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 8:
Landing Gear Drop Test

Andrew Doty, Andres Suniaga, Dennis Hom
Due Date: 04/08/2024

Contents

1 Introduction

In this experiment we take a look at the transient response of a landing gear as it is dropped from various heights. Drop tests are a useful measure to verify the performance and safety of an aircraft. In this lab we use a small scale landing gear equipped with a rotary potentiometer to measure the angle of the landing gear linkage and a piezoelectric accelerometer to measure the acceleration of it's response. From the potentiometer data we can calulate the stroke of the landing gear, which represents the compression or stretching of the spring attached to the landing leg.

Using a laser pointer and a photo-diode, we are able to perform triggered data acquisition of the transient response of the landing gear as it makes impact with the table surface. These triggered measurements allow us to gather consistent and time-resolved data for each drop height.

2 Equipment

Measurement devices and hardware used in this lab include:

- Small-Scale Landing Gear:

  Scaled-down landing gear used for drop testing. Setup shown in Figure 1

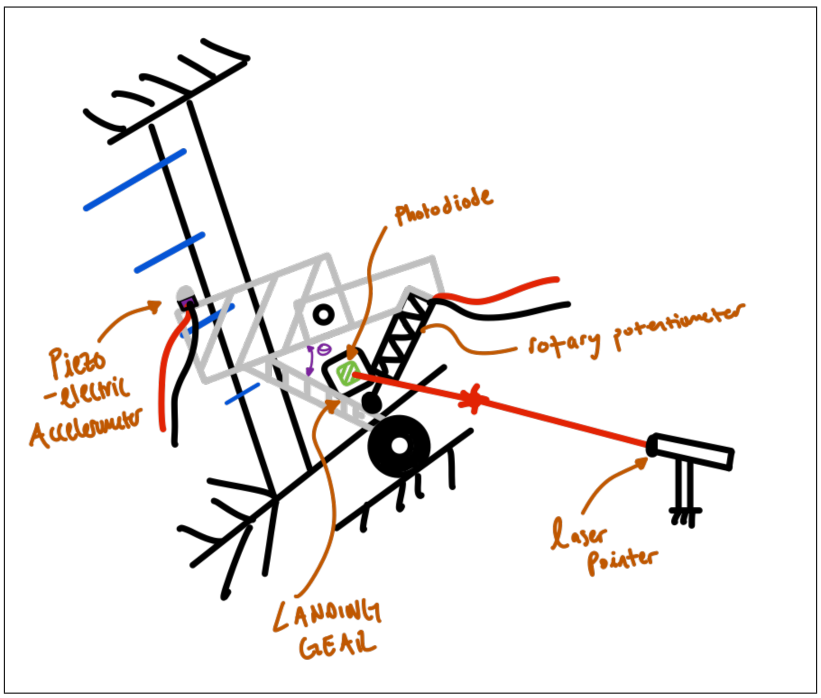

Figure 1: Landing Gear Drop Test Setup

- Piezoelectric Accelerometer [2]:

  The Piezoelectric accelerometer only measures acceleration in one direction, and is placed on the small-scale landing gear 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

- Laser Pointer (Red, $\gamma \approx 700$ nm) and Silicon Photodiode [3]:

  For this setup, a red laser pointer shines on the Si photodiode until interrupted by the dropped landing gear at which a response is triggered and we are able to model this transient response of the landing gears impact.
  The Si photodiode is able to convert optical power into electrical current, which as seen in Figure 2, allow passage of current when the diode is triggered or interrupted by the landing gear, allowing us to get the time-resolved V_{OUT} measurements for each height drop.

- Rotary Potentiometer:

  The rotary potentiometer is used to calculate the angle θ between the landing gear leg and the structure it is fixed on as seen in Figure 1.
  The working principle of the rotary potentiometer is angular movement. There is a shaft or knob which varies resistance as it is turned.

- DAQ, NI-9215 Voltage Input Module [1], and LabVIEW:

  Data Acquisition System used to process sample measurements into digital data for the computer to read.

  NI-9215 is an analog input module used to measure the output voltage signals of the sensors.

  LabVIEW used to model these output voltages read from the DAQ of the piezo-electric accelerometer, photodiode, and rotary potentiometer.

- Solderless Breadboard, Jumper Wires, 1 kΩ Resistor, 0.1 µF Capacitor, and 10 kΩ Resistor:

  Used to make connections to the input analog modules and to construct circuits. In this lab, we construct a circuit as shown in Figure 2 with the 1 kΩ Resistor and 0.1 µF Capacitor serving as the noise filter. The 10 kΩ Resistor is reached only if the laser to the diode is interrupted by the landing gear, which will trigger the measurements to begin.

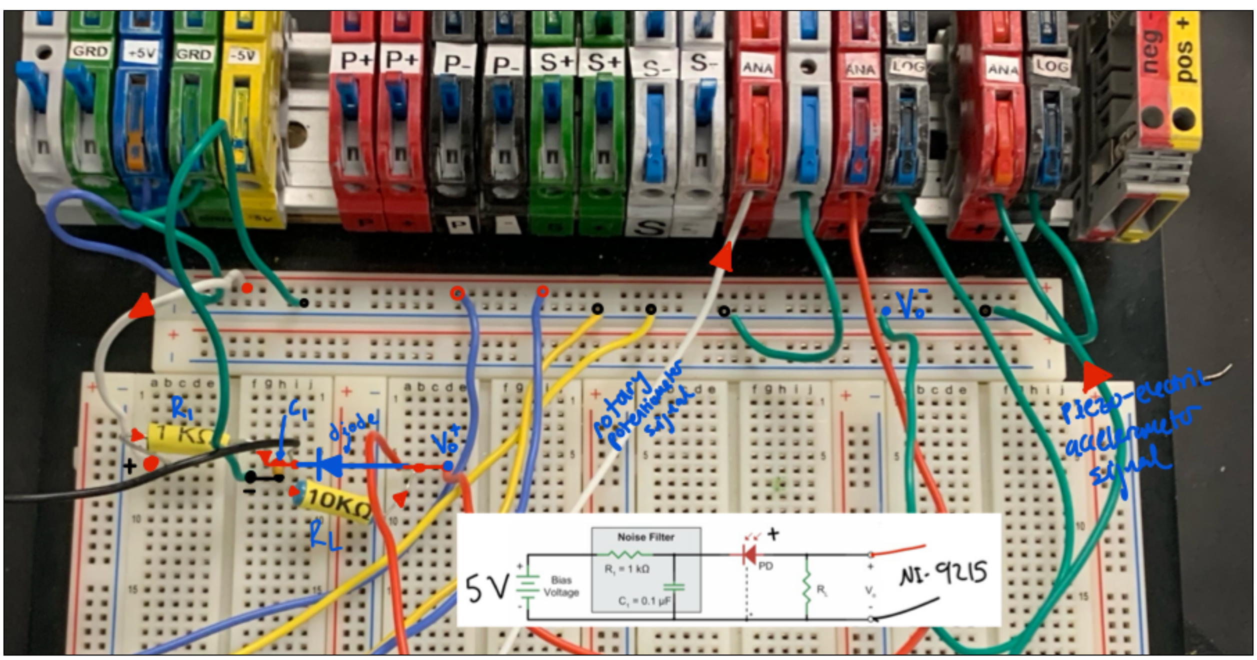

Figure 2: Photodiode Circuit on Breadboard

3 Procedure

Before beginning the experiment, setup the LabVIEW model to output the data from the photo-diode, potentiometer, and piezoelectric accelerometer:

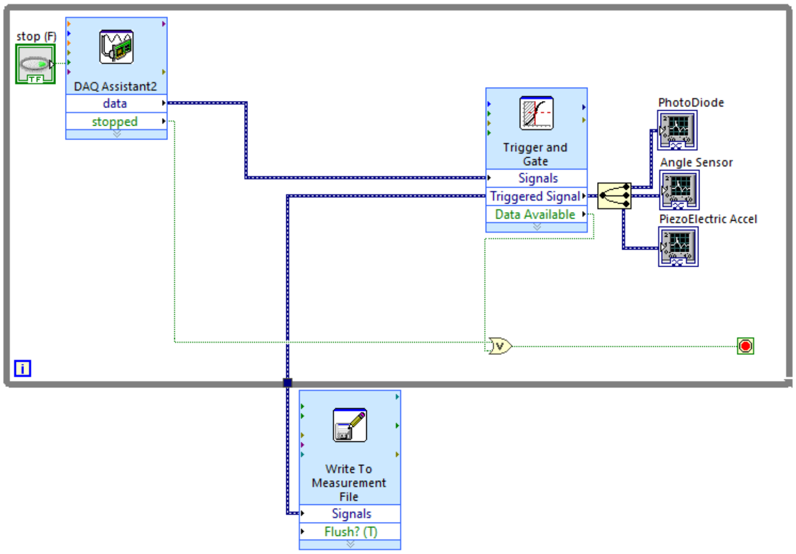

Figure 3: LabVIEW Experiment Setup

Run this model and test a few landing gear drops to ensure there is (correct) output measurements.

3.1 Drop Testing

1. Turn on the laser pointer so that it is shining directly onto the photodiode.
2. Mark 3-5 different heights to drop the landing gear from. Measured from the surface at which the wheel rests, we chose to drop the landing gear at these heights in centimeters:
$$\mathbf{h} = [18, 36, 54, 72]$$
3. For each h_i, raise the landing gear such that the bottom of the wheel sits atop the measurement marker. Start the LabVIEW model and then drop the landing gear. This should interrupt the photodiode as it passes through the laser pointers ray and trigger a response on the LabVIEW plots. This will be the transient response. Save each of the sensors measurements to a file.
4. After performing the landing gear drop test at each height, move on to Data Processing to plot this transient acceleration and landing gear stroke for each h_i.

4 Data Processing

4.1 Variables and Equations

Calibrated Output Voltage:

$$V_{OUT_c} = |V_{OUT} - V_o| \tag{1}$$

Variables:

- V_{OUT}: Output Voltage measurement from DAQ
- V_o: Initial voltage prior to drop

Piezo-electric Measured Transient Accleration:

$$\ddot{x} = \frac{V_{OUT_c}}{C_{\text{piezo}}} \tag{2}$$

Variables:

- $C_{\text{piezo}} = 10$ mV/g: Piezo-electric Accelerometer Calibration Constant

Rotary Potentiometer Angle [4]:

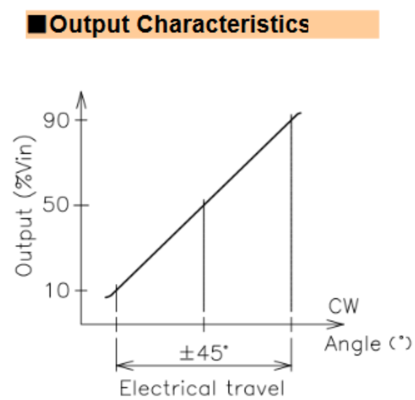

Figure 4: Linear Characteristic of the Potentiometer's Output

$$\theta = \frac{45^\circ}{(0.5 - 0.1)V_{IN}} \cdot (V_{OUT_c} - (0.5V_{IN})) \tag{3}$$

Variables:

- V_{IN}: Input Voltage

Law of Cosines:

$$c = \sqrt{a^2 + b^2 - 2ab\cos(\theta)} \tag{4}$$

Variables:

- a, b: Lengths in inches of the landing gear leg

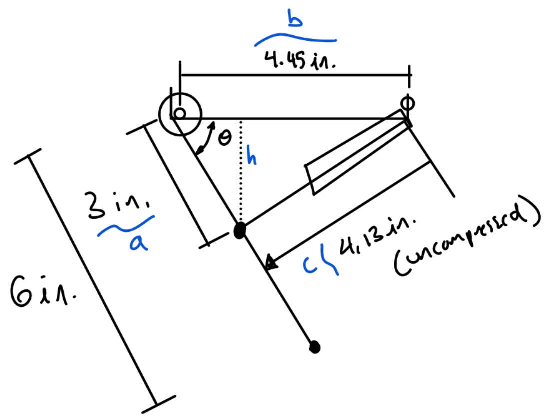

Figure 5: Dimensions of the Small-Scale Landing Gear

Area of a Triangle (Heron's Formula):

$$A = \sqrt{s(s-a)(s-b)(s-c)} \tag{5}$$

Variables:

- $s = \dfrac{a+b+c}{2}$: Semi-perimeter

Height of a Triangle:

$$h = \frac{2A}{b} \tag{6}$$

Stroke Length:

$$y = h_o - h \tag{7}$$

Variables:

- h_o: Uncompressed height, Figure 5.

5 Results and Analysis

For every drop height, the acceleration is at 0 until the moment of impact, where the acceleration increases as drop height increases. Since the landing gear has a spring attached, its velocity reaches a maximum value immediately before impact, then will reverse direction almost instantaneously. As the landing gear drops further, it's impact velocity will be higher.

The landing gear drop tests resulted in Stroke Heights of [9.75, 10.2, 13.1, 14.3]mm. As the drop height was increased, so was the stroke height. These graphs follow similar shapes. The initial deformation is at 0 until the impact from the drop. This peak is the impact of the drop, and after the graph settles at a height larger than the initial, signifying a permanent deformation.

The main source of error is inconsistencies in how the landing gear was dropped.

6 Conclusion

In this lab, we learned how a photodiode operates, and used a trigger to acquire data in a limited amount of time. The landing gear was dropped from multiple heights, with the stroke increasing as the drop height increases. The data also showed that after the initial impact of the landing gear, the system had a permanent deformation in its angle and height.

Appendix

A Datasheets

[1] **NI-9215 Datasheet:**
https://www.amc-systeme.de/files/pdf/ni-9215-amc.pdf

[2] **Piezo-electric IMI Series 660 Accelerometer:**
https://pim-kft.hu/wp-content/uploads/2016/02/PCB_LowCost_Embeddable_Accelerometers.pdf

[3] **Silicon Photodiode, FDS1010:**
https://www.thorlabs.com/drawings/e7e91d1f442ec5dc-834C7101-FD1F-1B62-609D921F0FC0E314/FDS1010-SpecSheet.pdf

[4] **QP-2H Rotary Potentiometer**
https://www.diltronic.com/wp-content/uploads/2020/03/DILTRONIC-QP-2H-serie-datasheet.pdf