Albatross – Vibrational Analysis Final Report

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December 12, 2023

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Introduction

- Natural frequency is one of the most used parameters for detecting damages and this experiment was purposed in finding the natural frequency of the Albatross to explore structural health via vibrational analysis under free-free boundary condition set-up
- Testing on albatross can be conducted to resemble testing conditions and utilization of PZT sensors along the wing
- Shifts in the natural frequency will be connected to the health of the albatross, therefore, monitoring the natural frequency will help indicate presence of damage

Method of Approach

- The process involvs the use of a data acquisition device, shaker, vibration controller, and PZT sensors through a frequency resonance method.
- With the use of a shaker at the wingtip and PZT sensors along the wing of the UAV, the natural frequency of the albatross can be detected
- By sending random vibrations throughout the albatross with a shaker can show us what the resonance and what frequency the UAV wants to naturally vibrate at

Process Data Collection

Data collection process:

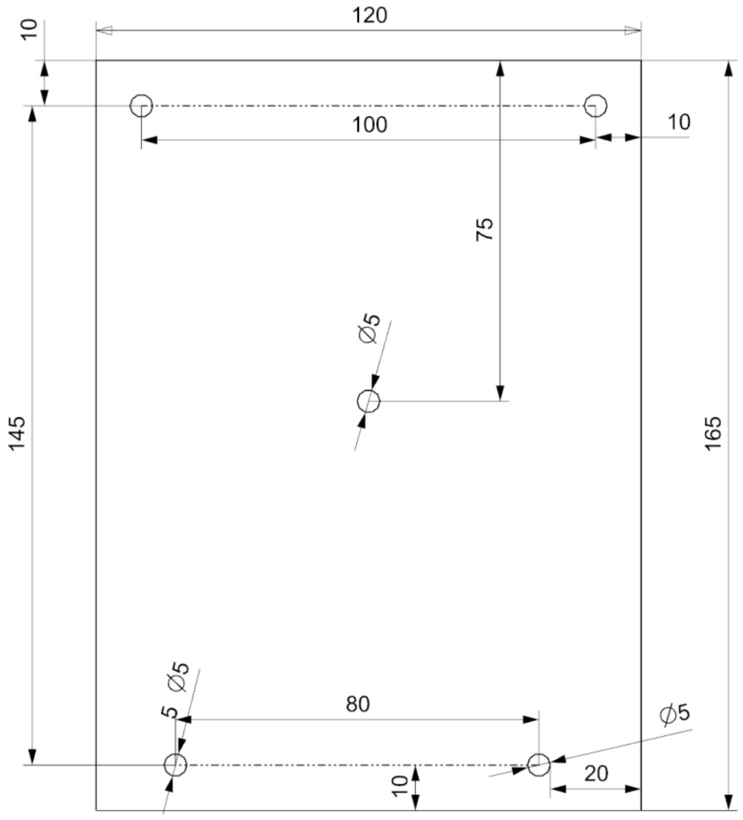
- Data Acquisition Systems:
  - PZT sensors along Albatross to monitor vibrations and potential damage, connected to data acquisition system for signal and with the accelerometer to capture vibrational data
  - Shaker inputs specific vibrations to the UAV and there will be random vibration frequency and amplitude
- From data acquisition; process data/results from sensors, such as resonant frequencies and damping ratios
- Comparison of expected vs actual vibrational patterns

Method of Approach

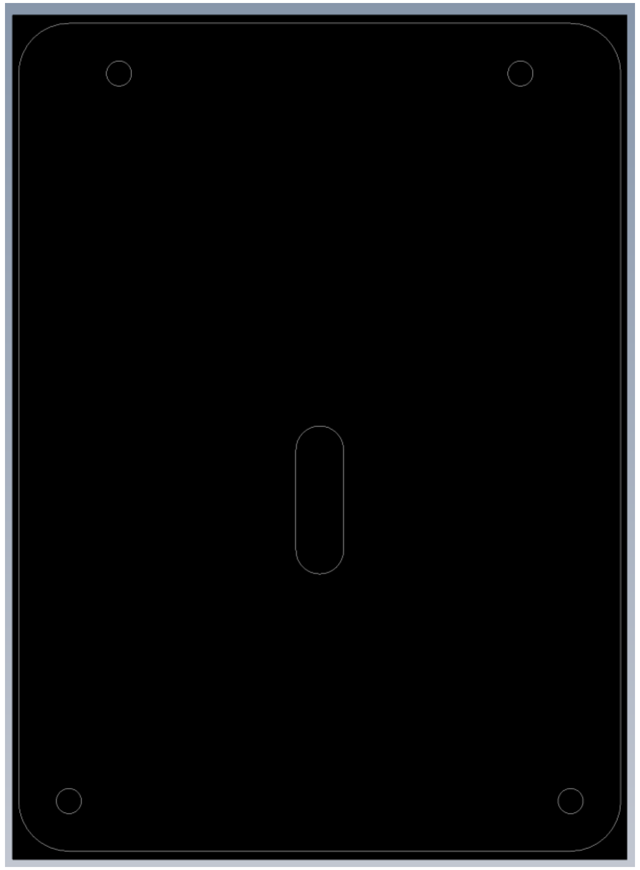
- Design backplate for albatross to conduct free-free analysis with the back plate designed in CAD, NX of corresponding measurements.
- Initial testing failure factors from designed backplate:
  - Initial calculated center of mass resulted in uneven mass distribution causing albatross to tip
  - Holes needed to be cut at angle to align with UAV's lower and upper nail lengths
  - The UAV required longer M5 screws for attachment of back plate with spacer adjustments

Method of Approach

Aluminum Backplate:



CAD, NX Drawing



DFX Drawing

Method of Approach – data collection

Topics of interest for data analysis:

- Key Vibrational Data:
  - Natural Frequencies - frequencies of natural UAV vibrations.
  - Mode Shapes – Deformation patterns at each natural frequency.
  - Damping Ratios – time of Vibrations decay for stability
- Structural Health Data:
  - Damage Detection - Changes in the expected vibration pattern
  - Dynamic Stress- Reaction to durability assessment

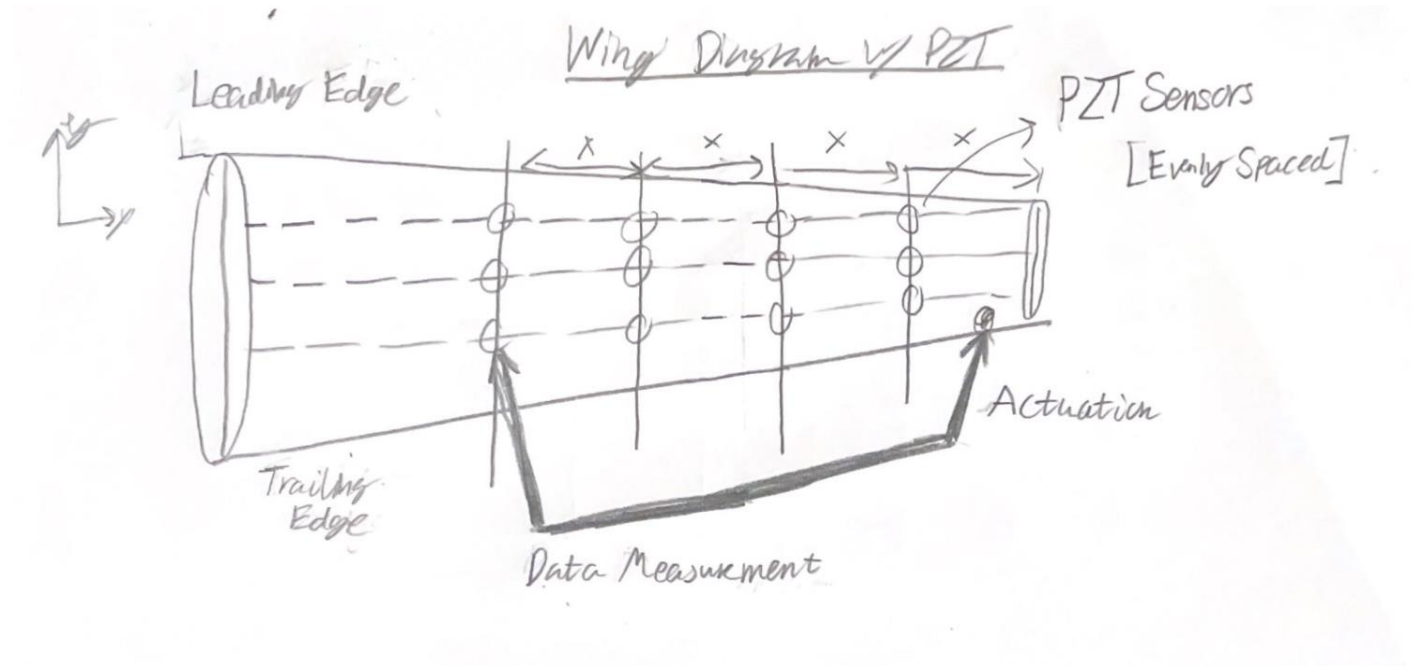
Method of Approach

Equipment and setup

- Equipment
  - PZT-sensors
  - Shaker
  - Data-acquisition
- Set-up
  - Elastic Chord
  - M5-75mm – albatross
  - Backplate
  - Hooks (ceiling and plate)

Diagram of PZT

PZT Sensor Distribution:



Key: monitor the difference between the the frequency at different locations of each PZT sensor

Problems Encountered

- Despite numerous MATLAB code variations, lack of synchronization between outputs did not allow for the generation of random vibrations throughout the Albatross
- Random vibration testing excites all the frequencies within the range and is the closest realistic representation of operating conditions
- While the synchronization errors were being worked on, data was collected from shaker on a metal slab to collect data from the equipment

Problems Encountered

- MATLAB failed code variations

```
clc
d = daqlist;
disp(d)

disp(d{1, "DeviceInfo"})

% Create Data Acquisition
dq = daq("ni");
dq.Rate = 2133;
disp(dq)

% Add input and output channels
addinput(dq, "cDAQ1Mod1", "ai0", "Voltage");
addoutput(dq, "cDAQ1ModX", "aoY", "Voltage");

% Define and send output signal
t = linspace(0, 10, dq.Rate * 10);  % 10 seconds of data
outputSignal = sin(2 * pi * 5 * t);  % Example: 5 Hz sine wave
write(dq, outputSignal);

% Read input data
data = read(dq, seconds(10));
```

```
% Clear the command window and workspace
clc
clear

% 1. Proper definition of the sampling rate based on the hardware module
% Query the connected DAQ devices
d = daqlist;
disp(d);

% Define the DAQ session
dq = daq("ni");
% Define the sampling rate based on your hardware module's capabilities
dq.Rate = 10000; % Example: 10 kHz, adjust this based on your hardware

% 2. Proper definition of excitation (output) and response (input) channels
% Add an output channel for excitation
excitationChannel = addoutput(dq, "cDAQ1Mod2", "ao0", "Voltage");
% Add an input channel for response
responseChannel = addinput(dq, "cDAQ1Mod1", "ai0", "Voltage");

% 3. Use Matlab to define an actuation and send it to the NI module, then to the amplifier and shaker
% Define an actuation signal, e.g., a sine wave
t = (0:dq.Rate-1)'/dq.Rate; % Time vector
actuationSignal = 1.5 * sin(2 * pi * 50 * t); % Example: 1.5V amplitude, 50Hz sine wave

% Write the actuation signal to the excitation channel
queueOutputData(dq, actuationSignal);

% 4. Ensure excitation and response signals are synchronized
% Read the response while simultaneously outputting the excitation signal
[data, time] = readwrite(dq, actuationSignal, seconds(10));

% Display end of data acquisition
disp("End of Data Acquisition");

% Plot the response data
figure();
plot(time, data.cDAQ1Mod1_ai0);
xlabel('Time (s)');
ylabel('Voltage (V)');
title('Response Signal');

% Further signal processing can be done here as required
```

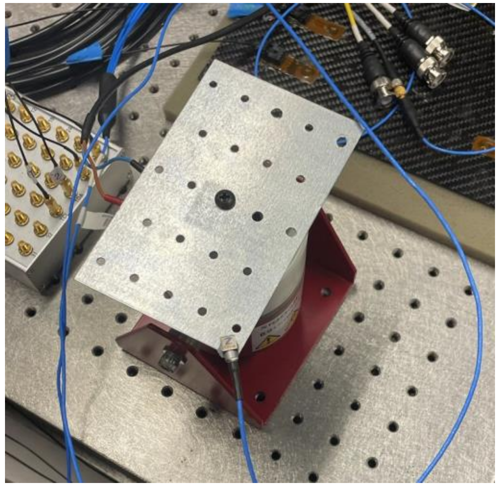
```
% Clear Command Window and Initialize
clc
disp('Initializing Data Acquisition System...');

% Connect to the Abacus 906 DAQ Device (Replace with specific connection command)
daqDevice = connectToAbacus906();  % Hypothetical function to connect to the device

% Set the Sampling Rate (Replace with a command compatible with Abacus 906)
setSamplingRate(daqDevice, 2133);  % Hypothetical function to set sampling rate

% Define and Add Input and Output Channels (Replace with relevant Abacus 906 commands)
addInputChannel(daqDevice, "ChannelID", "Voltage");   % Replace "ChannelID" with actual channel ID
addOutputChannel(daqDevice, "ChannelID", "Voltage");  % Same here

% Define Actuation Signal (e.g., a sine wave)
t = linspace(0, 10, 21330);  % 10 seconds at 2133 Hz
outputSignal = sin(2 * pi * 5 * t);  % Example: 5 Hz sine wave

% Send Actuation Signal to the Output Channel (Replace with Abacus 906 command)
sendOutputSignal(daqDevice, outputSignal);  % Hypothetical function

% Start Synchronized Data Acquisition (Replace with Abacus 906 command)
startAcquisition(daqDevice);  % Hypothetical function

% Read Data from Input Channel (Replace with Abacus 906 command)
inputData = readInputData(daqDevice, 10);  % Read for 10 seconds, hypothetical function

% Stop Acquisition
stopAcquisition(daqDevice);  % Hypothetical function

% Plotting the Input Signal
figure;
plot(t, inputData);
title('Input Signal');
xlabel('Time (seconds)');
ylabel('Voltage (V)');

% Process and Analyze Data (Example: Detrend and Normalize)
outputn = detrend(inputData./std(inputData));
N = length(outputn);
fs = 2133;  % Sampling rate
window = N; % Window length
noverlap = []; % Overlap
nfft = N; % Number of FFT points

% Power Spectral Density (PSD) Analysis
[psd, f_psd] = pwelch(outputn, window, noverlap, nfft, fs);
psd = 10*log10(psd);

% Plotting PSD
figure;
plot(f_psd, psd);
```

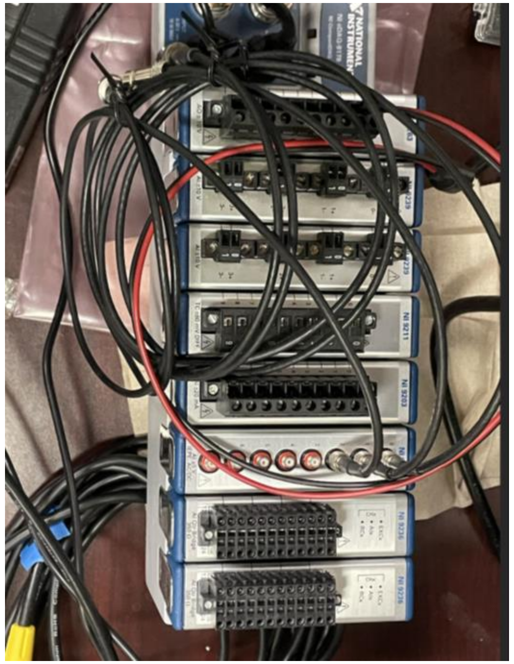
Problems Encountered

- Some concepts incorporated in MATLAB variations:
  - Actuation signal: Output sent to the NI module, and then to the amplifier and shaker. Modify the signal as needed for your application
  - Sampling rate: adjusted to hardware specifications
  - Channel output based on actuation ("cDAQ1Mod2", "ao0", "cDAQ1Mod1", "ai0")
- **Synchronization**: ensuring the actuation signal is output while simultaneously reading the response signal to achieve synchronization at 1-sample level.

Experiment on Plate

- Since the synchronization code variations failed, the albatross would not be testable. So, an experiment was tested on a 3"x5" piece of metal to simulate the albatross for the shaker.
- Purpose:
  - 1. To ensure proper equipment setup through data collection
  - 2. To find data to use in direct measurement of the Albatross UAV

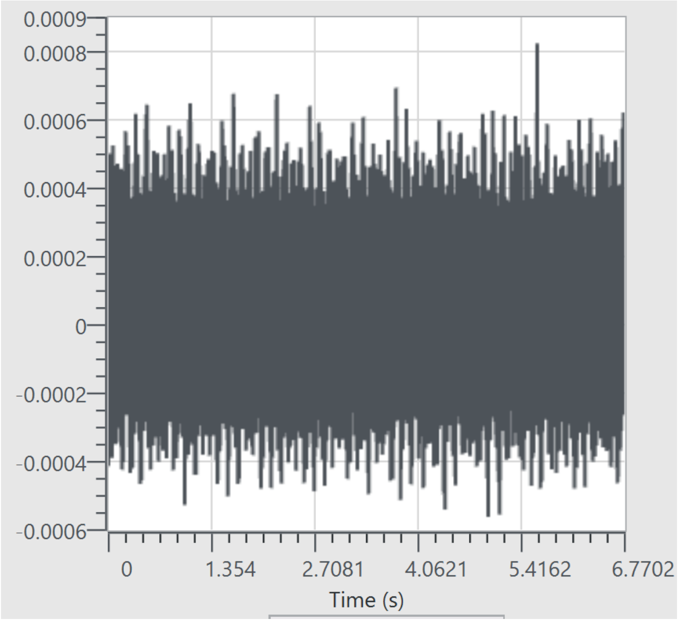




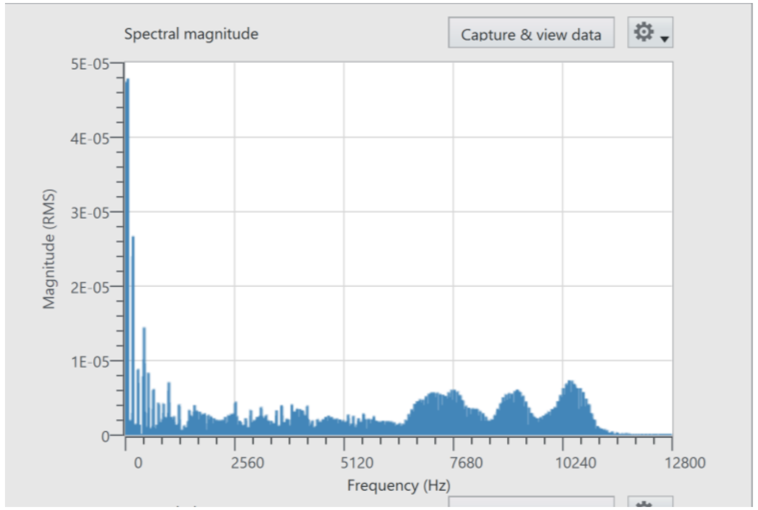
FFT Results

FFT results for shaker-backplate vibrational analysis

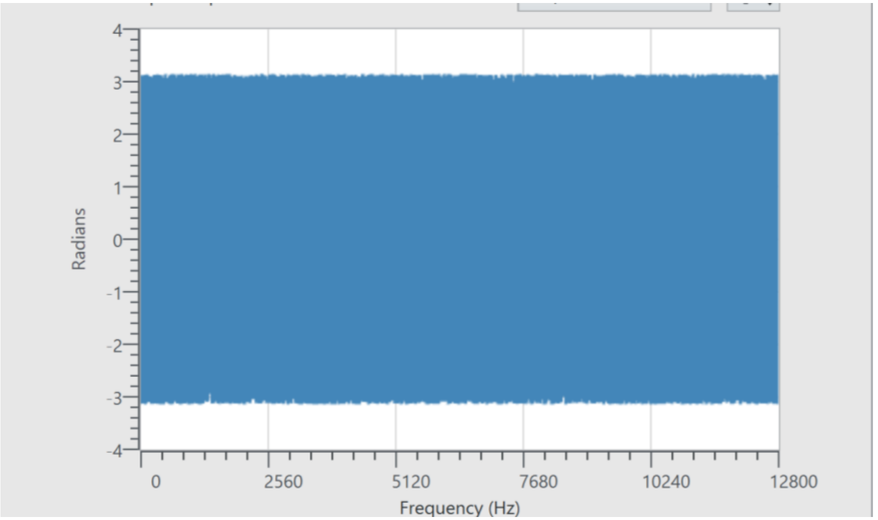
Time domain



Magnitude

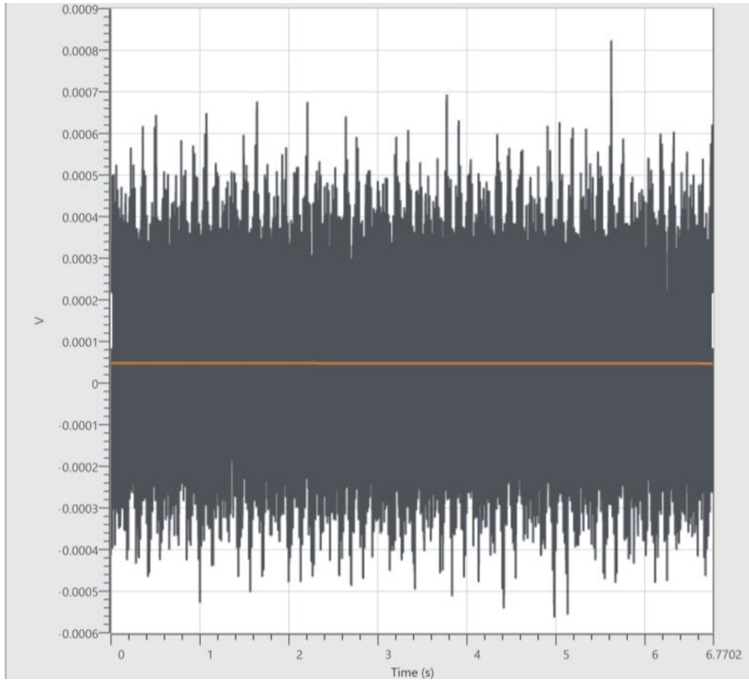


Phase

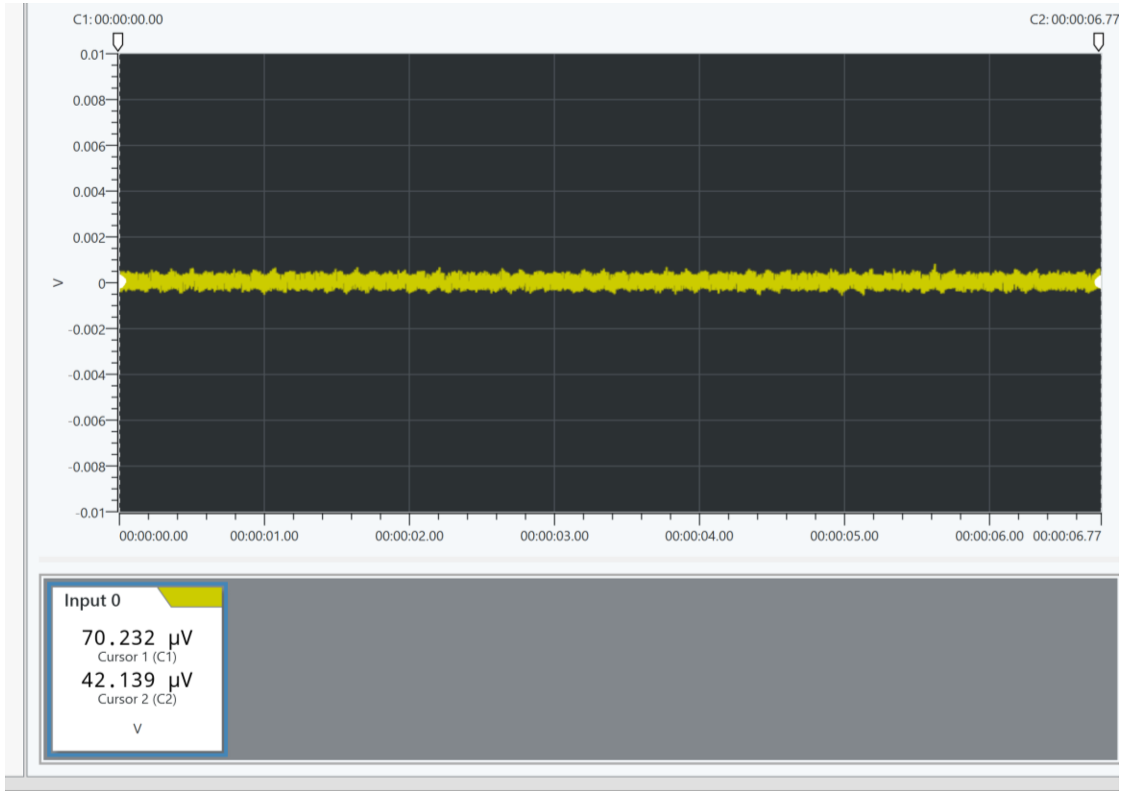


Input FFT results

Time domain results
At excitation of 6 Vpp
Transformation of time



Zoomed out



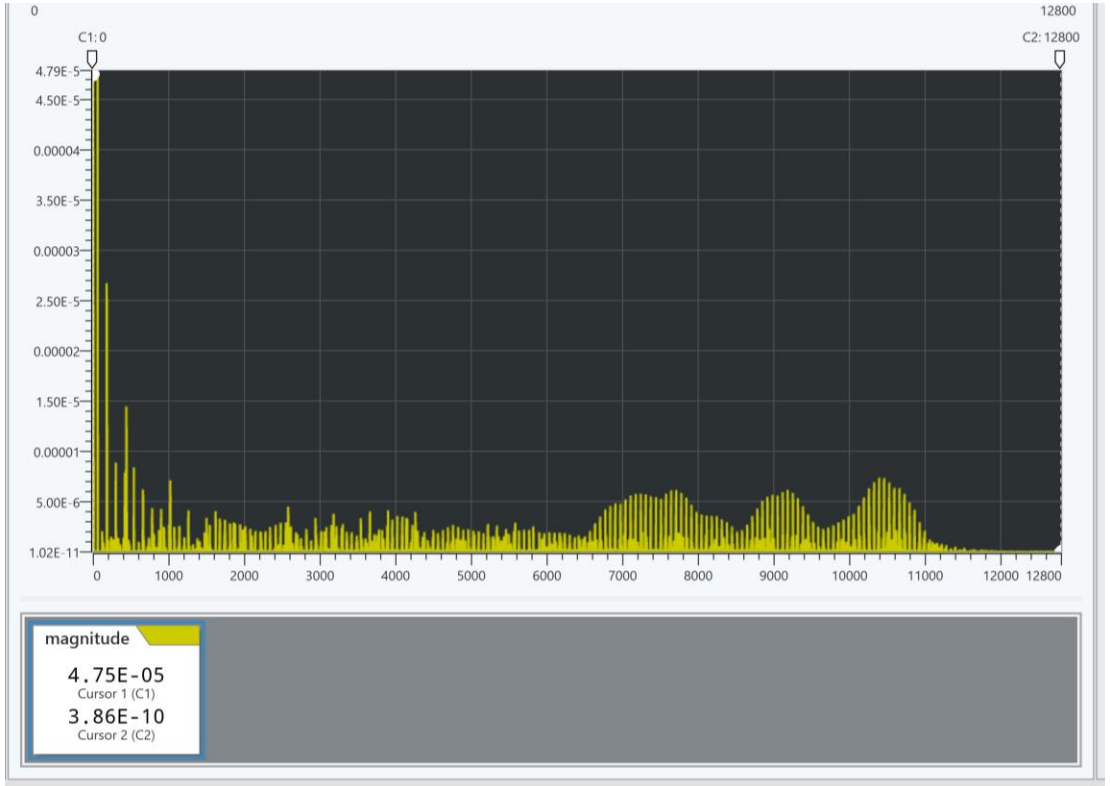
Time domain results

Magnitude FFT Results

Baseline: 2E-6
Time span: 6.77s
Resonance at 60fz

- Lower frequency peaks below 1000hz
- Higher frequency peaks past 5500hz

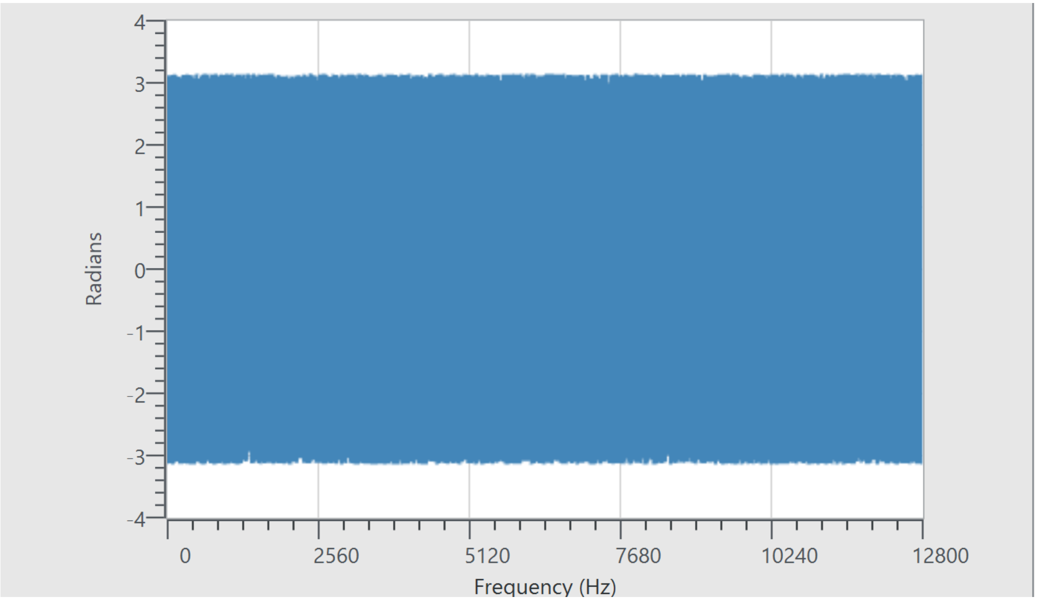
- Transformation of the time domain signal into the frequency
- Displaying amount of signal energy at each frequency with peaks being

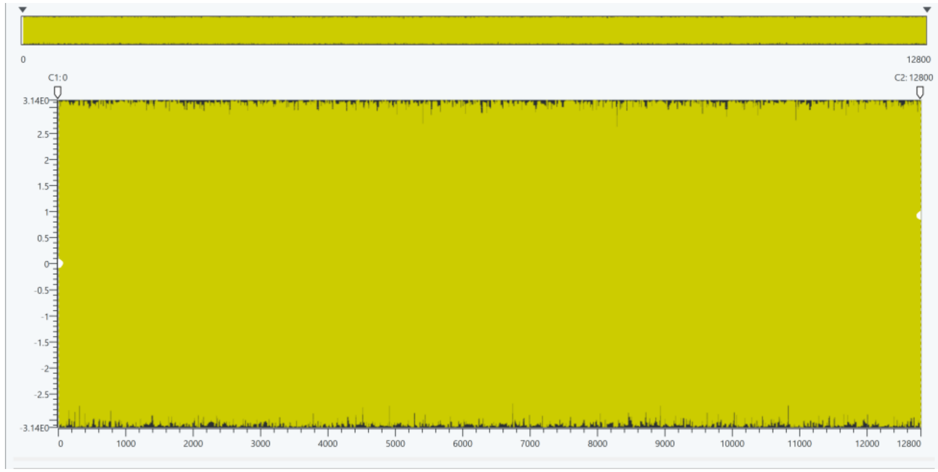


FFT Results

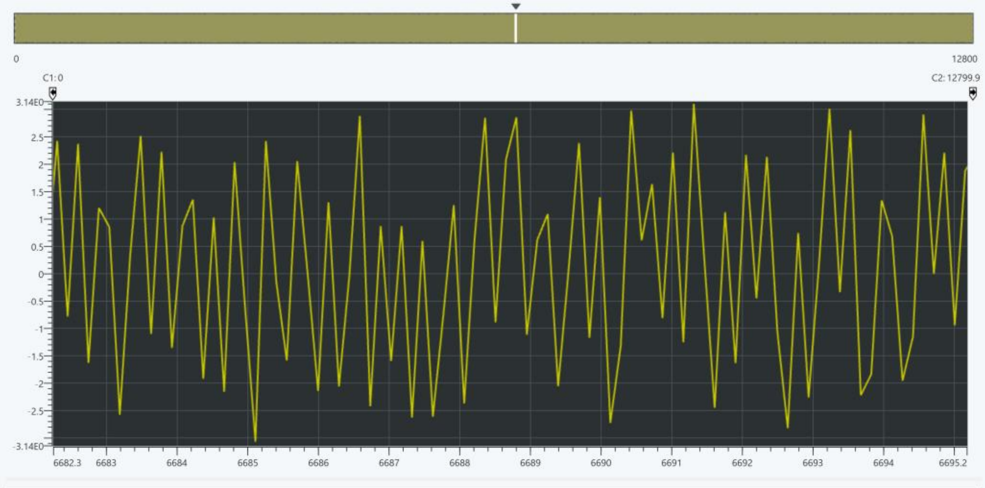
Phase FFT Results

The FFT phase graph displays the phase of each signal at each frequency, which paired with the magnitude graph would reflect the signal in the frequency domain



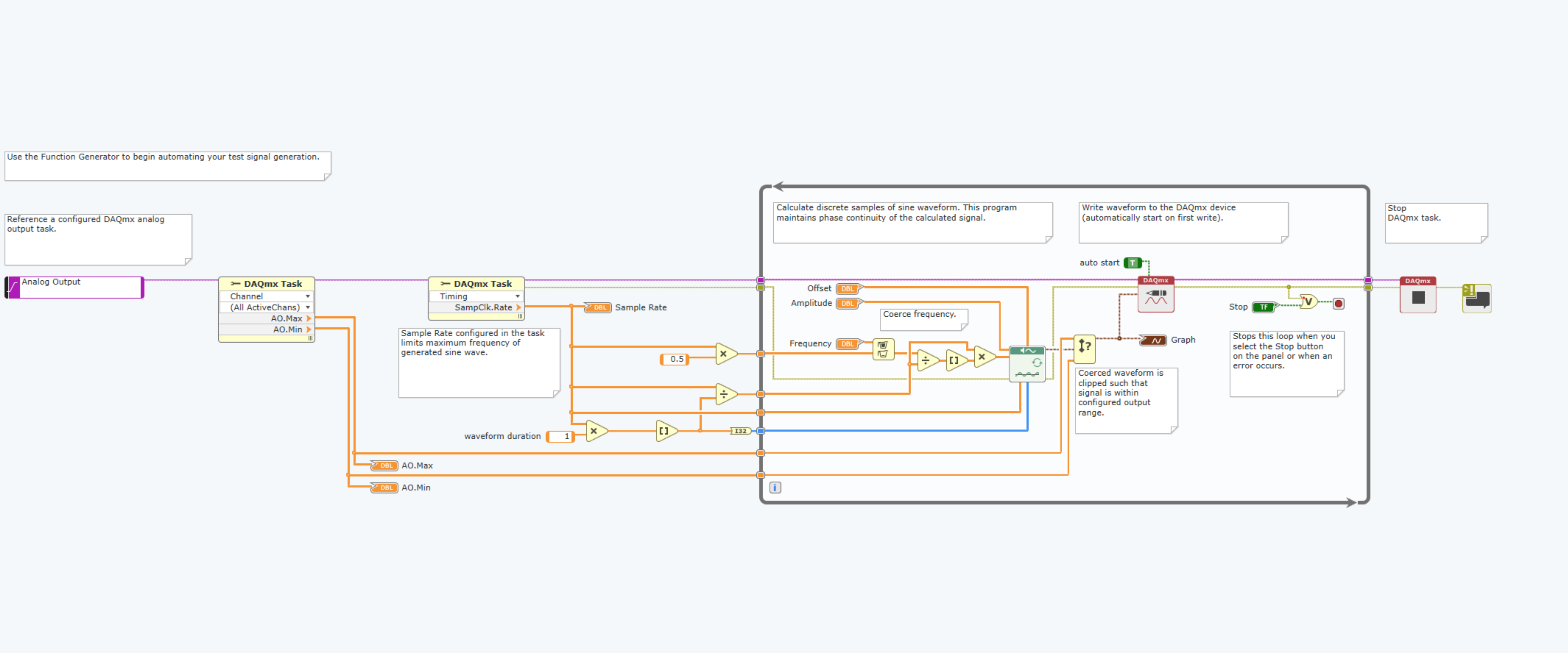


Zoomed Out

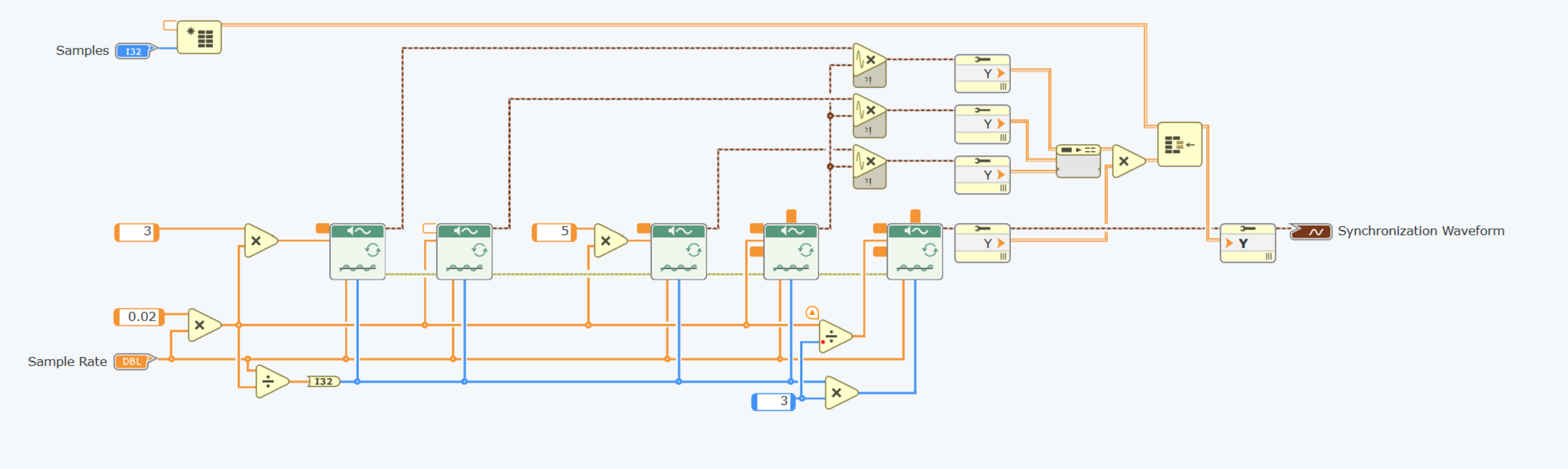


Zoomed in

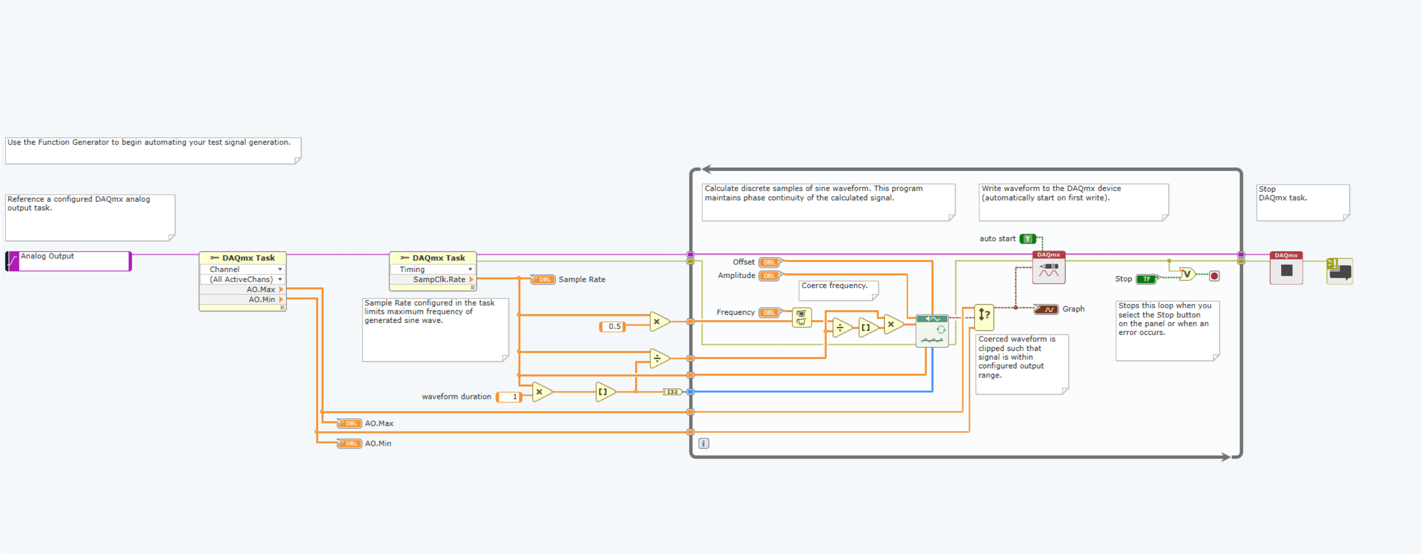
Synchronization Waveform 1

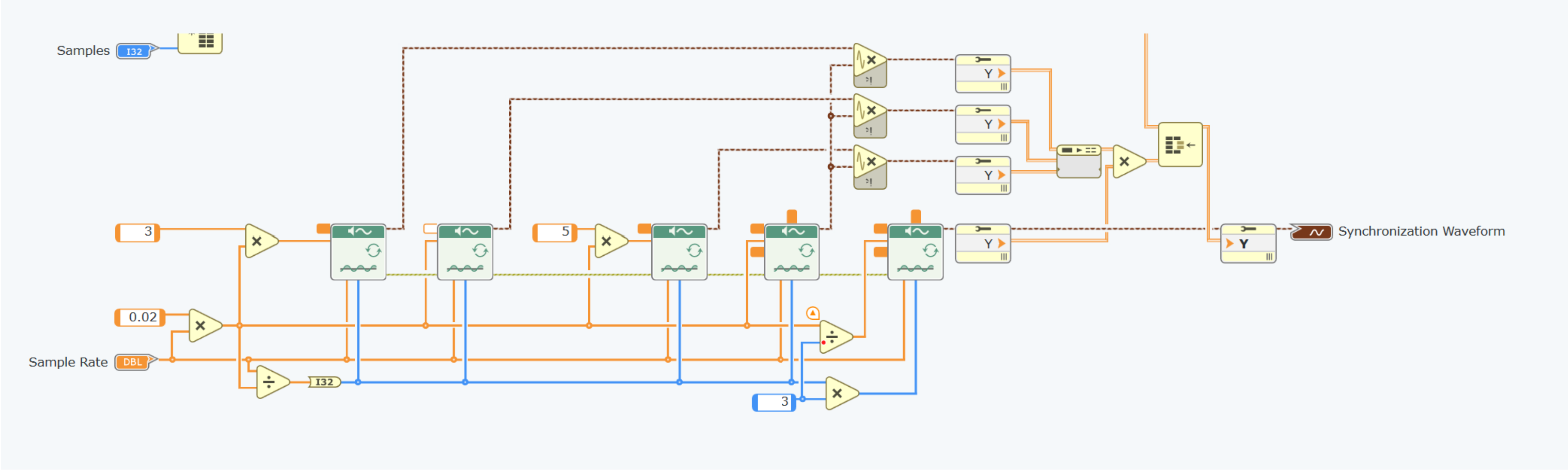


Synchronization Waveform 2



Synchronization Waveforms





Analysis

- The Data acquisition showed results from one signal and reflected a map of how synchronization will be achieved for the albatross with the current data acquisition being used.
- The two maps reflect visual representations a functional block for controlling simultaneous tasks to deal with signal processing and synchronizing events

If results were synchronized:

- FFT of each signal would be calculated over the same time intervals so that comparisons of frequency content are valid, which would be essential for identifying correlated frequency components across multiple signals.

Analysis

- This experiment of the plate simulated that of the UAV and illustraited what results are needed for when synchronization is completed.
- How this process be reflected for the Albatross:
    1. Collect baseline results
    2. Find results from shaker
    3. Compare baseline results to random vibration results

    Changes in resonant frequencies (peaks) between baseline and tested vibrations would also indicate damage at location of sensor

Conclusion and Future Steps

The summary of this experiment between the shaker and the data acquisition confirms that the equipment for the experiment will be set-up correctly and lays the foundation of how the vibrational analysis will be conducted following synchronization

- With two shakers and acquisition systems, this means that vibrational testing of albatross can be conducted without equipment from the blade tests.

Future Steps:

1. Synchronization
2. Conduct the experiment with Albatross
3. Compare results