The University of Texas at Austin
Aerospace Engineering and Engineering Mechanics
Cockrell School of Engineering

ASE 375 Electromechanical Systems
Section 14115

Monday: 3:00 - 6:00 pm

Report 6: Measuring Dynamic Response with Accelerometers

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Contents

1 Introduction

This experiment explores the dynamic response of a built-up wing from measurements using (1) a Piezo-electric accelerometer and (2) a Micro-Electro-Mechanical system (MEMS) accelerometer. The goal of this lab experiment is to learn how the accelerometers work by performing a resonance assessment profile (rap or impulse) test on the make-shift wing.

The piezoelectric accelerometer cannot measure static quantities, meaning it does not take into the account the force exerted by gravity. On the other hand, the MEMS accelerometer does take into account the gravitational force in its measurements. This lab experiment provides a foundation for understanding the operational aspects of the accelerometers as well as a rap test use-case that show how these sensors are applied in testing of aircraft surfaces.

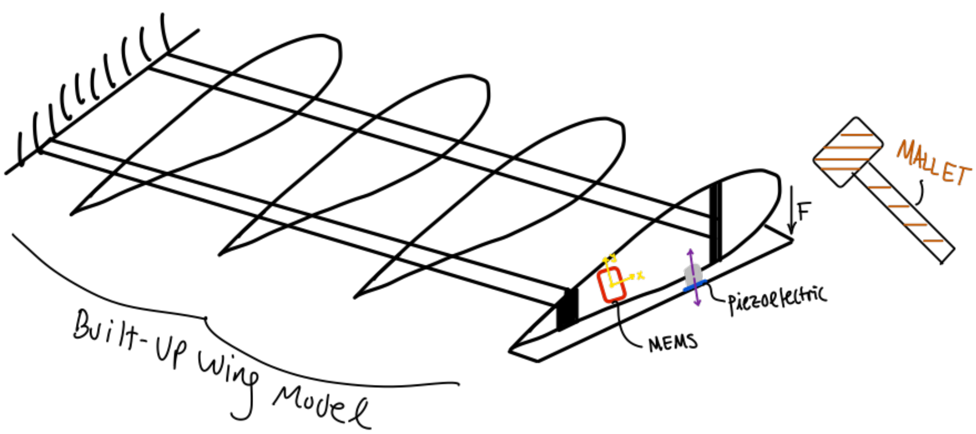
2 Equipment

Measurement devices and hardware used in this lab include:

- Built-Up Wing Model:

  In this lab we will use a scaled-down wing model for performing the rap test. This form of experiment is useful in application as rap tests are performed on control surfaces of aircraft.

  Figure 1: Sketch of Built-Up Wing Model setup

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- Piezoelectric Accelerometer (IMI 660)

  An IMI Series 660 accelerometer is used in the experiment. This Piezoelectric accelerometer only measures acceleration in one direction, and is placed on the built-up wing model as shown in Figure 1.

  The operational principle of the Piezoelectric accelerometer is in it piezoelectric crystal, which generates charge from applied stress. It converts mechanical energy into electrical energy. The crystal acts like a capacitor (stores electrical energy). Operational Voltage = 5V

- MEMS Accelerometer (ADXL335)

  The ADXL335 is a small 3-Axis MEMS Accelerometer which operates based on differential capacitance. An applied force or acceleration will change the capacitance within the MEMS accelerometer. In this experiment, the MEMS accelerometer is placed as shown in Figure 1, using only the X-and Y-axes. Operational Voltage = 3.3V

- Brass Mallet:

  A brass mallet is used to apply a tap force to the built-up wing model as shown in Figure 1.

- DAQ, NI-9215 Voltage Input Module, and LabVIEW:

  Data Acquisition System used to process sample measurements into digital data. NI-9215 is an analog input module used to measure the output voltage signals of sensors and send it through the DAQ system. LabVIEW used to model these output voltages read from the DAQ of the accelerometer measurements. We connect to the 3.3V and 5V ports of the DAQ for our experiment.

- Solderless Breadboard, Jumper Wires:

  Used to make connections to the input analog modules and to construct circuits. In this lab we connect the accelerometer inputs to the breadboard for power, ground, and signal to the measurement axes.

3 Procedure

Before beginning the experiment, we must build the block diagram which will be executed by LabVIEW to gather our accelerometer measurements.

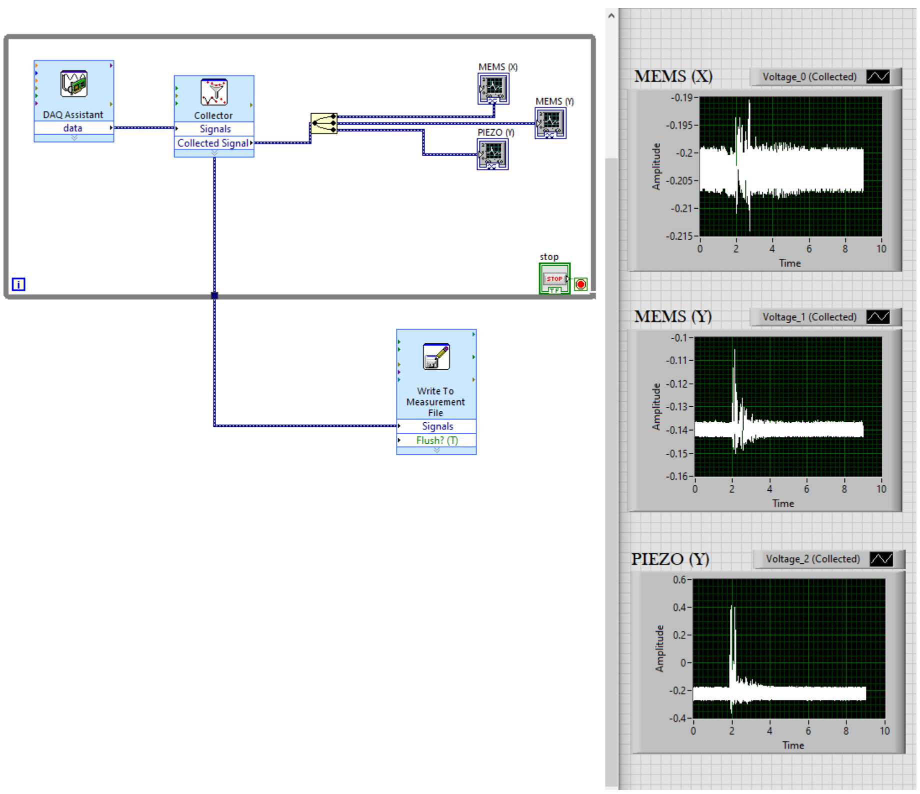

Figure 2: LabVIEW Model Setup for Accelerometers

3.1 Accelerometer Setup and Experiment

1. First, connect the MEMS and Piezoelectric accelerometers accordingly to power and ground, and connect the signal wires to corresponding NI-9215 ports.
2. Place the MEMS and Piezoelectric accelerometer on the wing model as shown in Figure 1.
3. Before hitting the wing with the brass mallet, the test that the MEMS and Piezoelectric accelerometers work by applying a force and observing the corresponding output in LabVIEW. Continue to the next step once working. If not working, check possible issues which may include:
   - Connections on breadboard
   - Faulty wires from NI-9215 Port
   - Faulty accelerometer sensor
4. Run the LabVIEW model as shown in Figure 2 and tap the wing with the brass mallet. Let it record the accelerometer data for 5 seconds. Save the data to a file and ensure it has been written correctly.
5. Repeat previous step (3) for 10 measurements.
6. Once complete, we are ready to plot the measured accelerations and evaluate the data. From this we can identify the natural frequencies of the wing.

4 Data Processing

4.1 Variables and Equations

Newton's 2nd Law:

$$a = \frac{F}{m} \tag{1}$$

Variables:

I. V: Voltage

5 Results and Analysis

NaturalFreq_5seconds =

59.9060 60.2289 59.8060 59.7060 59.8060 59.8060 59.7060 59.7844 59.6733 60.3060

NaturalFreq_LastSec =

60.0120 59.7911 59.8120 59.6119 59.8120 59.8120 59.8120 59.7911 59.5688 60.2120

Avg5SecFreq =

59.8729

AvgLastSecFreq =

59.8235

6 Conclusion

In this lab experiment we learned how the piezoelectric and MEMS accelerometers operate in order to measure acceleration and perform frequency analysis of an aircraft surface. These devices are very practical in analyzing aircraft control surfaces that experience lots of vibration as these sensors are very responsive to forces. Analysis of these surfaces provides critical information useful to the structural dynamics of an aircraft. Due to this, accelerometers play an important role in ensuring an aircraft is safe to fly.

Appendix

NI-9215 Datasheet

https://www.amc-systeme.de/files/pdf/ni-9215-amc.pdf

IMI Series 660 Accelerometer Datasheet

https://pim-kft.hu/wp-content/uploads/2016/02/PCB_LowCost_Embeddable_Accelerometers.pdf

ADXL335 Accelerometer Datasheet

https://www.analog.com/media/en/technical-documentation/data-sheets/adxl335.pdf