Team 39: FFT-Based Vibration Signature Analysis

Sponsored by Omron Automation

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***Abstract*—For this project, a student team elected to assist Omron Automation to design a program in a programmable logic controller that would classify vibrating parts into categories based on their fast Fourier transform signatures. The program designed detects changes in amplitude at frequencies characteristic of worn gears in motors. The experimental results indicate this program could reliably be used to autonomously and precisely measure changes in amplitudes of vibrating parts.**

I. Introduction

Omron Automation is investigating the feasibility of including vibrational diagnostics in their products. Analysis of the vibrational patterns of worn and unworn motorized parts has shown significant changes in their amplitudes in frequencies between 1 and 10 kHz. Vibration analyzers for diagnosing when motorized parts need maintenance are already on the market and have shown commercial success. Therefore, the team opted to design a system that could detect changes in signals of frequencies between 1 and 10 kHz.

II. Problem Description And Statement

The manufacturing process has many points at which quality of manufactured parts can decrease. Vibrations can be used to test for these defects, using a sensor and an OMRON Programmable Logic Controller (PLC) to compare vibrational patterns to a baseline using analysis software. Using this comparison, workers can use this system to gain accuracy in quality control.

III. Methods And Materials

A. Overview

A signal is created digitally using a function generator and an exciter transforms the signal into measurable vibrations. An accelerometer attached to the exciter converts the measured vibrations into an electrical signal interpretable by an analog input/output bus attached to a PLC. Using a Fast Fourier Transform (FFT) program, the PLC transforms the signals to the frequency / amplitude domain. The vibration signal from the exciter is run with various amplitudes and the PLC program used to measure the variety. Based on comparisons between the desired amplitude and the recorded amplitude, the PLC will set flags for downstream effectors.

B. Materials

<u>Hardware</u>

- TIRA Vibration Test System TV 51120 (exciter)
- TIRA BAA 120 Power Amplifier (power to exciter)
- PCB Piezotronics 621C40 (accelerometer)
- PCB Piezotronics 480E9 (signal conditioner)
- OMRON NJ-501 1320 Version 1.3.20 (PLC)
- Digilent Analog Discovery 2 (function generator)

<u>Software</u>

- Sysmac Studios (PLC program)
- Digilent WaveForms (function generator program)

C. Methods

<u>Creating The Comparison Signal</u>

Setup: A test was conducted using a constant sine wave signal created in the Digilent Function Generator with an amplitude of 1 (unitless) and a frequency of 3000 Hz. The signal was amplified by a TIRA Power Amplifier to match the input specifications of the TIRA Vibration Test System. The PCB Piezotronics 621C40 attached to the TIRA Vibration Test System converted the measured vibrations into a +/- 1V signal. That signal was fed into the PCB Piezotronics 480E9. The gain of the PCB Piezotronics 480E9 was set to 10, so that a signal of +/- 10V was fed into the NX-HAD402 connected to the NJ-501 1320. The NJ-501 1320 was programmed to read 2000 samples from the exciter 10 times every millisecond for 200 milliseconds (2000 samples total) during steady-state and take the FFT of the collected samples, storing them in an “FFT” array. The FFT array was scanned for amplitudes both significantly higher than others and consistent over several cycles. These amplitudes and frequencies were recorded in a “key” array.

<u>Using The Comparison Signal</u>

The procedure for creating a comparison signal is repeated using an amplitude lower than 1. The resulting values are stored in a “sample” array. The ratio of the input amplitudes to the function generator are compared with the ratio of the amplitudes of the key and sample arrays.

IV. Results

A. Amplitude Comparisons, Individual Signals.

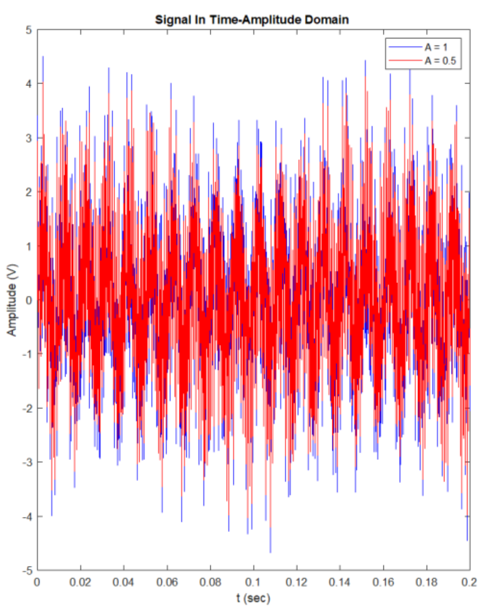
Trial	Input Amp.	Input Freq.	Sample Array Freqs.	Sample Array Amp
1	1	100	50	0.5290 (split)
2	1	1333	650	0.7220 (split)
3	1	2546	1240	0.5170 (split)
4	1	3000	1465	0.6667
5	0.5	3000	1465	0.8181
6	1	3871	1890	0.5815
7	1	5000	2440	0.8416

The table in A. shows the values recorded by the PLC when the function generator was used to create single sin wave inputs. (split) indicates the signal was split into 2 or more signals over 5-25 Hz.

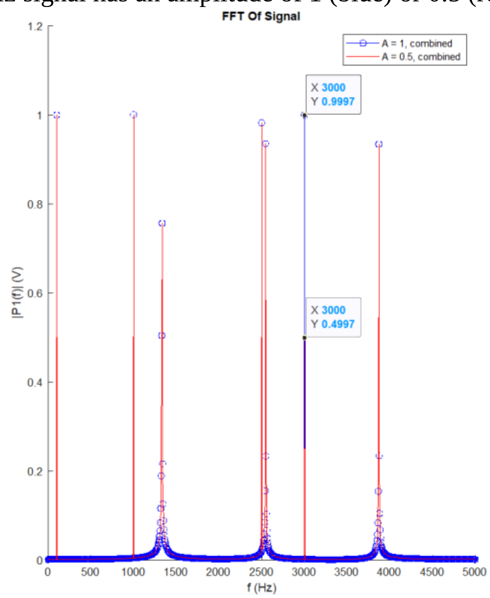
B. Amplitude Comparisons, Combined Signals

Trial	Input Amp.	Sample Array Freqs.	Sample Array Amp
1	1	100	0.2710
2	1	1333	0.2490
3	1	2546	0.1155 (split)
4	0.5	3000	0.5474 (split)
5	1	3871	0.4729
6	1	5000	0.1406

The table in B. shows the values recorded by the PLC when the function generator was used to create a signal of the sum of the sin waves in part A (excepting trial 4). (split) indicates the signal was split into 2 or more signals over 5-25 Hz



The figure above titled “Signal In Time-Amplitude Domain” graphically displays what direct readings from the accelerometer would look like for the combined signal if the 3000 Hz signal has an amplitude of 1 (blue) or 0.5 (red).



The figure above titled “FFT Of Signal” graphically displays the theoretical results the PLC calculates from the FFT function performed on the signal from part B. if the 3000 Hz signal has an amplitude of 1 (blue) or 0.5 (red).

V. Discussion Of Results

Comparing the results in A to the results in B. shows that with a variety of signals of comparable amplitudes, our program cannot yet consistently distinguish small changes in amplitudes from signals. The frequencies displayed in the PLC sample array are not always consistent with the input frequencies, but they are consistent with how they are measured (i.e. during the test the sample array frequency of 650 was always associated with the actual input frequency of 1333). It is suggested for future research to create a running average of the sample array amplitudes as they could vary by 1 or more order of magnitude per reading.

VI. Conclusions

The program’s ability to separate frequencies in signals in the frequency spectrum where the wearing of motorized parts can be detected make it suitable for pursuing further research in developing a program capable of automating this process, but first a consistent way of measuring the amplitude in the sample array must be developed.

VII. Acknowledgments

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