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Arduino and Raspberry Pi in a Laboratory Setting

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Utah State University Physics Department

Arduino and Raspberry Pi in a Laboratory Setting

Physics 4900 Research Paper

Abstract

The purpose of this research project was to study the use of Arduino and Raspberry Pi's and investigate the practicality of integrating them into the intermediate and advance laboratory classes. After purchasing diverse types of sensors to use with Arduino and Raspberry Pi, the sensors were then performance tested. The types of sensors that were characterized were an accelerometer, altimeter, barometric pressure, gyroscopic, humidity, magnetic, temperature, and vibrational sensors. Using this analysis, the existing labs can be upgraded and their manuals can be updated and improved to use these sensors where appropriate. This will allow students to learn valuable programming and circuitry skills while using them to advance their knowledge of different physics concepts.

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Spring 2017

Background

Arduino is an open source hardware and software project that began in 2003 at the Interaction Design Institute Ivrea (IDII) in Ivrea, Italy.[2] It began as a project to create low cost, easy to use, and effective digital products by non-engineers. Adafruit Industries, a New York City supplier of Arduino boards, parts, and assemblies, estimated in mid-2011 that over 300,000 official Arduinos had been commercially produced, and in 2013 that 700,000 official boards were in users' hands.[1]

This project aims to test the usefulness and then implement low cost and easy to use Arduino sensors in a laboratory setting. It has been shown that this is possible by students at the French University Paris-Sud.[3] Being able to use these sensors effectively would allow students to create a data center that would give students real time data on pressure, temperature, humidity, lighting conditions, or any other condition the sensors are able to measure. Since these sensors are not overly expensive, this would also help reduce the cost of lab equipment in the future, provided the sensors are able to collect data effectively enough to be used.

Setup and Procedures

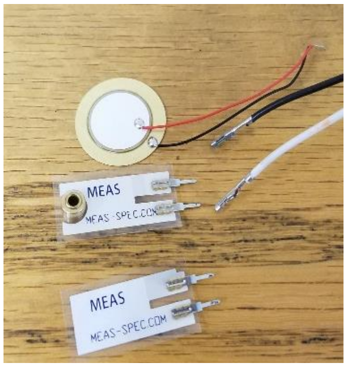


Figure 1: The Piezo Element, Large Flat Vibration Sensor with and

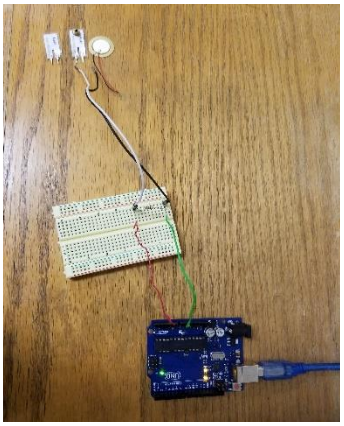


Figure 2: Simple setup of the Arduino Uno and the three vibration sensors

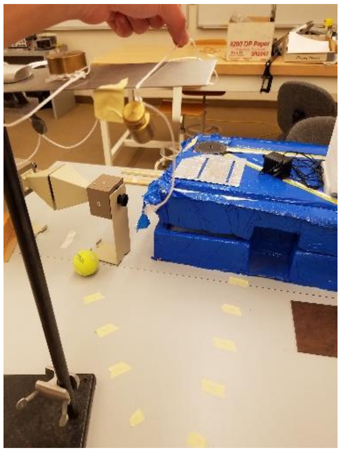
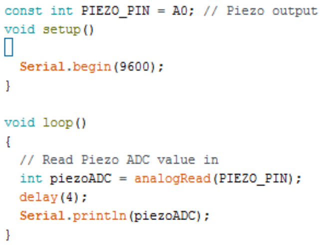


Figure 3: Setup used to drop the masses during data runs with tape placed every 10 cm

The initial steps involved becoming familiar with Arduino and the Arduino IDE. This free IDE is based on the C/C++ coding languages and is documented at Arduino.cc, which makes it much easier to use by students as there are many helpful websites dedicated to walking students through the basics. The first sensors to be characterized were vibration sensors. The ones tested were from Sparkfun and included the round Piezo element sensor, the Piezo large flat sensor with attached mass and the Piezo large flat sensor without attached mass (see Figure 1). We started with these sensors as they were the easiest to write code for and the characterization was thought to be fairly strait forward. The sensor was connected to an analog-in pin, placed in a parallel circuit with a 1 Megaohm resistor and then grounded (see Figure 2). The sensor that was being characterized was placed on various locations on the table or floor, and the surface was marked every 10 cm away from the sensor, (see Figure 3). Using this set up, the performance of the vibration sensors could be characterized by dropping a heavy mass from a 50 cm or 100 cm height and landing at multiples of 10 cm away up to 50 cm from the



```
const int PIEZO_PIN = A0; // Piezo output
void setup()
{
  Serial.begin(9600);
}

void loop()
{
  // Read Piezo ADC value in
  int piezoADC = analogRead(PIEZO_PIN);
  delay(4);
  Serial.println(piezoADC);
}
```

Figure 4: Simplified code used to obtain the digital values

sensor. In order to drop the mass more consistently, a string was attached to the mass and was draped over a hanging piece of material. The string was pulled until the mass was at the same height each time, then released. This helped reduce human error in the setup. There was a total of six different sensor setups and two different drop heights for each of the set-ups. A code was implemented to collect data every four milliseconds. The built in analog to digital converter (ADC) reads the raw voltage from the sensor and converts it into a digital value in the range of 0-1023. The code would then print this value to the serial monitor or plotter in an endless loop (see Figure 4). These values were then exported into an Excel spreadsheet for data analysis.

Results

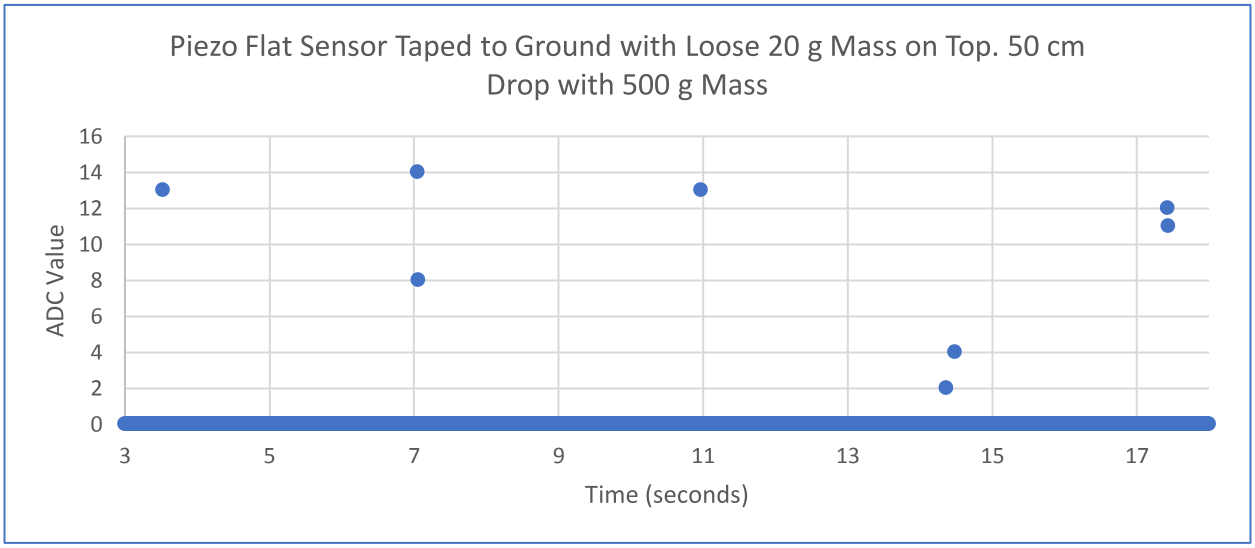


Figure 5: Flat sensor taped to carpeted ground. 50 cm drop with 500 g mass. The first data spike in time corresponds to a 10 cm distance from the mass drop point and each subsequent spike corresponds to a further 10 cm from the previous spike.

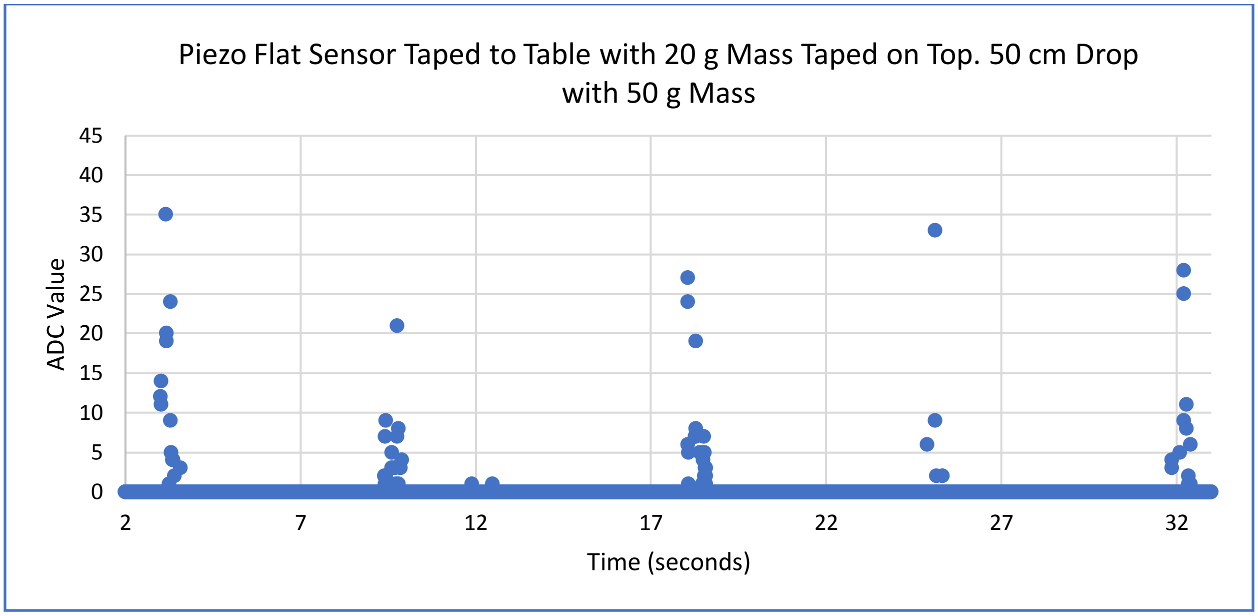


Figure 6: Flat sensor taped to the top surface of the table.

Each of the data points in each the runs collected during this project correspond to a digital value (ADC) that is the result of the code used. For the purpose of this project, the digital range value output was suitable to compare the sensors with each other. Further analysis would be able to take this ADC value and extract useful information such as the force or magnitude of the vibration within the sensor. In order to retrieve these values, additional testing and calibration of the vibration sensors would be necessary.

Looking at each run, it is easy to tell that the vibrations picked up by the sensors did not last long, and were inconsistent in magnitude. As the mass was dropped at the same height for each

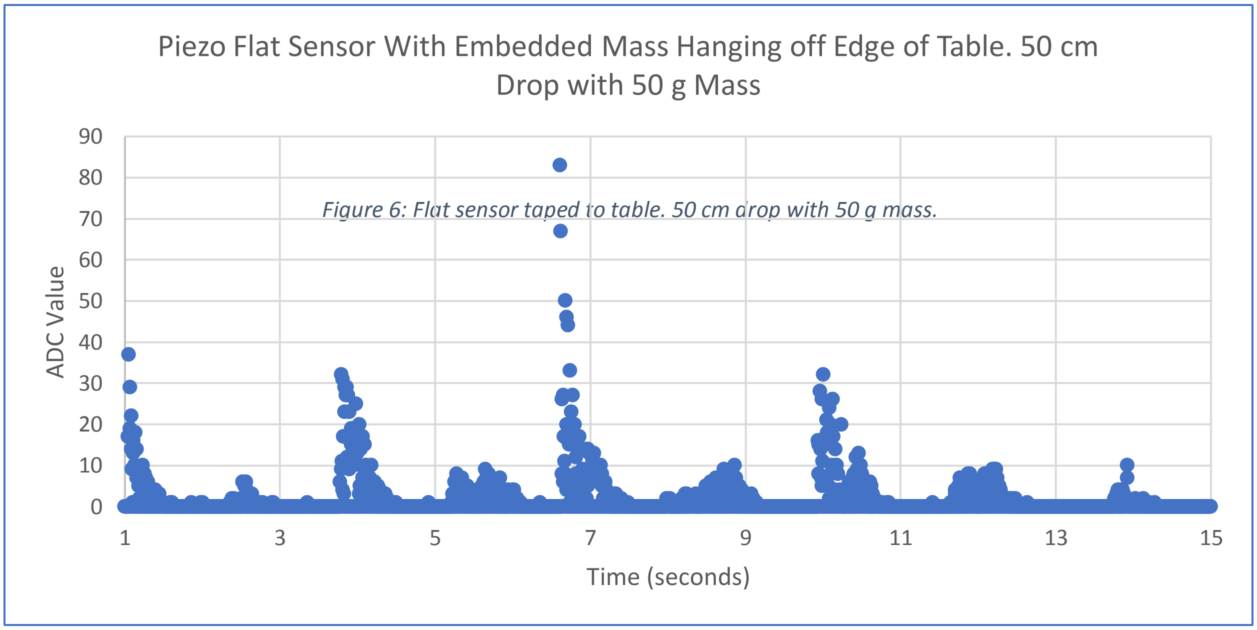


Figure 6: Flat sensor taped to table. 50 cm drop with 50 g mass.

Figure 7: Flat sensor with embedded mass taped such that the sensor was hanging from the table. 50 cm drop with 50 g mass

run, it would make sense that the largest response would be at the closest drop to the sensor for each run. This was not the case for many of the runs collected during this project. Figure 5 shows that the vibration that occurred for each drop lasted four to eight milliseconds while Figure 6’s vibrations lasted about forty milliseconds.

The setups that had the sensors hanging off the edge of the table showed to most response to stimulation. The smaller peaks occurred as the setup was moved to prepare for the next drop. The large spike in Figure 7 shows the random nature of the mass striking the table again. There is a clear start to the data points at the time of impact, but the fading out of the vibration through the surface is shown. This is drastically different from Figures 5 and 6 which showed a jagged start and stop of data collection.

The amplitude of the vibration for each run held little to no correlation to the distance that the impact occurred from the sensor. There are many factors that can attribute to this inconsistency including the impact point of the mass as it hit the surface. Depending on if the edge or the flat or rounded surface of the mass landed first could cause different vibrations to travel through the surface to the sensor. The surface itself might cause some variation in the vibrations as different surfaces have varying mediums and speeds of sound and could dampen or amplify the vibration due to resonance.

See the appendix for additional figures.

Conclusion and Future Work

With additional time and a more controlled environment to conduct the experimentation, this project could lead to useful progress of incorporating Arduino and eventually Raspberry Pi’s into a laboratory setting. In order for the vibration sensors to pick up any reading, a large force in close proximity to the sensor in needed. A force that strong would likely not occur naturally, and the intended use of the vibration sensors to monitor small disturbances in a room was not fulfilled. The inconsistency and sporadic nature of the sensors makes it nearly impossible to effectively use them in a scientific manner in a laboratory setting. The best sensor would be the flat sensor with the embedded mass since it was the most responsive while it was hanging off the edge of the table. This could be due to the fact that it was not taped down to the surface which could have dampened the sensors motion but instead was hanging freely allowing for more motion and more data points to be collected.

This project was unable to effectively include the vibration sensors into the existing intermediate and advanced lab work. However, no real conclusion can be made concerning reducing the cost of sensors used by lab students and exposure to learning a coding language and using that language effectively. Future endeavors in this field of study might yield successful incorporation of other sensors into the existing labs. Further experiments and work with this equipment could incorporate Raspberry Pi’s into the system to create a server that could report information from sensors connected to the Arduino Uno. This server could be used by students to have useful data without having to collect it themselves. The introduction of the Raspberry Pi would further expand student’s knowledge of coding and circuitry as well as allow instantaneous data analysis and the ability to passively collect data over an extended period of time.

References

1. "How many Arduinos are "in the wild?" About 300,000". Adafruit Industries. May 15, 2011.

2. David Kushner (2011-10-26). "The Making of Arduino". IEEE Spectrum

3. American Journal of Physics **85**, 216 (2017); doi: http://dx.doi.org/10.1119/1.4972043

Appendix

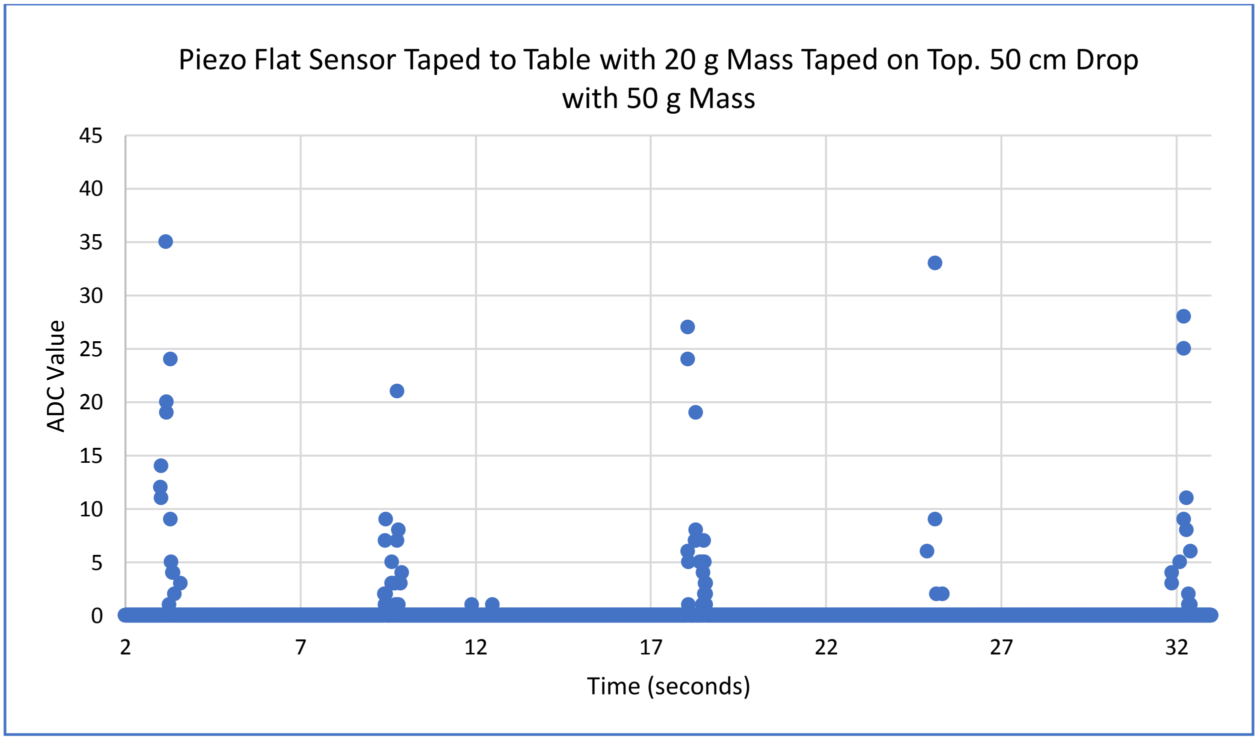


Figure I. Flat sensor taped to table. 50 cm drop with 50 g mass

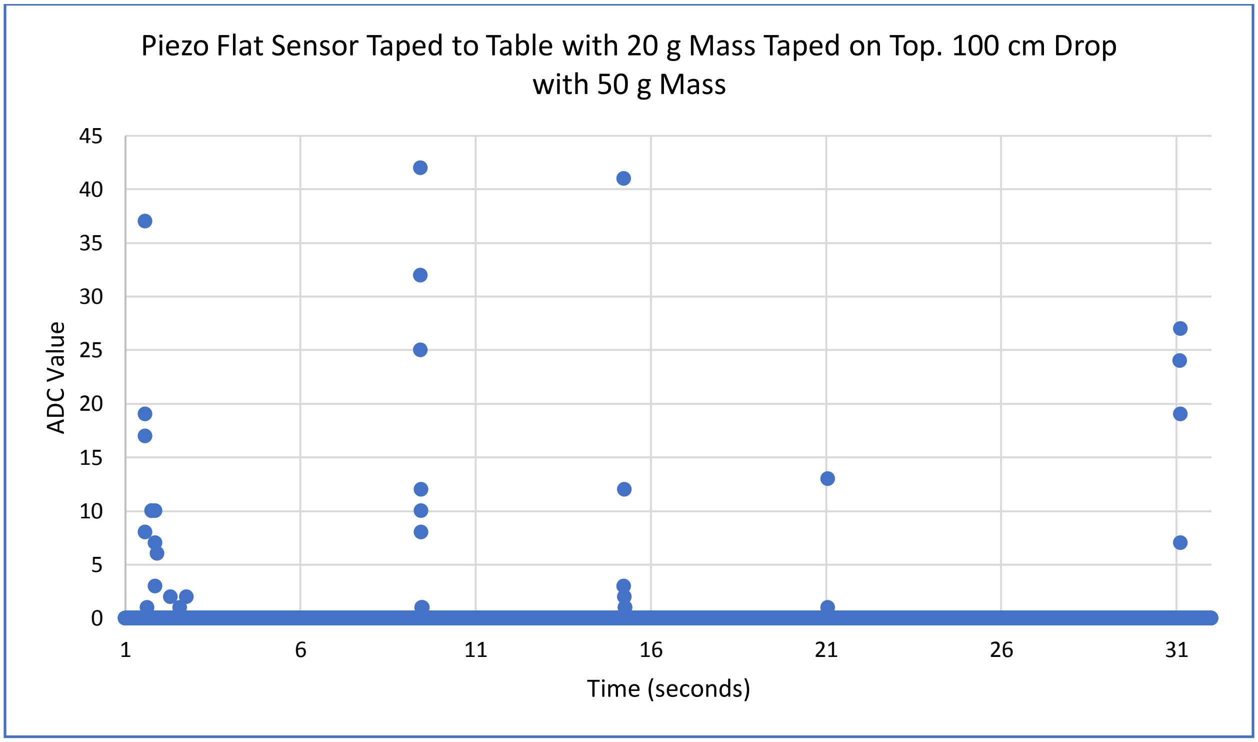


Figure II. Flat sensor taped to table. 100 cm drop with 50 g mass

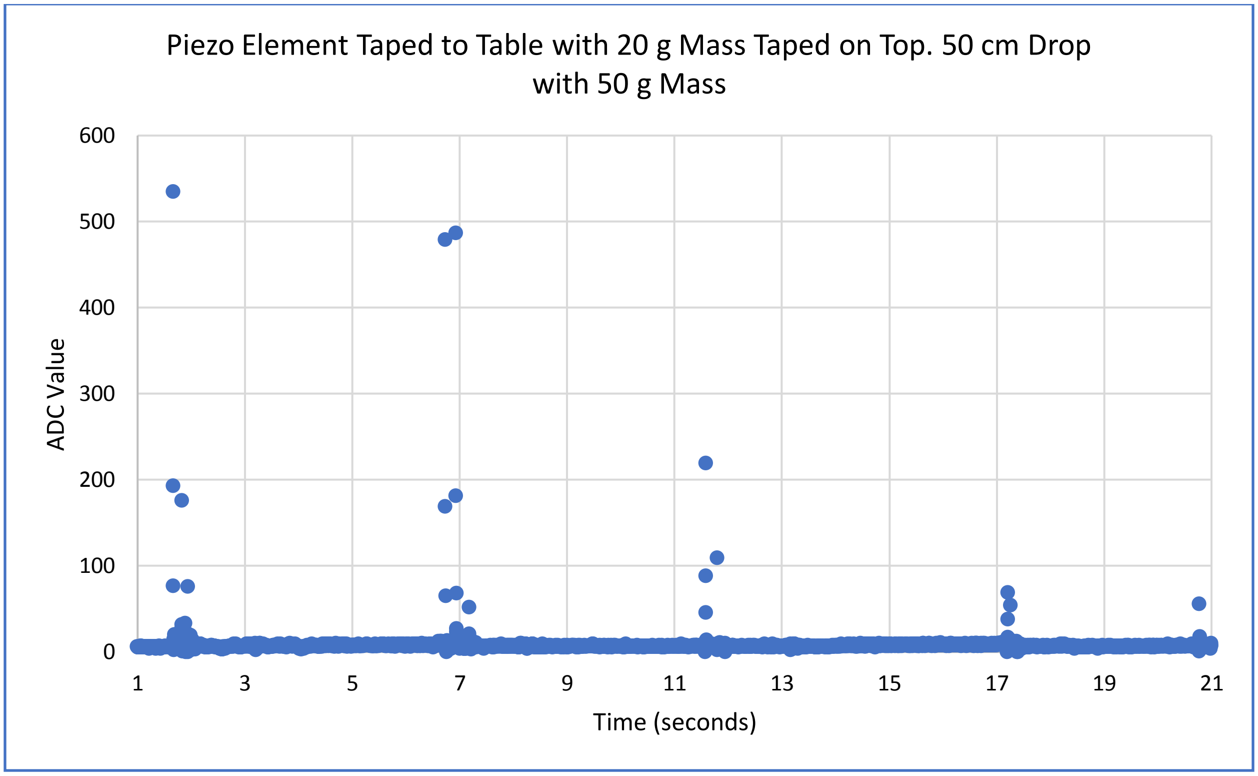


Figure III. Element taped to table. 50 cm drop with 50 g mass

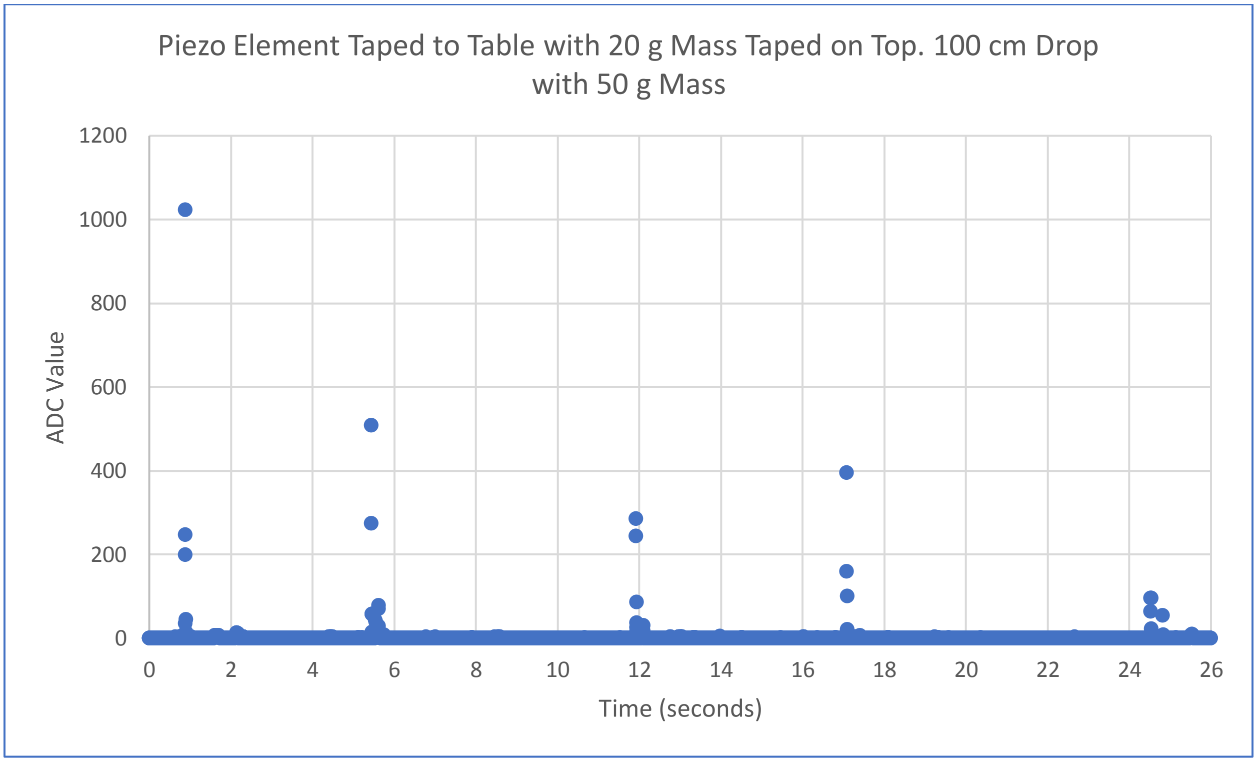


Figure IV. Element taped to table. 100 cm drop with 50 g mass

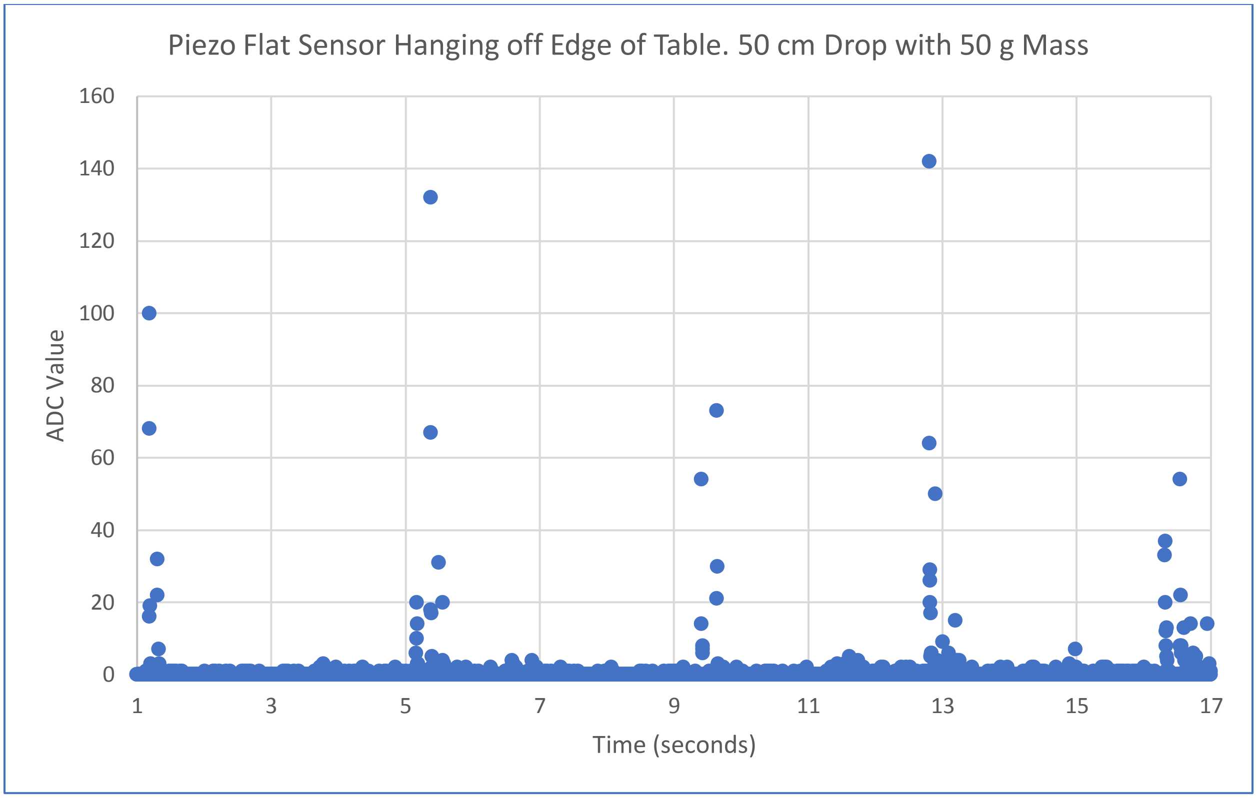


Figure V. Flat sensor taped such that the sensor was hanging from the table. 50 cm drop with 50 g mass

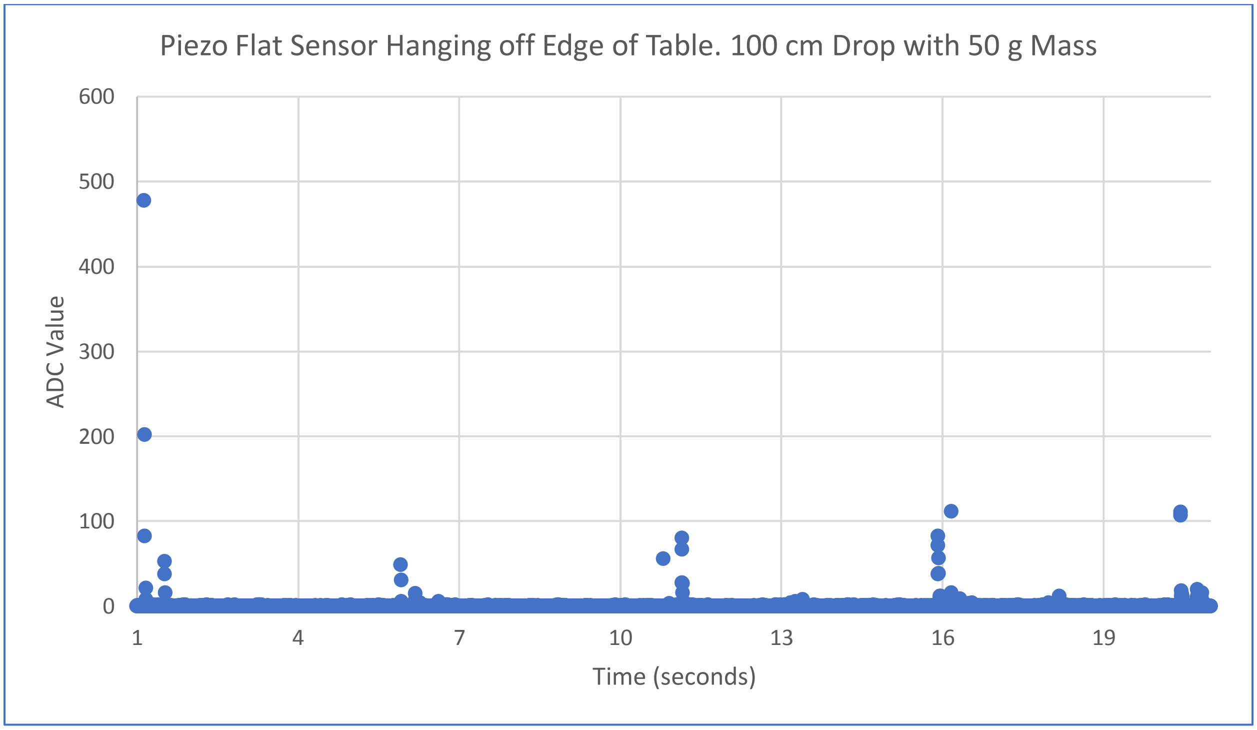


Figure VI. Flat sensor taped such that the sensor was hanging from the table. 100 cm drop with 50 g mass

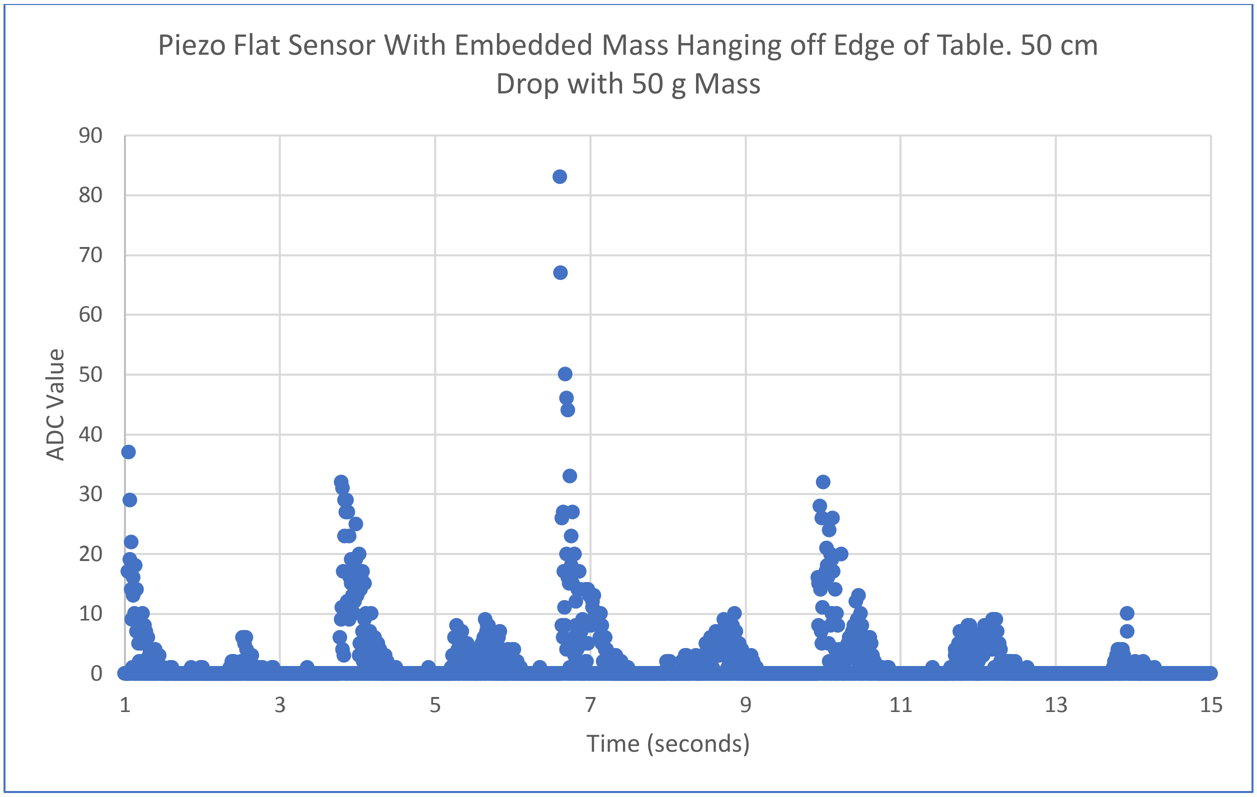


Figure VII. Flat sensor with embedded mass taped such that the sensor was hanging from the table. 50 cm drop with 50 g mass

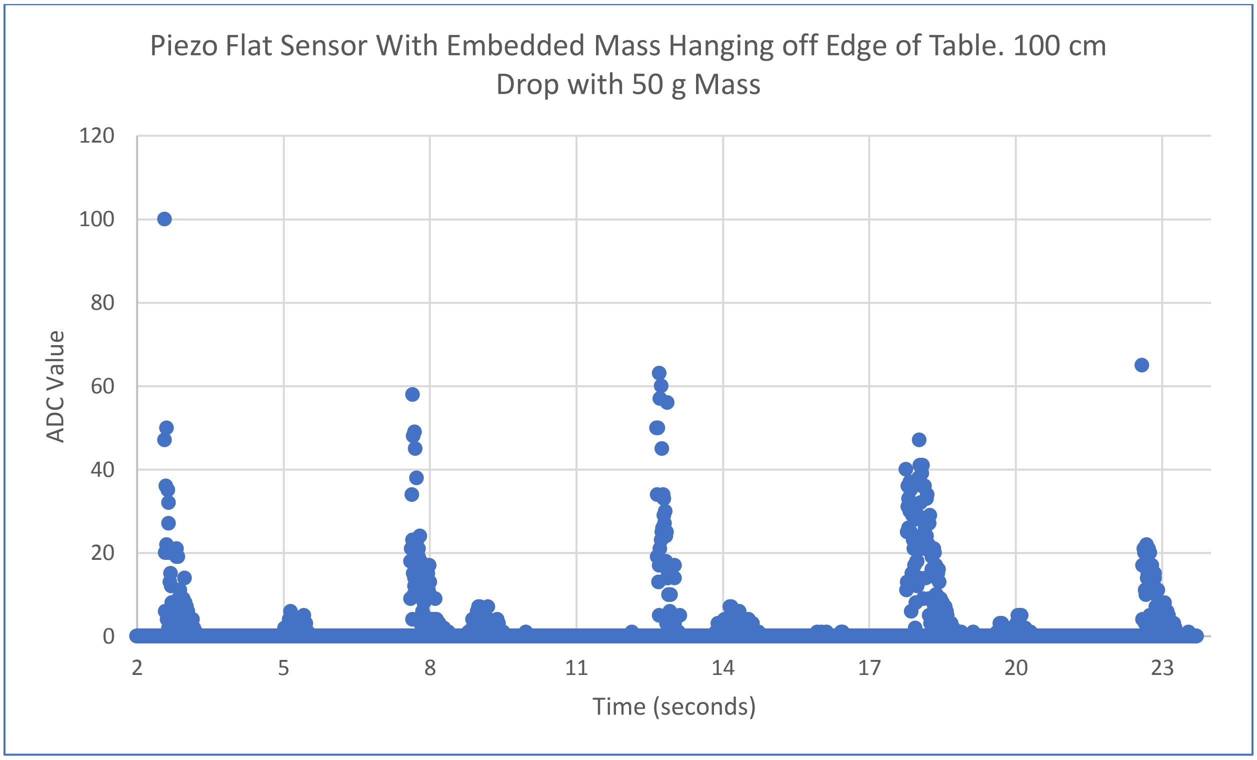


Figure VIII. Flat sensor with embedded mass taped such that the sensor was hanging from the table. 100 cm drop with 50 g mass

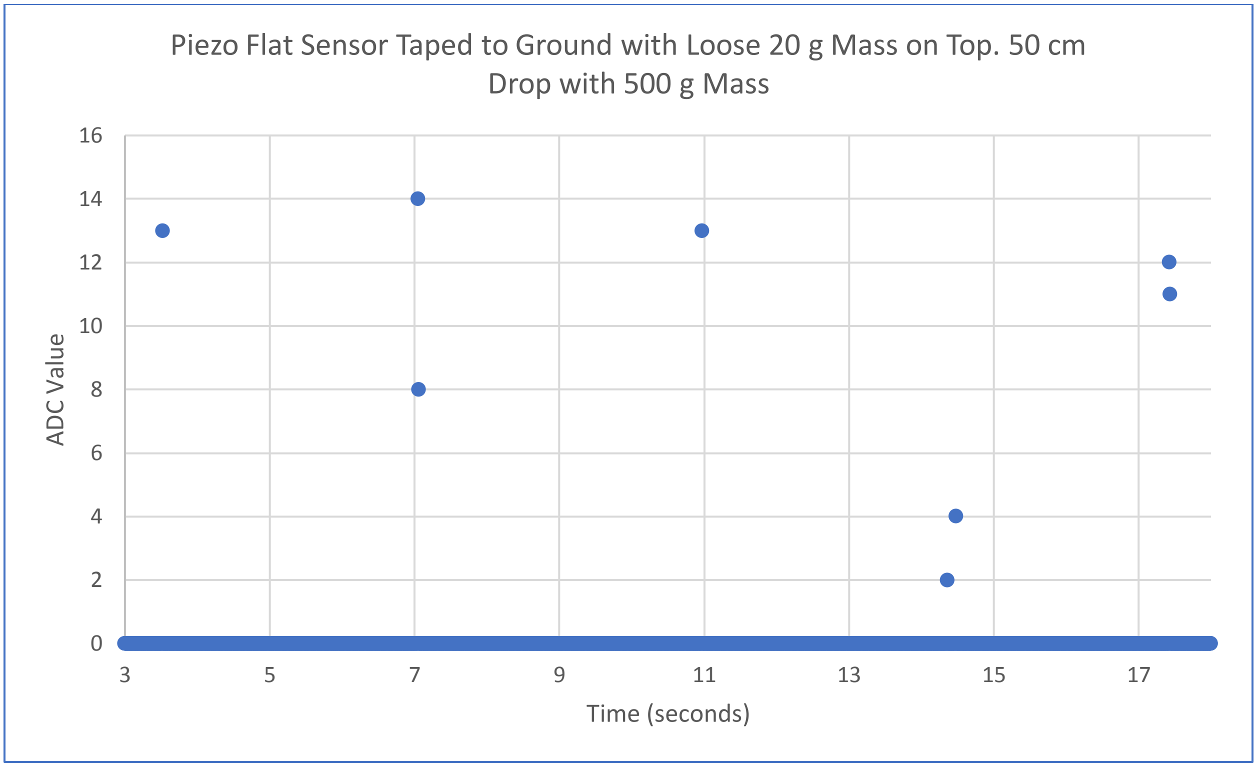


Figure IX. Flat sensor taped to carpeted ground. 50 cm drop with 500 g mass

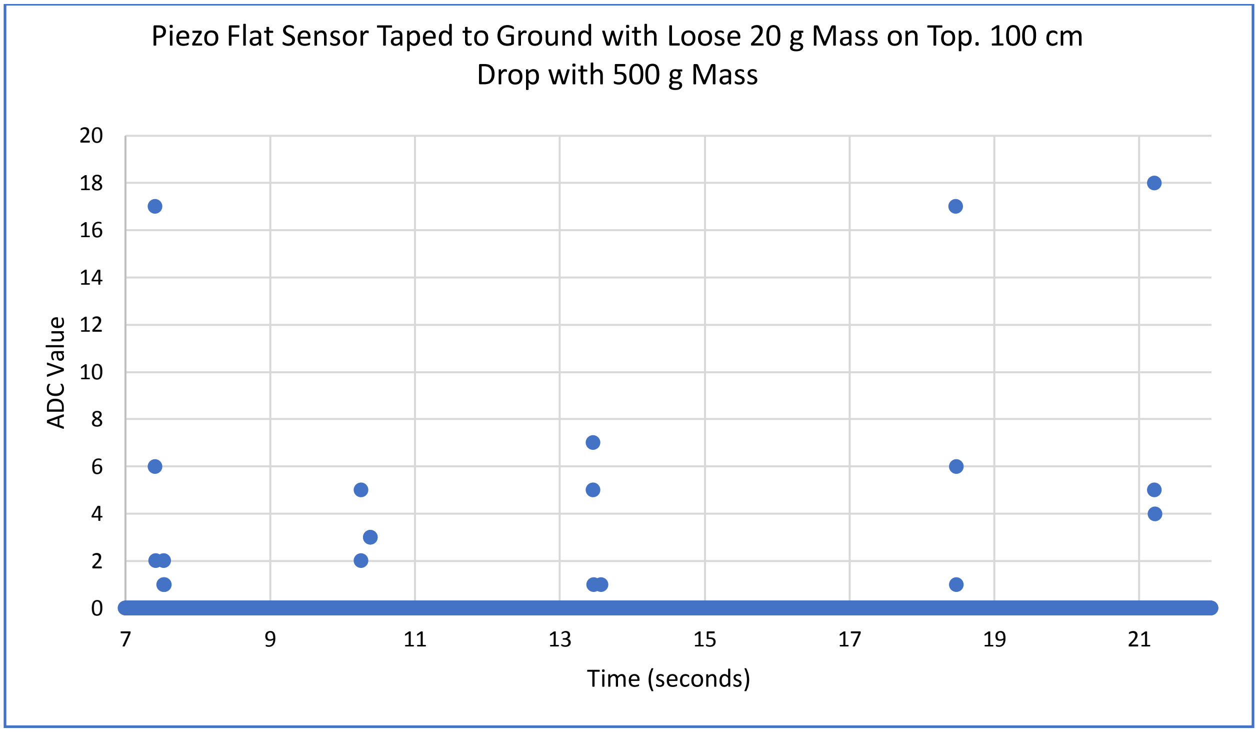


Figure X. Flat sensor taped to carpeted ground. 100 cm drop with 500 g mass

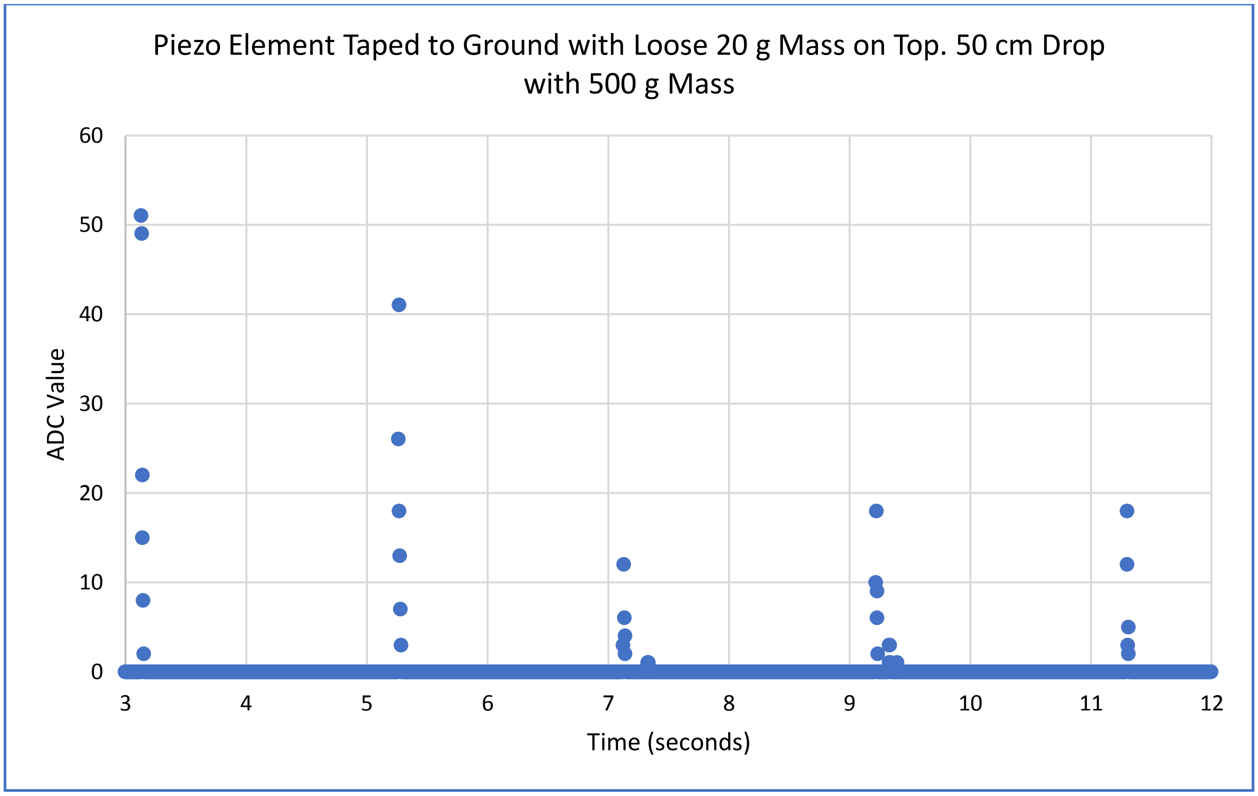


Figure XI. Element taped to carpeted ground. 50 cm drop with 500 g mass

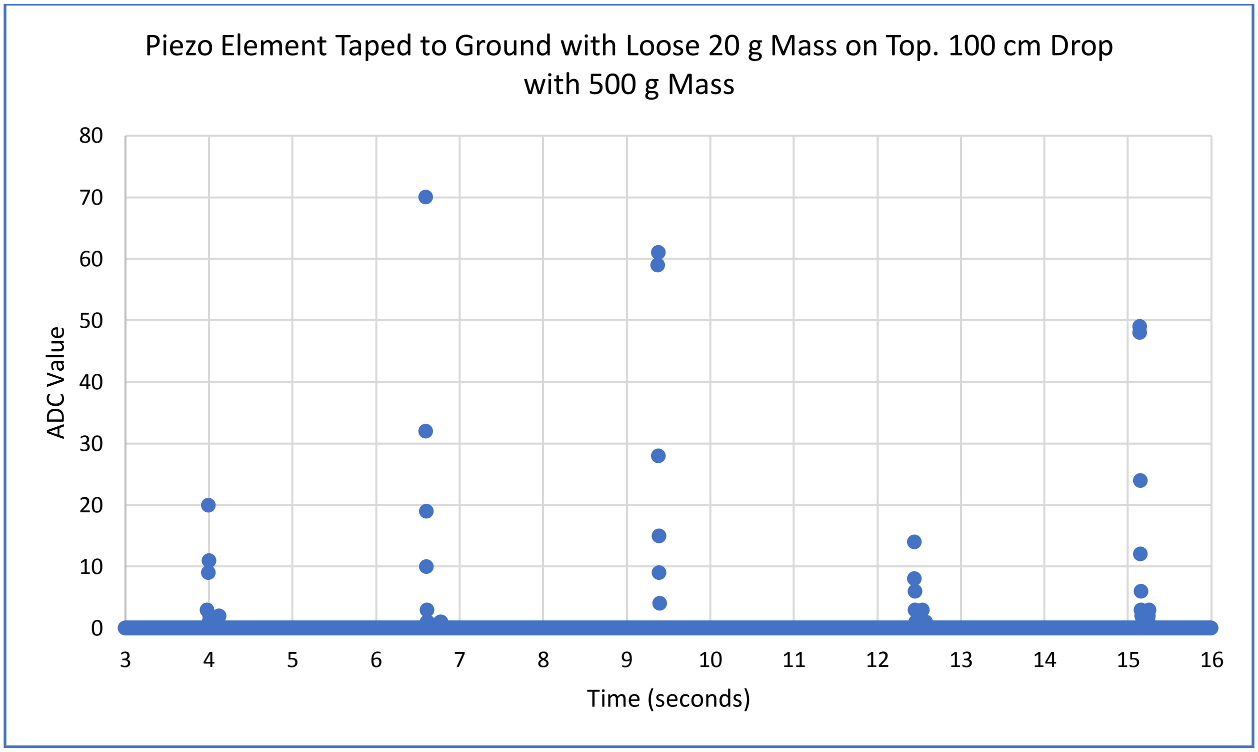


Figure XII. Element taped to carpeted ground. 100 cm drop with 500 g mass