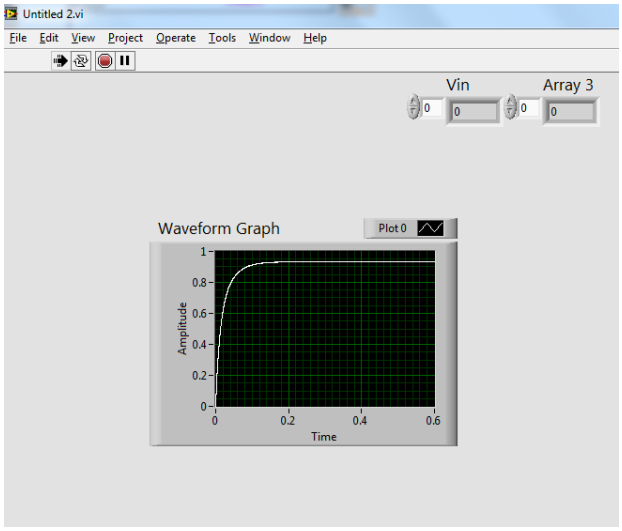



Untitled 2.vi Front Panel *
File Edit View Project Operate Tools Window Help
24pt Application Font
Vin
0
0
Waveform Graph
Plot 0
Amplitude
Time
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6

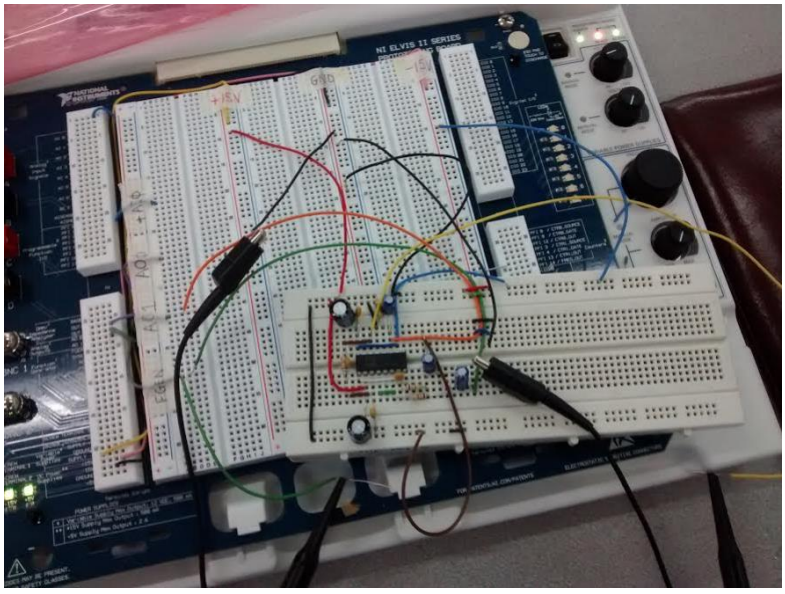


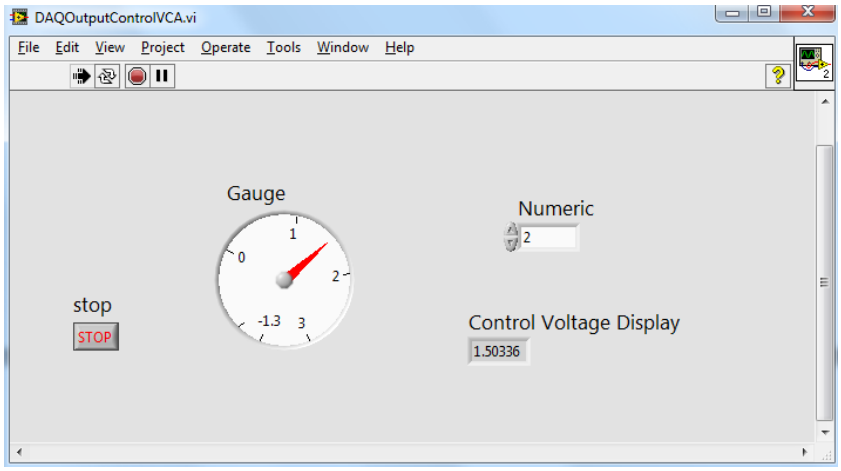

Untitled 2.vi Front Panel
File Edit View Project Operate Tools Window Help
24pt Application Font
Vin
Array 3
Waveform Graph
Plot 0
Amplitude
Time

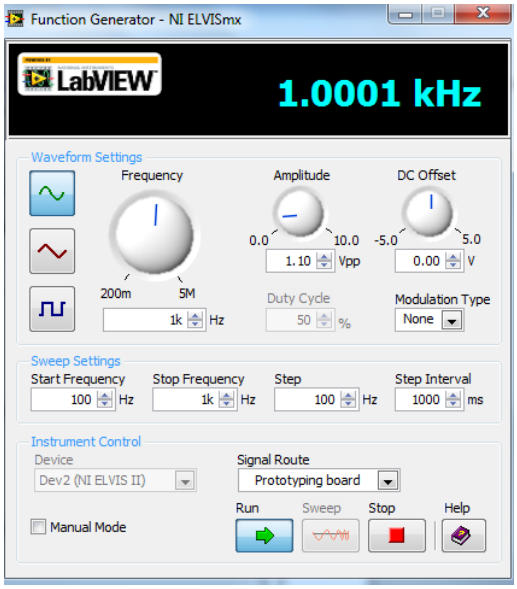


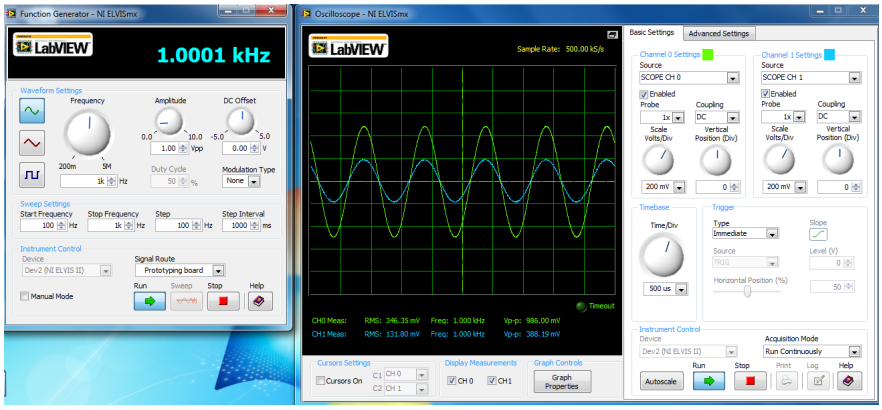

Untitled 2.vi
File Edit View Project Operate Tools Window Help
Vin
Array 3
Waveform Graph
Plot 0
Amplitude
Time

Week 7:

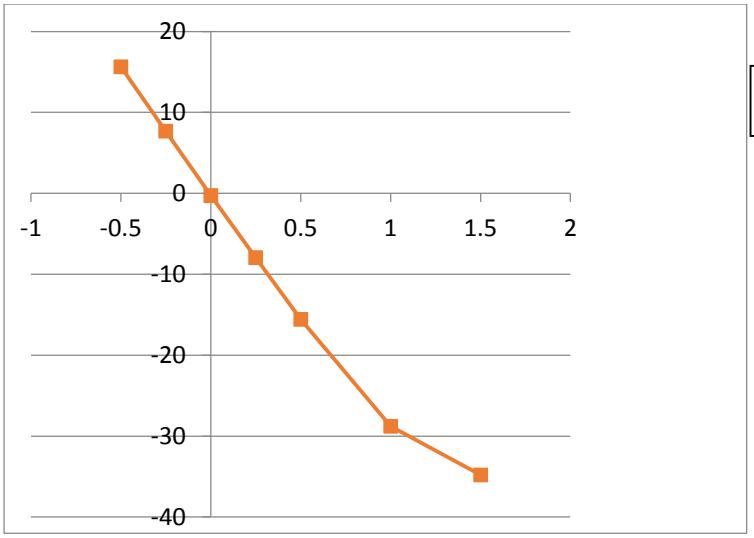



DAQOutputControlVCA.vi
File Edit View Project Operate Tools Window Help
Gauge
Numeric
stop
STOP
Control Voltage Display
1.50336



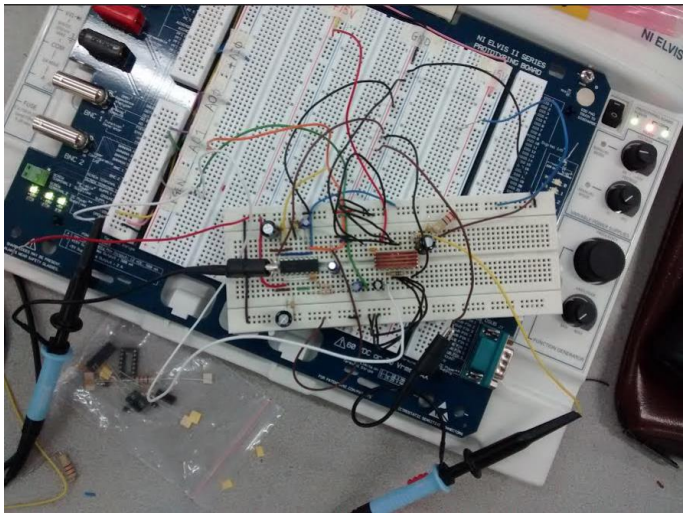


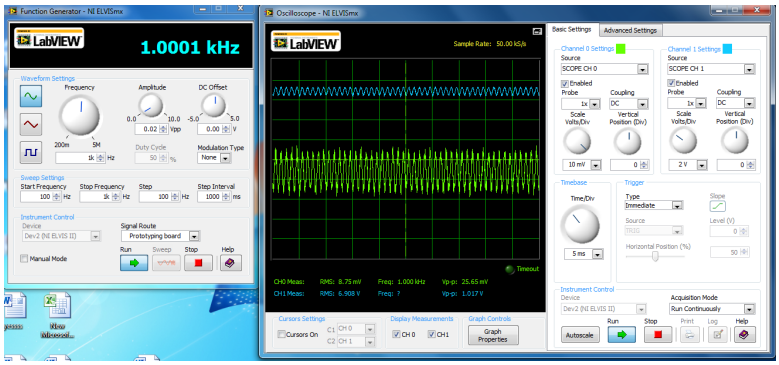
VIN (Vpp)	VC (V)	VOUT (Vpp)	Measured Gain = VOUT/VIN	Measured Gain (dB)	Theoretical Gain	Theoretical Gain (dB)
Ma Jiaheng						
1.2	1.5	0.02	0.016666667	-35.56302501	0.004363416	-47.20346724
1.2	1	0.045	0.0375	-28.51937465	0.026702449	-31.46897816
1	0.5	0.17	0.17	-15.39102157	0.16340884	-15.73448908
1.8	0.25	0.71	0.394444444	-8.080283128	0.404238592	-7.86724454
1.4	0	1.34	0.957142857	-0.380464746	1	0
0.5	-0.25	1.22	2.44	7.747796527	2.473786567	7.86724454
0.1	-0.5	0.58	5.8	15.26855987	6.119619981	15.73448908
0.1	-1	3.5	35	30.88136089	37.44974871	31.46897816
Liu Song:						
1.1	1.5	0.02	0.018181818	-34.80725379	0.004363416	-47.20346724
1.1	1	0.04	0.036363636	-28.78665388	0.026702449	-31.46897816
1.2	0.5	0.2	0.166666667	-15.56302501	0.16340884	-15.73448908
1.2	0.25	0.48	0.4	-7.958800173	0.404238592	-7.86724454
1.7	0	1.65	0.970588235	-0.259299543	1	0
0.4	-0.25	0.97	2.425	7.694234859	2.473786567	7.86724454
0.7	-0.5	4.23	6.042857143	15.62484655	6.119619981	15.73448908
0.7	-1	N/A			37.44974871	31.46897816


20
10
0
-10
-20
-30
-40
-1
-0.5
0
0.5
1
1.5
2

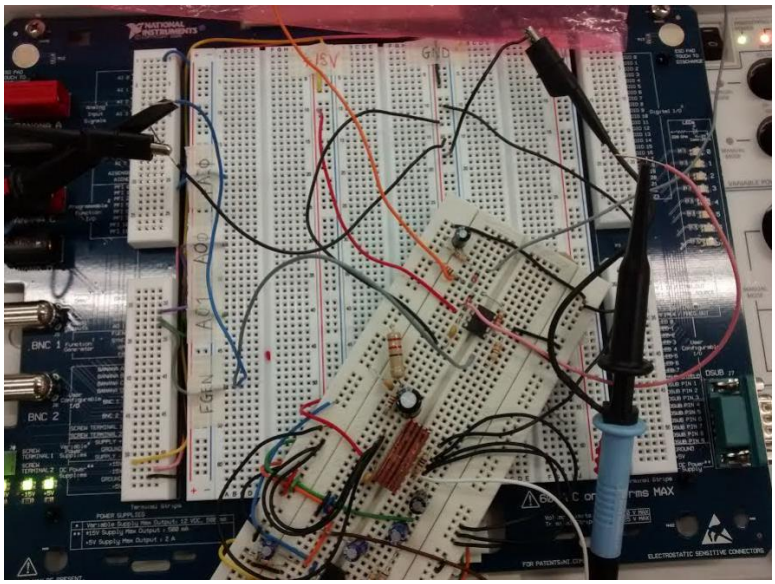
Vp(V)	Bode analyser window capture
0.02	
0.01	
0.07	
0.04	

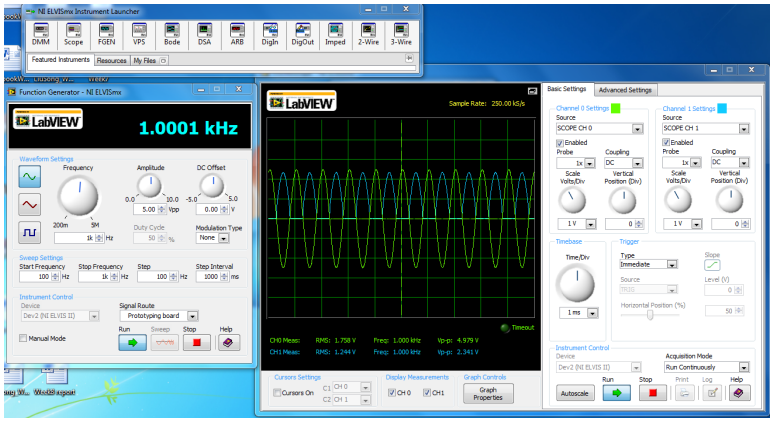
Week 8:



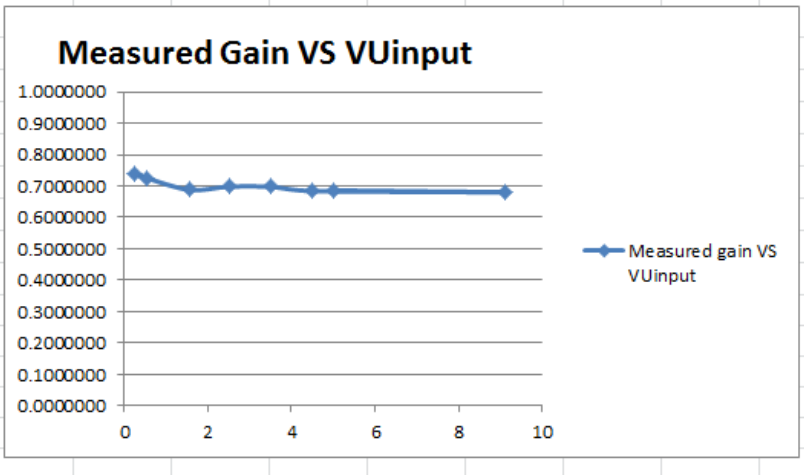

Function Generator - NI ELVISmx
LabVIEW
1.0001 kHz
Oscilloscope - NI ELVISmx
LabVIEW

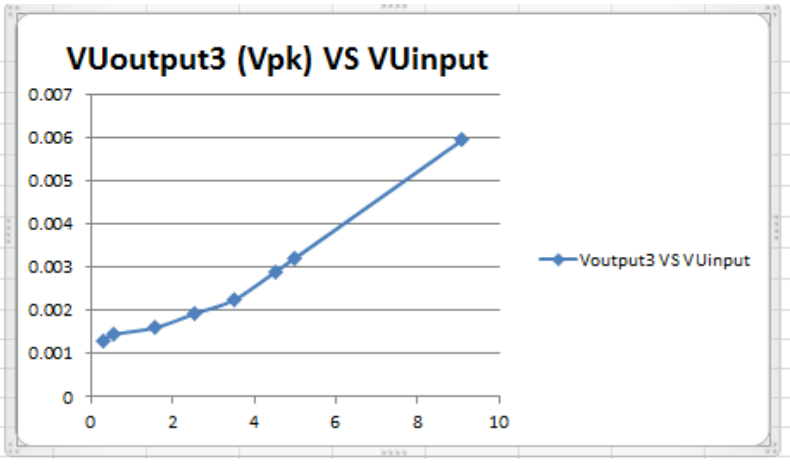
Week 9



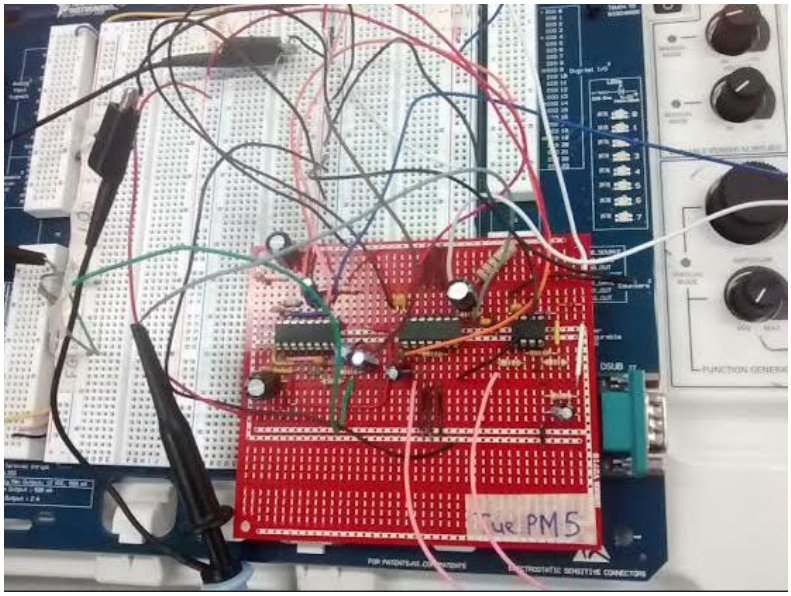


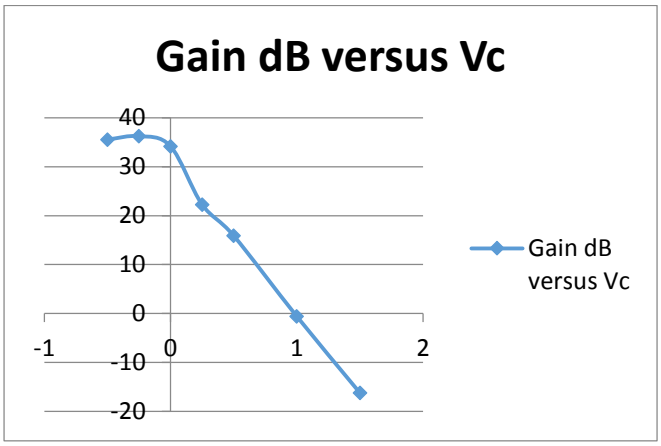
VUinput (Vpp)	VUoutput1 (Vpk)	VUoutput2 (Vpk)	VUoutput3 (Vpk)		Measured Gain
5	2.34	1.716	0.00322		0.6864000
9.1	3.812	3.095	0.00596		0.6802198
4.51	2.162	1.543	0.0029		0.6842572
3.52	1.801	1.228	0.00226		0.6977273
2.52	1.43	0.88	0.00193		0.6984127
1.57	1.068	0.54	0.00161		0.6878981
0.54	0.66	0.196	0.00145		0.7259259
0.27	0.532	0.1	0.00129		0.7407407



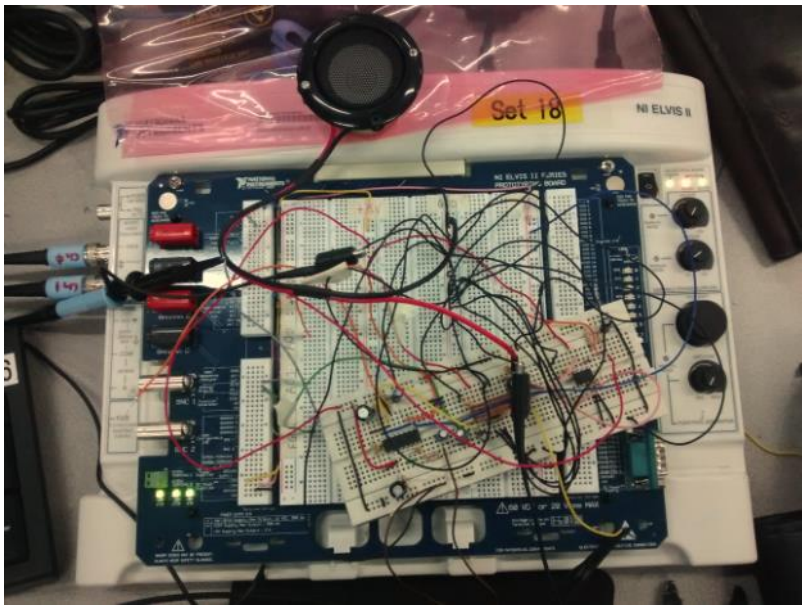


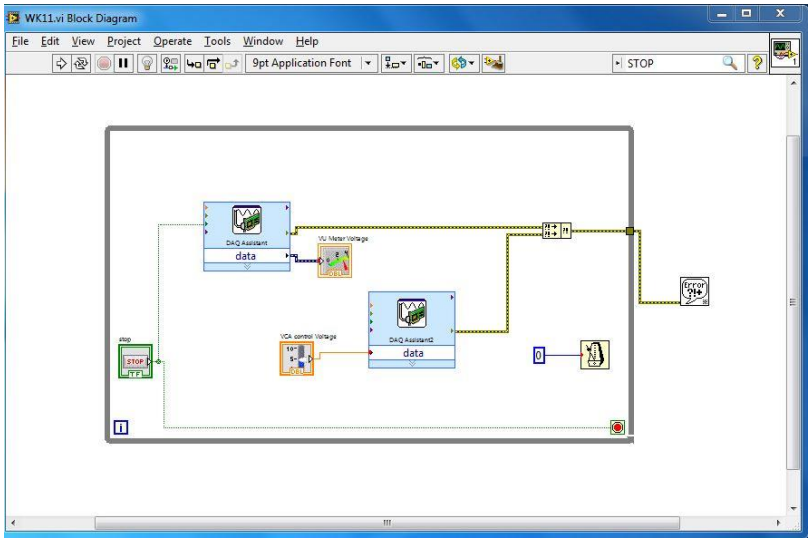
Week 10

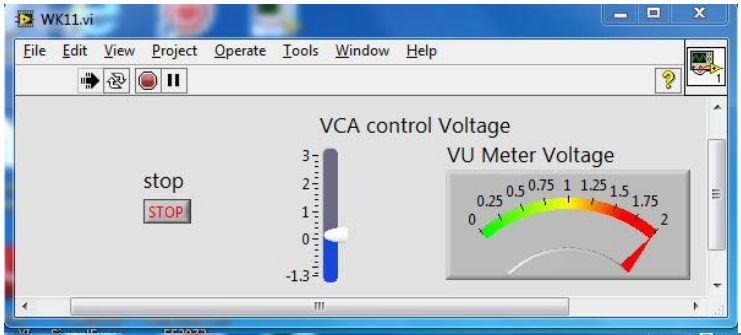

Tue PM 5

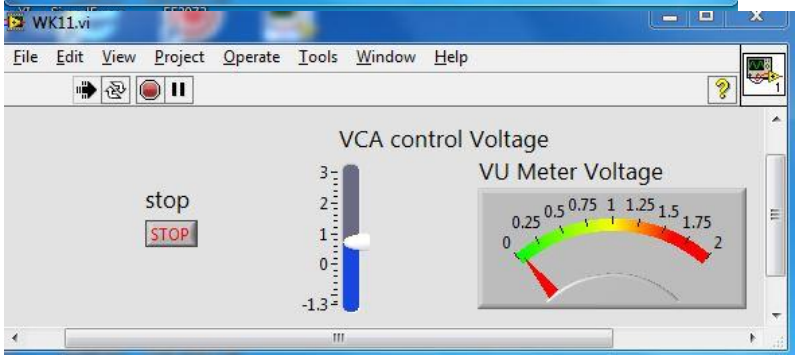

Gain dB versus Vc
40
30
20
10
0
-10
-20
-1
0
1
2
Gain dB versus Vc

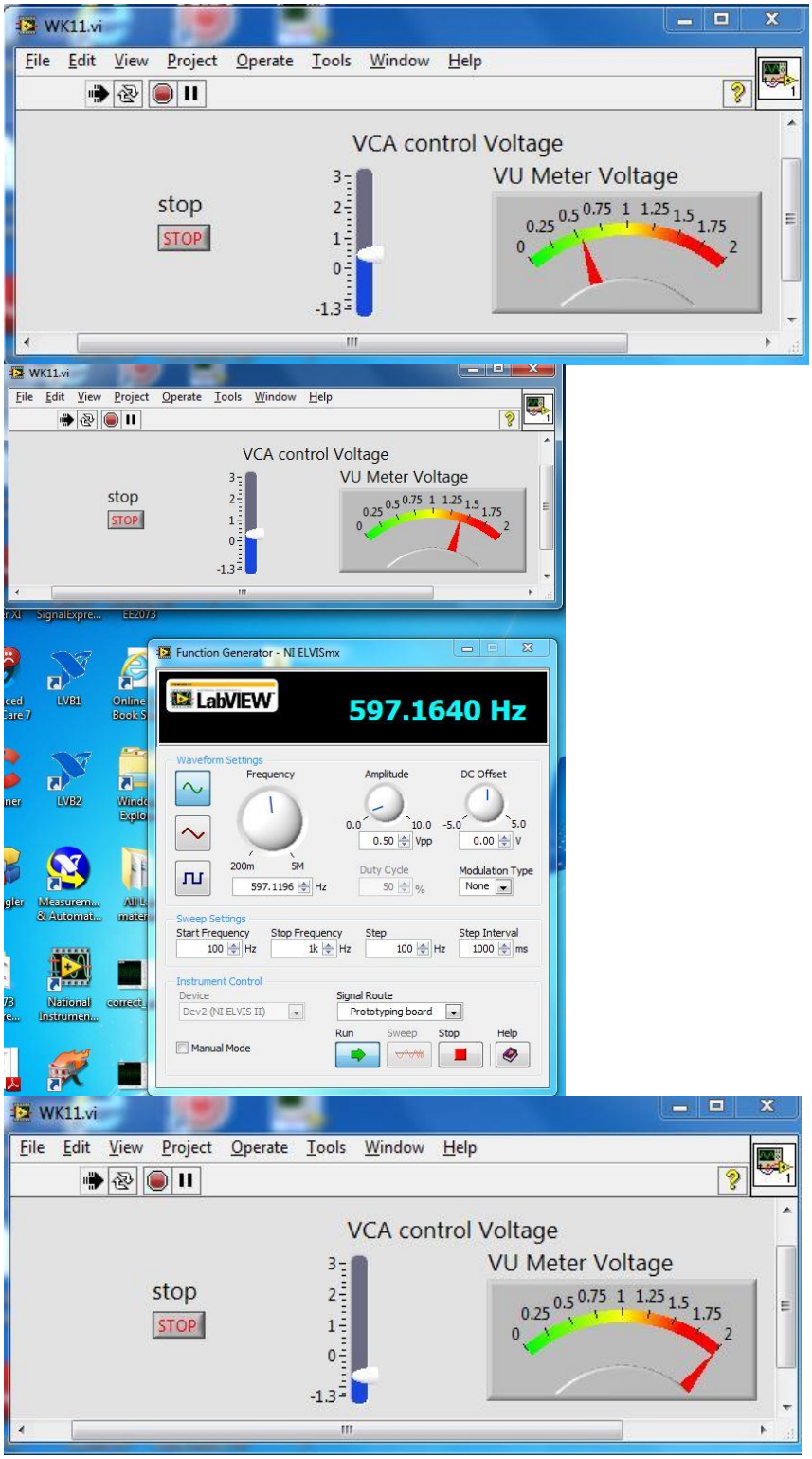
Week 11

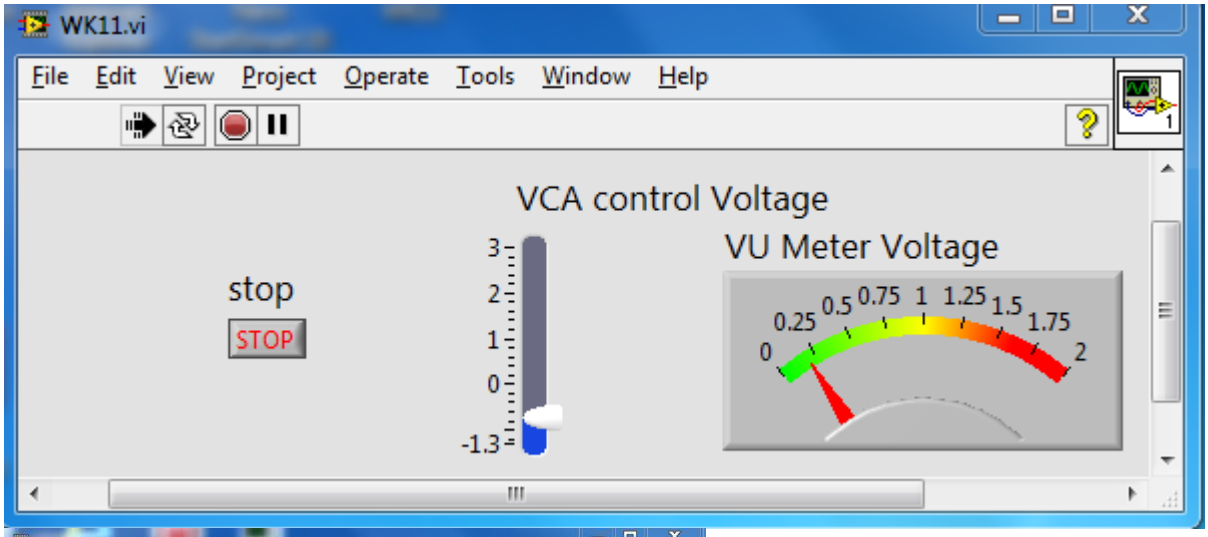

Set 18
NI ELVIS II

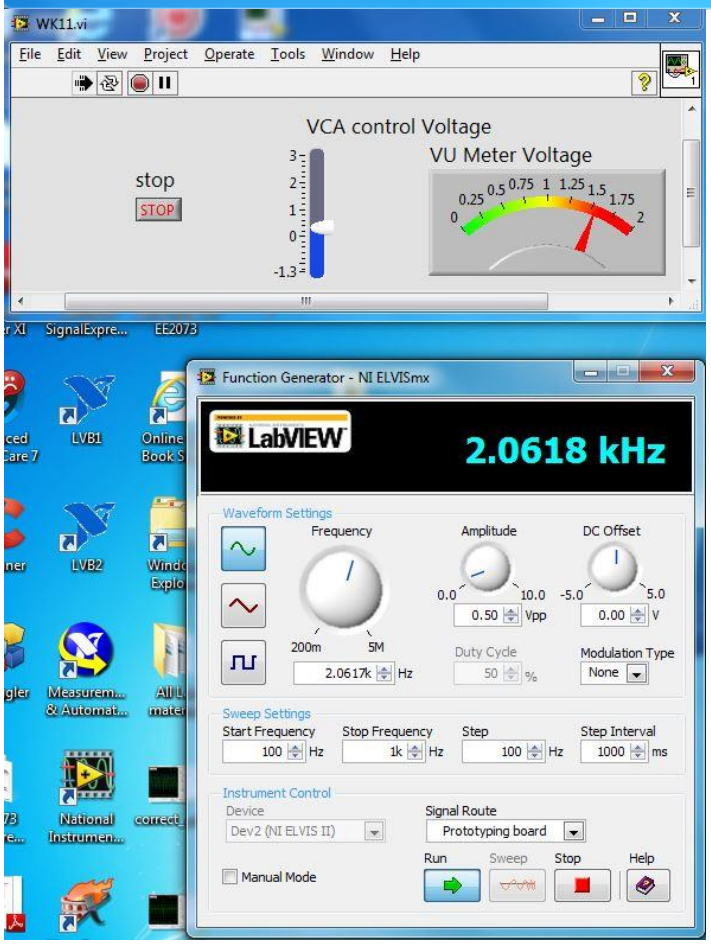

WK11.vi Block Diagram
File Edit View Project Operate Tools Window Help
9pt Application Font
STOP
DAQ Assistant
data
VU Meter Voltage
VCA control Voltage
DAQ Assistant2
data
stop
STOP
TF
Error
0
1


WK11.vi
File Edit View Project Operate Tools Window Help
VCA control Voltage
VU Meter Voltage
stop
STOP
3
2
1
0
-1.3
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2

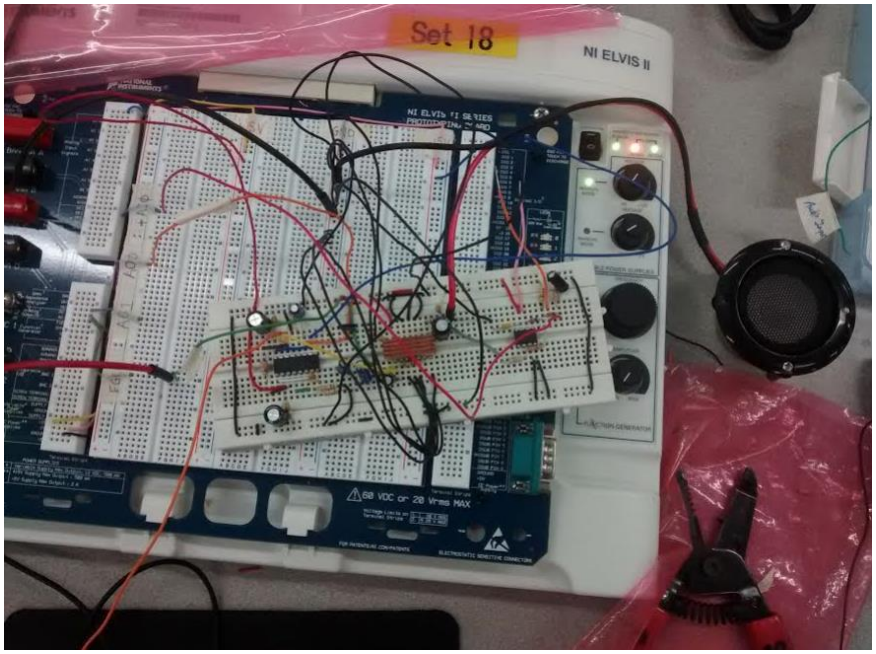

WK11.vi
File Edit View Project Operate Tools Window Help
VCA control Voltage
VU Meter Voltage
stop
STOP
3
2
1
0
-1.3
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2

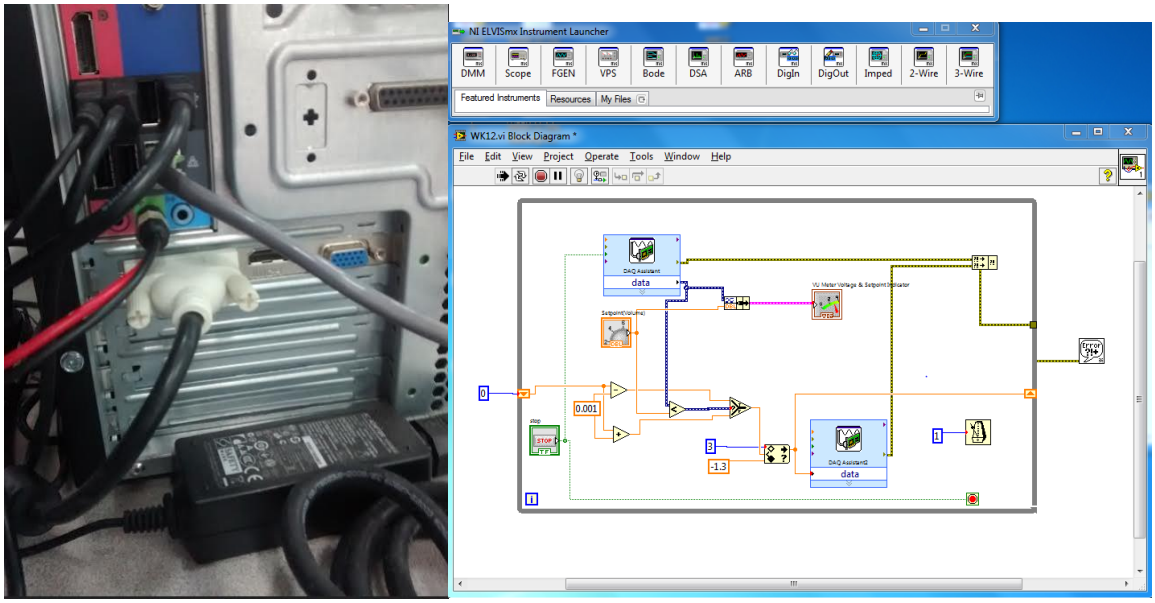

WK11.vi
File Edit View Project Operate Tools Window Help
VCA control Voltage
stop
STOP
VU Meter Voltage
Function Generator - NI ELVISmx
LabVIEW
597.1640 Hz
Waveform Settings
Frequency
Amplitude
DC Offset
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
Instrument Control
Device
Signal Route
Prototyping board
Run
Sweep
Stop
Help
Manual Mode

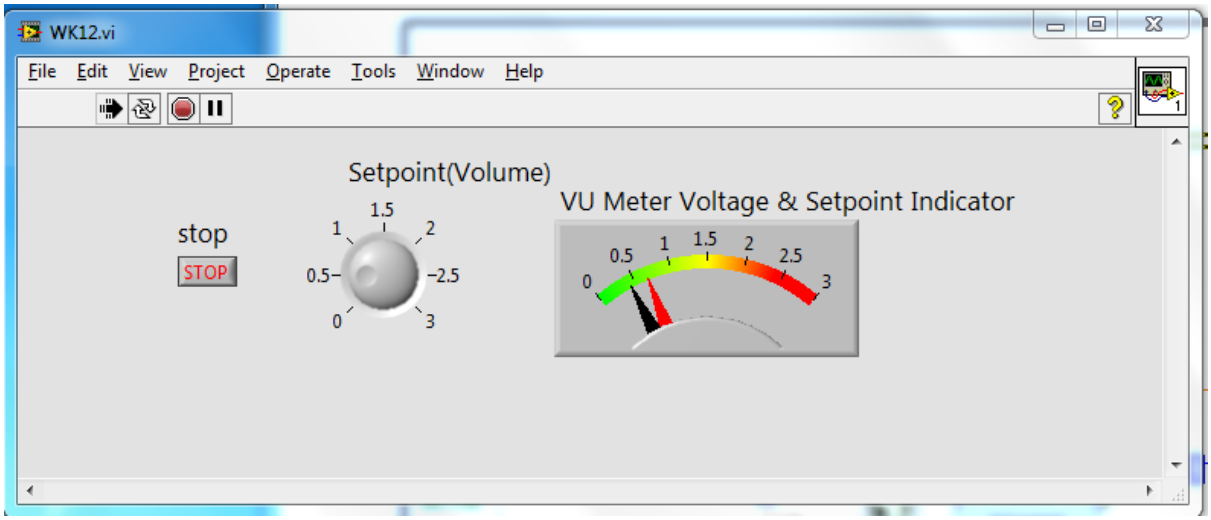

WK11.vi
File Edit View Project Operate Tools Window Help
VCA control Voltage
stop
STOP
3
2
1
0
-1.3
VU Meter Voltage
0 0.25 0.5 0.75 1 1.25 1.5 1.75 2

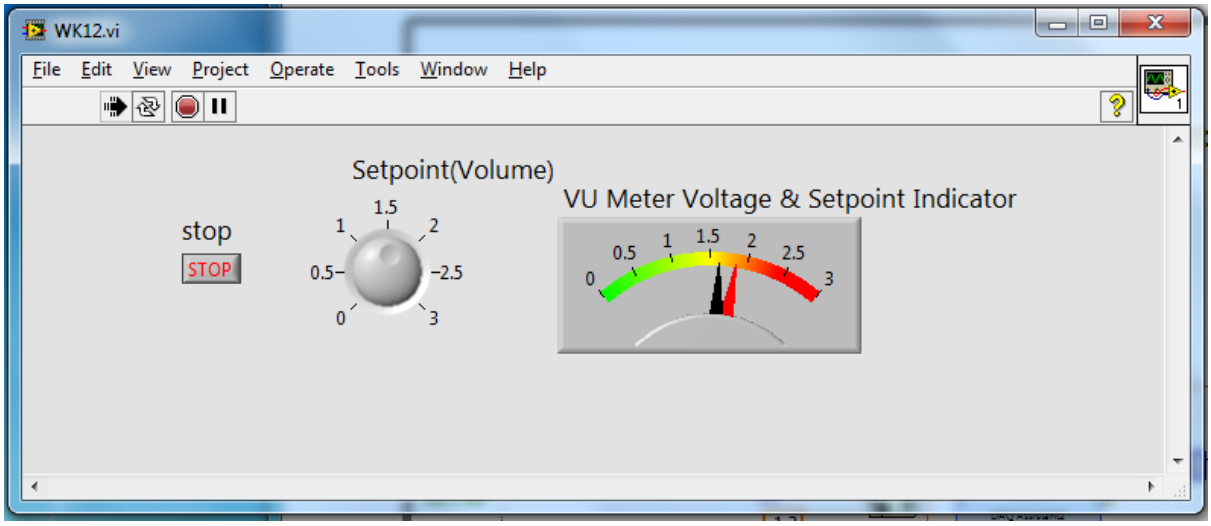

WK11.vi
File Edit View Project Operate Tools Window Help
VCA control Voltage
stop
STOP
VU Meter Voltage
Function Generator - NI ELVISmx
LabVIEW
2.0618 kHz
Waveform Settings
Frequency
Amplitude
DC Offset
200m 5M
2.0617k Hz
0.0 10.0
0.50 Vpp
-5.0 5.0
0.00 V
Duty Cycle
50 %
Modulation Type
None
Sweep Settings
Start Frequency
Stop Frequency
Step
Step Interval
100 Hz
1k Hz
100 Hz
1000 ms
Instrument Control
Device
Dev2 (NI ELVIS II)
Signal Route
Prototyping board
Run
Sweep
Stop
Help
Manual Mode

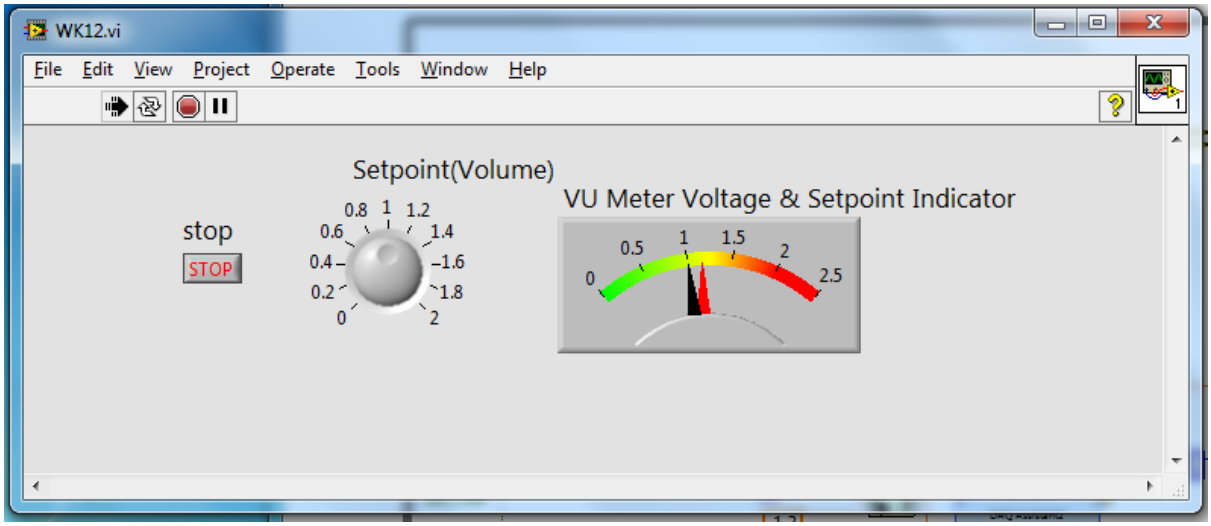
Week 12


Set 18
NI ELVIS II


NI ELVISmx Instrument Launcher
DMM
Scope
FGEN
VPS
Bode
DSA
ARB
DigIn
DigOut
Imped
2-Wire
3-Wire
Featured Instruments
Resources
My Files
WK12.vi Block Diagram *
File Edit View Project Operate Tools Window Help
DAQ Assistant
data
VU Meter Voltage & Setpoint Indicator
0.001
-1.3
DAQ Assistant2
data


WK12.vi
File Edit View Project Operate Tools Window Help
Setpoint(Volume)
stop
STOP
1.5
1
2
0.5
-2.5
0
3
VU Meter Voltage & Setpoint Indicator
0.5
1
1.5
2
2.5
0
3


WK12.vi
File Edit View Project Operate Tools Window Help
Setpoint(Volume)
VU Meter Voltage & Setpoint Indicator
stop
STOP
0 0.5 1 1.5 2 2.5 3
0 0.5 1 1.5 2 2.5 3


WK12.vi
File Edit View Project Operate Tools Window Help
Setpoint(Volume)
VU Meter Voltage & Setpoint Indicator
stop
STOP
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
0 0.5 1 1.5 2 2.5