

Cranial Impact Detection System for Youth Participating in High-Impact Sports

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Hanna Lin

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Abstract

Traumatic brain injuries are serious health problems that contribute to a substantial number of deaths and cases of permanent disability each year. Of these injuries, mild traumatic brain injuries (MTBIs), in which consciousness or loss of brain function can be brief, are the most common with young (<18yrs) and old (>65 yrs) people suffering the majority of these cases. Though the symptoms may be less grievous for MTBIs, these injuries tend to be ignored but can still inflict a heavy burden on the victim and exact significant societal costs as well, and especially with repeated instances.

Even with the recent rise in awareness of MTBIs and their long-term side-effects, the exact cause and a direct diagnosis is yet unknown, and as such, a cure is still out of reach. With the only current solution being a preventative one, a better understanding of the causes of MTBIs are needed. Current research in this field focuses on professional, and college-age athletes, neglecting the more vulnerable younger category.

The objective of this project is to develop a system that can be used to monitor younger players, ages 15-24, during high-impact activities and indicate significant collisions. An accelerometer-based system was designed and fabricated for this purpose. The next step would be for improvement and validation of this device, and to follow with data collection with test dummies and live test subjects.

Biographical Sketch

Hanna Lin was born in Ithaca, New York on June 12, 1991. She grew up in Lawrenceville, Georgia where she developed an interest in science and engineering. A benign tumor in her middle ear made prosthetic bones necessary, and the experience turned her interest towards the crossroads at which biology and engineering meet. At Cornell University, she earned her Bachelor of Science degree in Biological Engineering in 2013. Afterwards, she elected to stay to pursue a Master of Engineering degree with a concentration in Bioinstrumentation in order to build upon her previous education through practical application.

To my family, friends, and all who supported me through this endeavor.

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Ch1. Introduction

Brain injuries and concussions contribute to a high degree of mortality and morbidity in society. It is estimated that in the United States alone, there are 2 million cases of brain injuries, and cause as many as 56,000 deaths per year [18]. While traumatic brain injuries (TBIs) encompass all injuries that occur when an external force injures the brain, it can be classified based on severity with the most commonly occurring being mild traumatic brain injuries (MTBIs) which are injuries that cause concussions, or temporary loss of brain function where the victim can fall unconscious for a period of time. Not only can these injuries cause serious trauma or even death for the victims, but they also exact a heavy monetary, social, and emotional price on all of those involved. These injuries have multiple causes such as falls, motor vehicle and traffic-related crashes, and high-impact activities [5].

It has been documented that the elderly and children experience the highest number of brain injuries due to the aforementioned causes [Post]. According to studies by the Center of Disease Control (CDC), individuals over the age of 75 and young children make up equivalent parts of roughly 40% of all TBI-related emergency department visits. Current studies [Post, 25] also indicate that, especially in children, there is an increased risk of greater brain injury and long-term damage from second and further concussions [Post], and it has also been observed that the effects of brain injury are cumulative, though the mechanisms are yet to be fully understood [9, 10, 11]. Of the multiple causes of brain injury, those that are sports-related occur relatively frequently in children and adolescents [17]. The risk of MTBIs are higher in younger people between ages 15-24

years old [18], and especially with younger athletes due to the less developed cranial bones and musculature that helps absorb the impact and reduce the force transmitted to the brain [29]. It has also been theorized that the immature brain is more susceptible to misregulation of metabolic processes, and takes longer to recover [21].

Recently, public awareness of the need for more safety measures in high-impact sports has also increased. Much of the awareness comes from the light cast upon the effects of head injuries in professional athletes caused by collisions inherent to their sport. The effects of these collisions range from the short-term concussions, fatalities, and cranial fractures as well as long-term cognitive, psychological, and motor dysfunction [4, Pellman]. It is estimated that between 1 and 4 million sports and high impact-related concussions occur each year in the United States alone [27], though this may be a conservative estimate due to the multitude of more minor head injuries that go unreported and undocumented. It has also been recognized that there is an increase in MTBIs reported from impacts experienced in recreational and professional sports, both high-impact and low-impact, even with the use of preventative equipment [14, 32].

In order to prevent brain injuries and concussions, several measures have been put in place, such as the requirement of helmets in high-impact sports and the use of criterion that help calculate the severity of injury upon impact, such as the Gadd Severity Index (GSI), Head Injury Criterion (HIC)[23], or Head Severity Index (HSI) [16,8]. These standards cannot fully account for the complex motion of the brain within a deformable skull and neglect the contribution of angular acceleration to injuries and the cumulative nature of MTBIs altogether. The cumulative nature of brain injury has lead to

suggestions to measure the severity of impacts throughout a time period (such as a single high-impact sports game). One method to do this would be to instrument the cranial protective gear to measure the impacts in real-time, and to signal when a threshold has been reached, calculated using the aforementioned criterion. Such “smart” protective gear has recently been introduced to the market, but little or no validation or tests have been shown to have been performed to prove the accuracy of these instruments. Most of the gear currently available for children and adolescents does not provide quantitative data for the user at all, which hinders the gathering of much-needed information on MTBIs in young persons. Though quantitative data for younger people is still lacking, there have been many studies performed to model and simulate brain injuries for the average person in order to better understand how MTBIs occur.

1.1 Brain Injury Mechanisms and Visualizations

Traumatic brain injury can be defined as damage to the neural and vascular elements of the brain due to an outside force. The damage is caused by pressure differences and shear within the brain due to pressure gradients or the relative motion of the brain with respect to the skull [McCrory, 15], where the relative motion can be caused by linear and rotational accelerations of the head during an impact. Positive pressure occurs at the site of impact and can cause contusions on the brain, which can be seen when diagnosing the motion of the brain relative to the skull in an impact. At the countrecoup site, negative pressure occurs and can be due to either tensile loading or cavitation, which is the shockwave generated due to the implosion of a void created in a liquid that is subjected to rapid changes in pressure [15, 19]. These pressures cause the shear stress and strain on the brain, though the complex structure and difference in material

properties between the different tissues of the brain make it difficult to model or visualize these effects.

Even with the difficulties, many attempts at modeling MTBIs have been made by different groups [32, 31, 28]. These different studies have been used to verify different hypotheses on the causes of MTBIs, but still have several downsides. Of these, one is the mathematical approximations that are made in order to describe the mechanical properties and simulate the materials. There is also a lack of experimental data that can help to thoroughly validate the models that are created. Another challenge in modeling MTBIs accurately is the motion of the brain relative to the skull, which is thought to be one of the main causes of MTBIs. This is due to the many different points of interactions between multiple substance types that must be accounted for in a simulation.

Unfortunately, the measurement of the relative motion of the brain along with the stresses and strains within a brain is also nearly impossible during an impact, especially with an *in vivo* study. Much of the mechanical response data obtained from impacts are from experimentation on animal and human cadavers. An example of this is a study from 2001 by Hardy et al. in which relative brain motion data was obtained through the use of a bi-axial high-speed X-ray system to track radio-opaque targets that were implanted in the brain of recently deceased cadaver. Even with the advancing recent technology used by Hardy, obtaining *in vivo* data on the relative motion of the brain, stress, and strains are still out of reach. In order to circumvent these problems, a few of the more accessible methods of solving the inner workings of MTBIs are described in the following section.

Ch2. Recent Studies

There have been many methods that have been employed in order to better study the mechanisms behind MTBIs and ways to better protect the head from injury in sports. Of these, a few of the more accessible methods and examples are detailed below.

One method, such as the study by Pellman et al. use video surveillance of multiple football games involving mild traumatic brain injuries (MTBIs) and then reconstruct them in the laboratory. In Pellman's study, the collisions in the videos were first analyzed using a cinematographic analysis to find the speed at which the players were moving. The speed was then used in order to reconstruct the collision in a laboratory using a helmeted crash test dummy. Accelerations were measured from within the dummy's head at the head center of gravity, and high-speed cameras were used to record the reconstructed tests in order for one-to-one comparisons with the footage from the football games. From this study, it was concluded that concussions are more closely related to linear accelerations rather than angular accelerations, and that the injuries to players are occurring outside of the crown and periphery of the head, which most equipment safety standards now focus on protecting.

A second method of studying MTBIs involves the use of instrumented protective gear. One particular study on concussions in collegiate football players involved the use of an instrumented helmet [27]. This device had six degrees of freedom and was used in order to measure both the linear and angular accelerations of the head during the thousands of impacts that occurred during an entire season of the sport. From this, though none of

the players had a concussion during the season, a large set of data was obtained for impacts of varying severity to the head. The set of data may be used with current concussive data in order to further study the causes of concussions.

A final study is a comparison of linear and angular momentum applied to the head. In this study, King (2003) first reviews the biomechanics of head injuries and different studies that have investigated the effects of linear and angular acceleration on the head. The paper then analyses data from recent research looking at the motion of the brain relative to the skull during impacts and the effectiveness of a helmet for reducing the linear and angular accelerations of the head during impacts. The conclusion was drawn that the injuries sustained are intimately related to the local response of the brain and not just the general forces on the head from the impact, and it was also proposed that instead of accelerations, that the strain rate within affecting the brain may be a better predictor of concussions.

Though research shows that younger people are more susceptible to MTBIs, the focus of most recent research using the more accessible methods of studying MTBIs in sports has mainly been on professional and college-level athletes, including the examples discussed above. The objective of this project is to create a device that makes it easier to collect more data on MTBIs in younger athletes.

Ch3. Purpose/Motivation

Though many studies on MTBIs have been performed on professional and collegiate-level athletes, there has been little done to analyze the effects of injuries sustained by younger persons in high-impact sports. There is little current data on whether the effects of impacts on head injuries scale with body size or with age. Fortunately, the recent increase in availability of accelerometer-based “smart” protective gear for athletes has allowed for the first steps to be taken by monitoring collisions during high-impact activities. However, no real analysis has been done on the products used on children or adolescents or to test the accuracy or reliability of these products. For this project, a unique accelerometer-based data acquisition system has been designed in order to aid in both the analysis of the currently available “smart” gear and the accumulation of quantitative data to better understand the immediate and cumulative effects of MTBIs on young persons.

Because a cure is not yet known for brain injuries, the only alternative is to develop intervention strategies to prevent or minimize the occurrences of these injuries. In order to develop such strategies, a better understanding of the injury mechanisms, responses, and tolerance levels of the brain are needed. Also, given the cumulative effect of brain injuries and the lack of available data on youth and high impact sports, the applicability of this project is broad. The objective of this project is to develop an accelerometer-based system with a higher bandwidth than is available in current systems in order to allow for more and accurate data collection for better understanding.

3.1 Objectives

From the motivations introduced above, the main objectives of this project are to develop an accelerometer-based system that can be used in studies on MTBIs experienced by youth in high impact sports. The intermediate steps:

- 1) create a list of desirable specifications for the system accelerometer
- 2) explore methods of calibrating the accelerometer
- 3) design a system around the chosen accelerometer
- 4) test the device in vertical drop tests

Ch4. System Design

4.1 Accelerometer Specifications

In order to design a system around an accelerometer, the proper specifications should be calculated in order to find the appropriate sensor. From previous works [12, 25], it was noted that impact accelerations in sports do not typically reach over 150g's, so an accelerometer capable of reading impacts up to 150g's would be appropriate for this system. In this case, g's refer to g-force, which is a measurement of acceleration that can be described as weight per unit mass, and distinguishes between acceleration relative to free-fall and simple acceleration. One g is the acceleration due to gravity at the Earth's surface, or 9.806 Newtons of force per kilogram of mass. In order to read the accelerations about all axes of the skull, the accelerometer should be at least 3-axis, if not 6-axis for rotational acceleration measurements as well. For efficiency, the accelerometer should also be low power; low enough to be powered by a coin cell battery for several hours at a time while periodically transmitting data. The sensitivity of an electronic device is the minimum input signal required for the device to register and produce a specified output signal. In this case, a high sensitivity device would be optimal, but not completely necessary given that the range of g's over which the impacts will be measured will be large (possibly +/- 150g's).

There are also spatial requirements, as the sensor should have a small enough footprint to fit on a small board inside of an enclosure held to the subject's head or inside of a mouthguard. Generally, the boards and enclosures are as small as possible, so a sensor that is also as small as possible would be ideal. For the most accurate data possible, the

highest possible sensitivity should be required, and an analog system would be ideal to keep losses to a minimum.

The accelerometer that best matches the specifications was found to be the ADXL377 from Analog Devices, which suggests “concussion and head trauma detection” and “high force event detection” [1] as possible applications. It is a 3-axis analog microelectromechanical system (MEMS)-based linear accelerometer with low power consumption (300 μ A) and runs on a 3V power supply, which can be supplied by a battery. The accelerometer’s full scale range is $\pm 200g$, and has a listed shock survivability of 10,000g. It also has a relatively small footprint (3mm x 3mm x 1.45mm), as it is a MEMS device. From the datasheet, the sensitivity is listed at 6.5 mV/g with -3 dB bandwidth at 1.6 kHz, which is high enough for this application.

4.2 Methods of Calibration

Although inertial sensors come trimmed and calibrated by the manufacturer, the core of the sensor is mechanical. This means that any stress on the part after assembly of the system could affect the offset and sensitivity compared to the datasheet specifications. This can result in errors that could significantly affect the results gained from measurement.

There are several methods that can be used in order to calibrate an accelerometer. Of the many lower-cost methods known, one of the cheapest is to calibrate the sensor using static measurements, with the accelerometer in different orientations relative to Earth. Another calibration method, specifically for systems measuring impacts, is to tie the

accelerometer to a measured mass and to perform vertical drop tests onto a relatively soft surface in order to assume an inelastic impact [3].

A final method is the one chosen to calibrate the accelerometer found in the previous section. This method involves driving an audio speaker with the accelerometer attached to the cone of the speaker, and a microphone is used as the standard for measuring the acceleration of the accelerometer versus the sound pressure levels (SPLs) detected by the microphone. The noise floor can first be found for the accelerometer by simply recording from the microphone and comparing the noise of the chamber to the output of the accelerometer. Next, the speaker is driven by a voltage sweep at a fixed frequency and then a frequency sweep at a fixed voltage. For each sweep, the microphone records the sound pressure level in decibels (dB). From there, the pressure measured in Pascals can be found by using the following equation:

$$P = 10^{(\text{dB SPL}/20)} * 20[\mu\text{Pa}] \quad [1]$$

where P is the pressure in Pascals and dB SPL is the recorded SPL. The $20\mu\text{Pa}$ is necessary as it is the lower limit of human hearing, and SPL is the pressure relative to the threshold of human hearing. Once the pressure has been determined, the acceleration can be found by the equations:

$$F = P/A \quad [2]$$

$$a = F/m \quad [3]$$

where F is the force produced by the speaker, A is the area of the recording microphone, a is the acceleration, and m is the mass of the system attached to the speaker. The force of the speakers is first found by dividing the calculated pressure by the surface area of the microphone using equation 2. The acceleration is then found from the calculated

force, then divided by the mass of the system attached to the speaker using equation 3. This method allows the user to calibrate the accelerometer by first finding the noise floor of the device, and then using frequency and voltage sweeps in order to vary the accelerations experienced by the sensor.

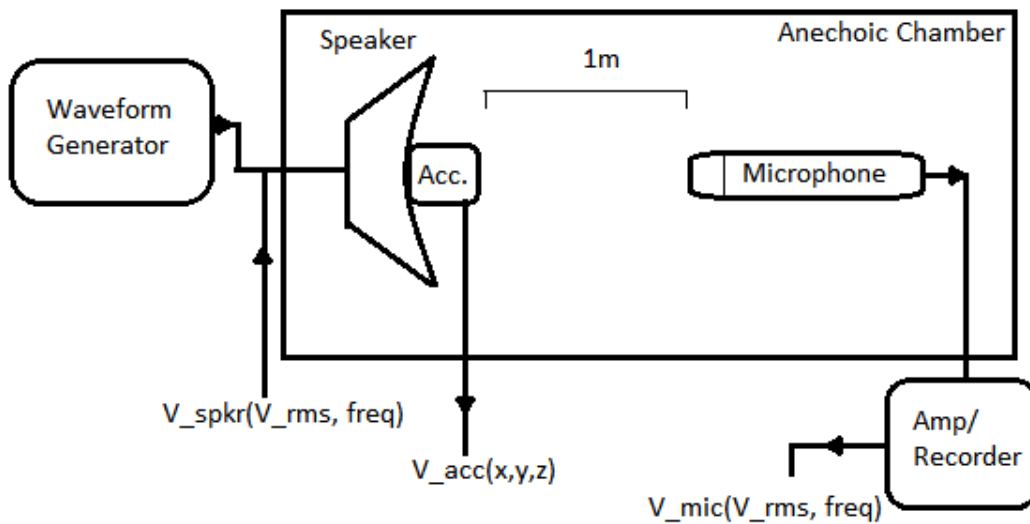


Figure 1. Experimental Setup for Accelerometer Calibration.

The experimental setup for this calibration can be seen above in Figure 1. The setup involves the use of a JBL Control 1 speaker with the accelerometer fixed to the diaphragm, 1 meter away from a microphone. The entire apparatus is located in an anechoic chamber in order to reduce as much external noise as possible. The signal for both the frequency and voltage sweeps are transmitted to the speaker from an audio analyzer, and the outputs of the microphone and the accelerometer are simultaneously recorded using the same analyzer. The speaker signal is converted from an electrical signal into pressure waves through the electromagnet that is housed within the speaker

and attached to the cone. The passing of an electrical current through the speaker causes the direction of the magnetic field of the electromagnet to change rapidly, causing it, and the cone, to vibrate. The outputs of both the microphone and accelerometer are recorded as voltages. Afterwards, an audio-analyzing software can be used in order to find the characteristics of the accelerometer in use.

4.3 General Device Design Parameters

In designing this device, there are several characteristics that should be included. For one, the device should be portable, rugged, and waterproof, given that it will be attached to mobile athletes in which the games might be rough, and the weather conditions may not be ideal. The battery life should last at least as long as a typical sports game. Soccer games last around 95 minutes on average, football games can last 2-3 hours, and martial arts matches, such as mixed martial arts, last for only a few minutes. Based on this, the system should be able to last for at least a few hours on a single charge, and in order to make the system fully self-contained, the data transfer system should be wireless.

The system should be small enough to be unobtrusively and non-invasively applied to the head or fit inside of a mouthguard based on the work by Higgins[14], showing that an accelerometer embedded in a mouthguard provides more accurate readings than an accelerometer mounted on a helmet, and also by others [20], which showed that the acceleration of the head can be less than 10% of the acceleration experienced by the user's helmet. The ability to apply the system directly to the head of the user would provide more accuracy, though the system would be farther away from the center of mass of the head than with a mouthguard. A smaller, less-noticeable footprint for the

system would be essential to not distract test subjects and for maintaining experimental integrity.

The system should sample data at the highest sampling frequency possible in order to obtain as much data as possible during an impact to obtain clear a picture as possible. From other studies [33,26,14] sampling frequencies of anywhere between 1kHz and 20kHz have been used in data collection with instrumented protective gear. The sampling should also only occur for the duration of a significant impact in order to save energy and extend the charge cycle. For this application, the threshold for a significant impact that could cause an MTBI would be set at 80g based on the compilation of thresholds used by other researchers gathered by Post et al [33]. The sampling duration is set at 30 msec in order to encompass the entirety of the event after the threshold is met, based on impact graphs of several studies [32].

5.1 Device Design/Fabrication

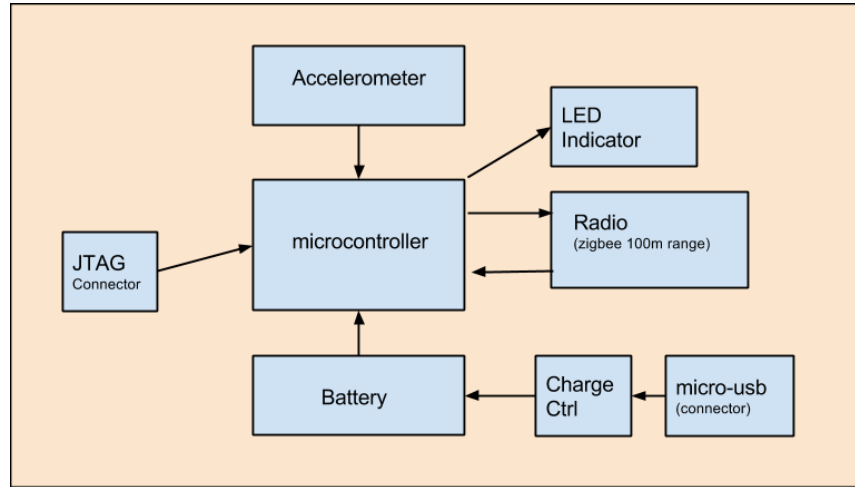


Figure 2. Basic system design

A basic flowchart for the system was drawn up using parameters discussed above and can be seen in Figure 2. For the main components of the system other than the accelerometer discussed in previous sections, the microcontroller chosen for this project was the Atmega 168 [2] for its low power consumption, and a XBee Series 1 RF Module was chosen for wireless data transmission [7]. The circuit based off of the flowchart in Figure 2 was designed and fabricated by Dane Kouttron, and the schematic and board layout can be found in the Appendix.

The device was fabricated using the components listed above and in the bill of materials located in the Appendix. A reflow soldering gun was used in order to attach the accelerometer to the board and the rest of the components were mounted using a fine-tipped soldering iron. A 3D rendering of the device can be seen in Figure 3.

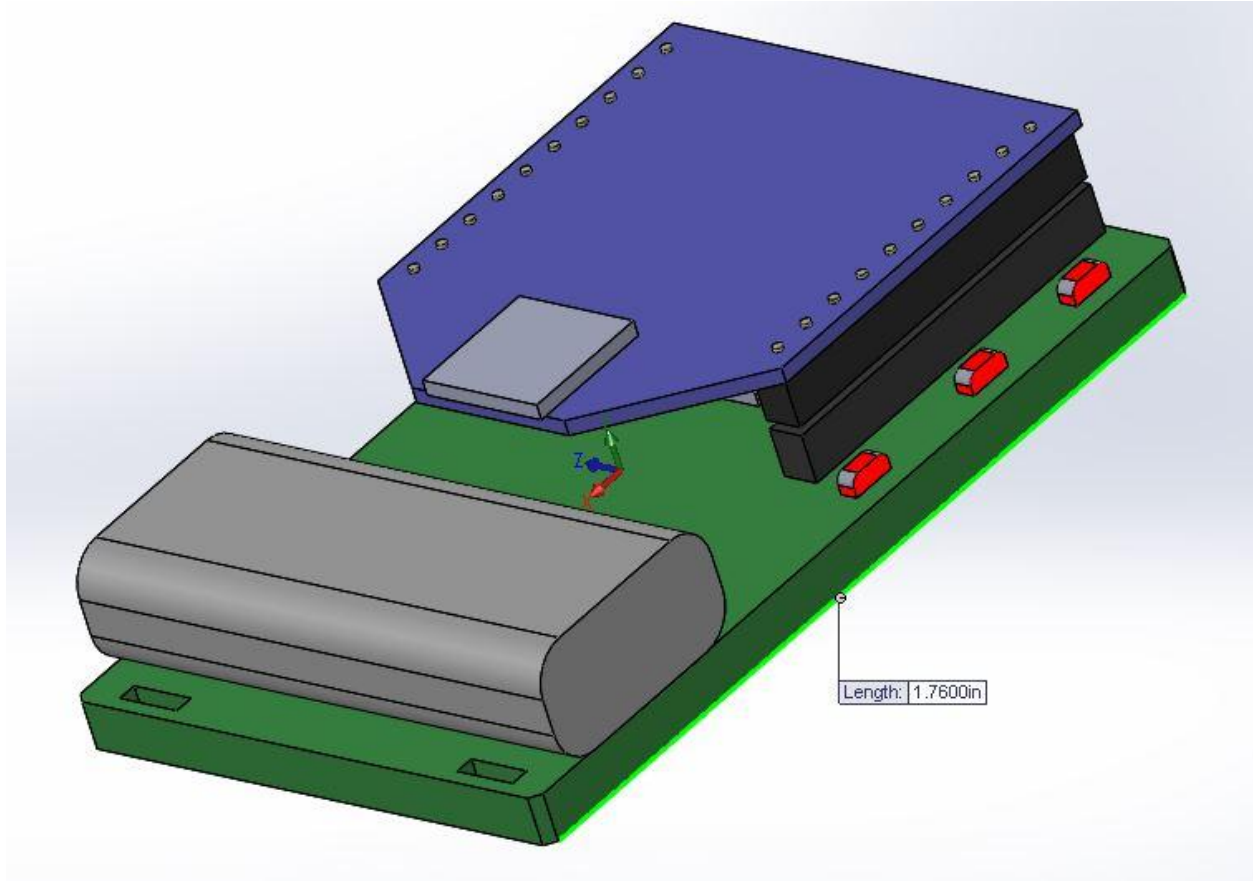


Figure 3. 3D rendering of board with battery and wireless card.

The device was also programmed in order to follow the specifications mentioned in previous sections. The code used in the initial testing of the device can be found in the Appendix, and a state diagram representing the function of the code can be seen below in Figure 4. The default state of the device is to be in a designated sleep mode in order to save power. When a change in voltage from the accelerometer axes is detected to be higher than the set threshold, the controller then reads the values from the accelerometer and transmits them wirelessly for 1000 cycles. Afterwards, the controller waits for 1 second in order to allow values to settle and returns to the sleep mode once again.

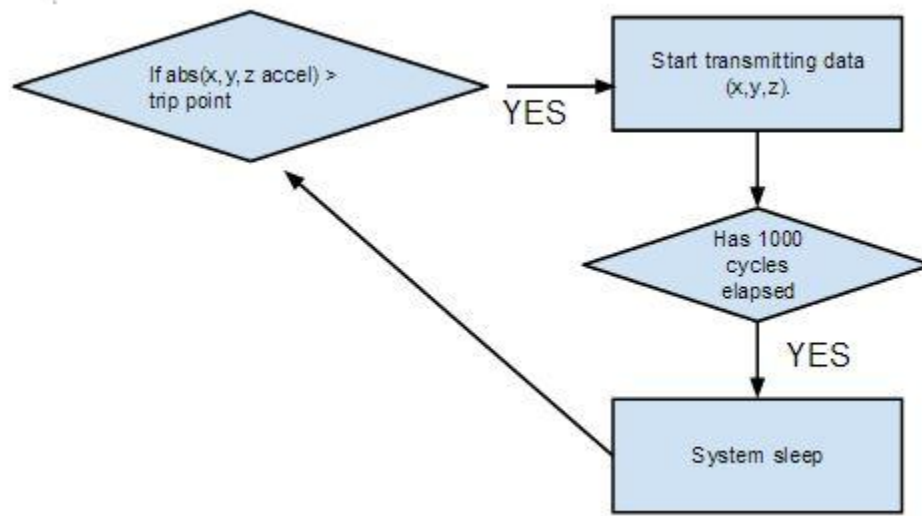


Figure 4. State Diagram of the Code for the ATmega168

5.2 Device Testing Method

A simple impact test was derived in order to determine that the device functions as planned. The device was placed upon a flat surface and hit with a mallet on different faces. The mallet followed the same trajectory and fell from the same height for each impact.

6.1 Accelerometer Calibration Results and Discussion

In order to calibrate the accelerometer, the method described in the Calibration Methods section was used. The following results were obtained using Raven, software that allows users to record, save, and analyze audio signals.

For the voltage sweep recordings, the frequency emitted by the speaker was held at 1kHz while the voltage was swept from 1mVrms to 2Vrms. For the frequency sweep recordings, the voltage to the speaker was held at 100mV while the frequency was modulated from 2Hz to 20kHz.

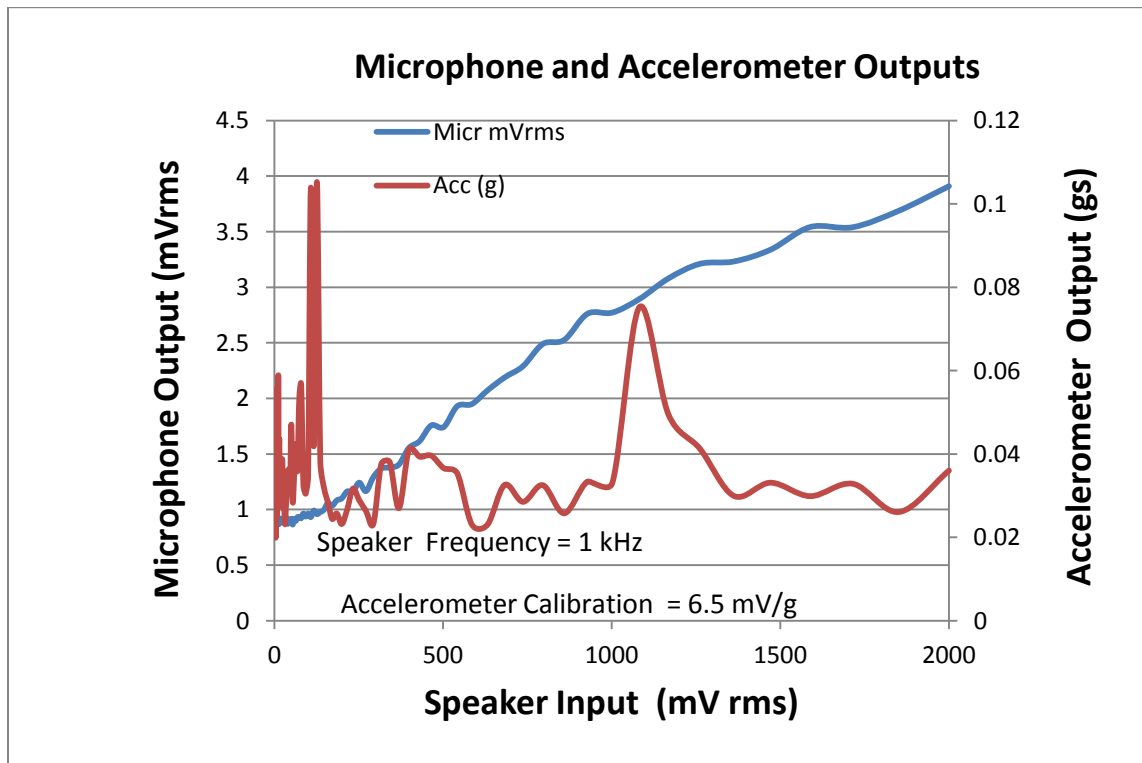


Figure 5. Calibration Raw Data, Voltage Sweep.

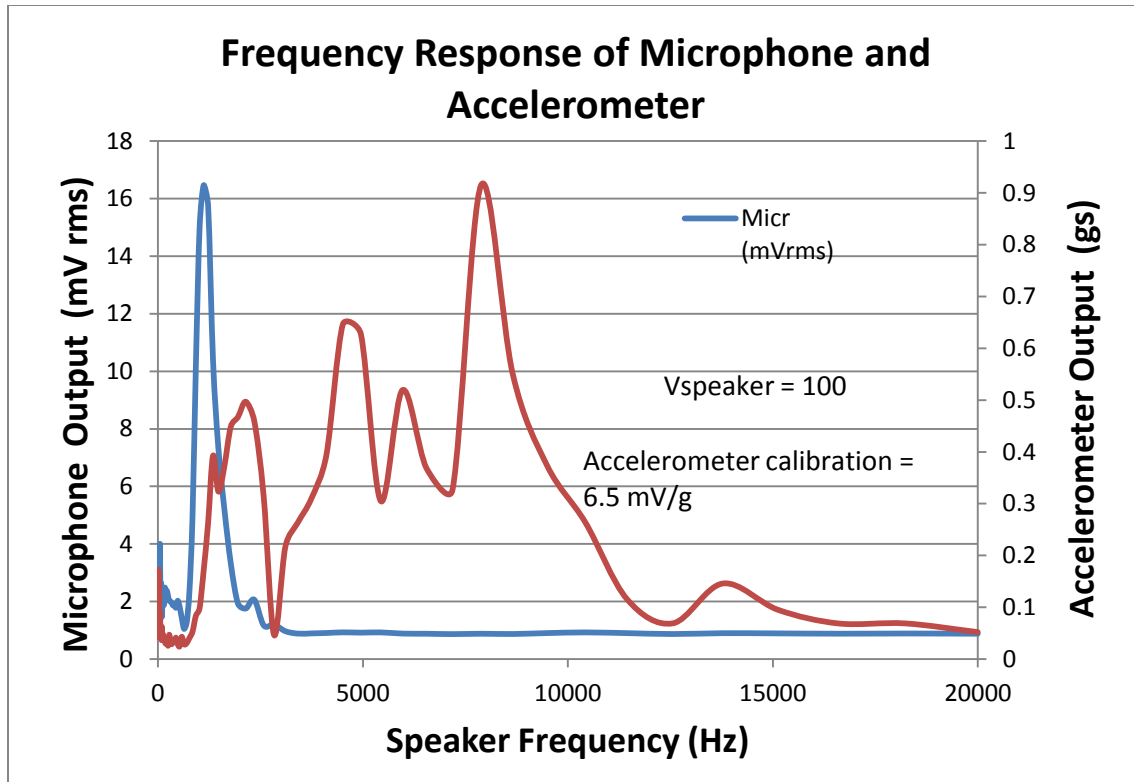


Figure 6. Calibration Raw Data, Voltage Sweep

6.2 Experimental Results and Discussion

The following data is from the initial testing of the device. In this test, the device was subjected to three blows from a mallet. The data from each test was concatenated and graphed on the following plot in Figure 7. A closer look at the first impact can be seen in Figure 8. The raw data from the three tests can be found in the Appendix. The raw data was received from the device in bit values using PuTTY, a free terminal emulator and serial console. The values were then converted to the accelerations experienced by the sensor by assuming that the range of the accelerometer was $\pm 200g$ and that the bit range was from 0 to 1024 bits.

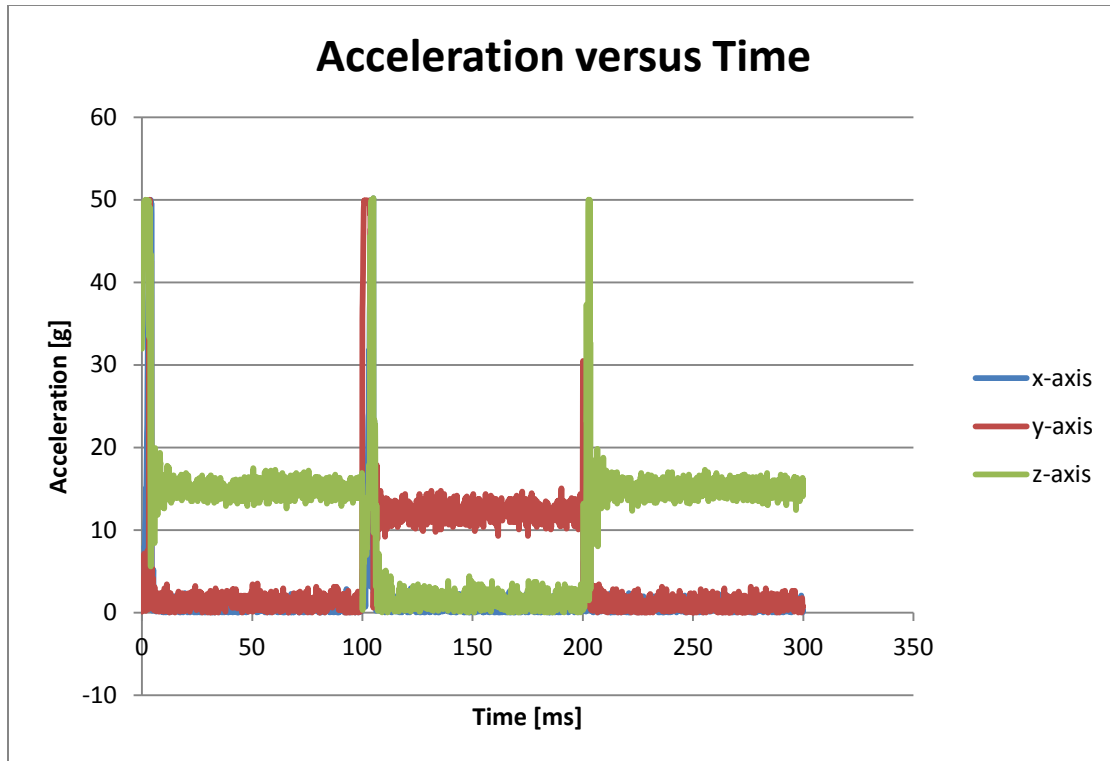


Figure 7. Concatenated Data from 3 Detected Impacts

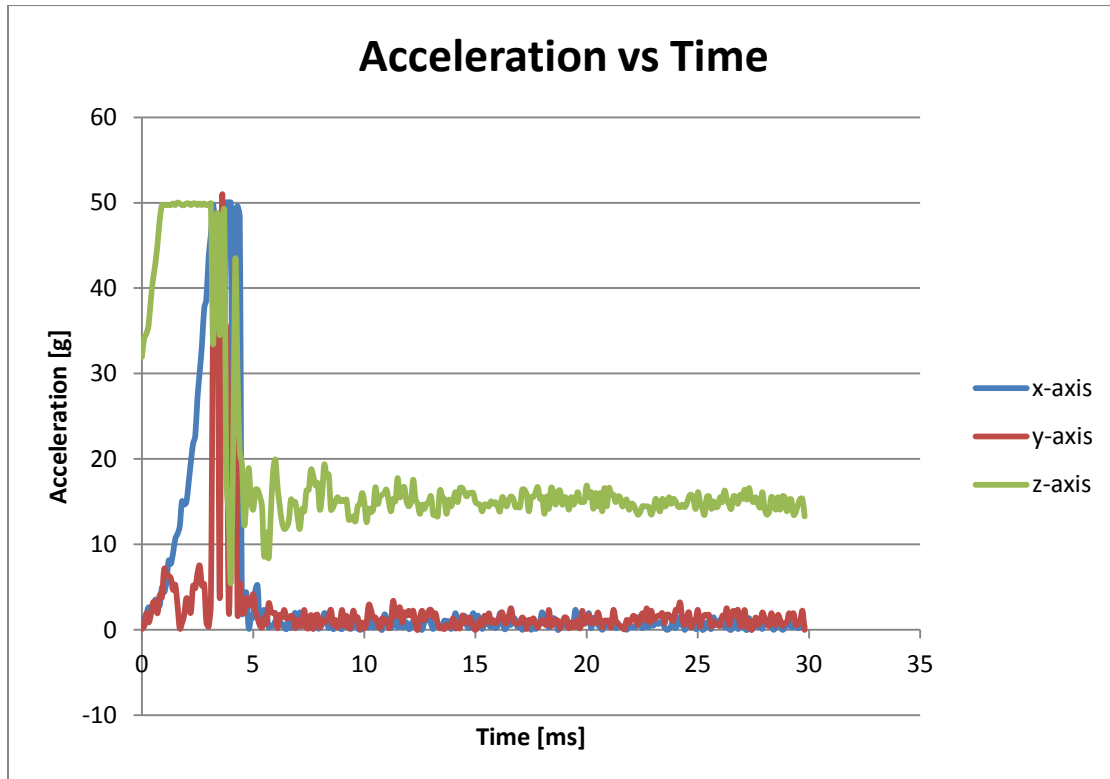


Figure 8. Single Impact Data from Device Testing.

In Figure 7, the three blows from the mallet can be seen distinctly in the on the graph. The impacts from the mallet were on two different sides of the device, as can be seen in the plot. Each blow recorded at roughly 50g per hit from the mallet. Figure 8 shows a closer look at a singular blow to the device. The floating z axis following the impact indicates that the device did bounce after being impacted.

The sampling frequency of the device was set to as high as possible at around 30kHz. Rough measurements revealed the true sampling frequency to be around 10 kHz due to serial data inclusion. The accelerometer itself has a bandwidth of 1300Hz for the x and y axes and 1000Hz for the z axis, and so the Nyquist rate of 2600 Hz was the lowest possible sampling frequency for this particular device. The frequency was set higher than needed in order to prove the capability of the device to use a device with a higher bandwidth at a later time.

Ch 7. Limitations and Future Applications

7.1 Limitations

The device fabricated for this project was not thoroughly validated. The next step would be to test the response of this device against a calibrated standard, such as a force transducer in a vertical drop test or impact test.

In this study, the designed system only measured linear acceleration and not rotational accelerations due to impacts. Rotational acceleration has been reported to be a cause of neuronal injury because of the shearing forces experienced by neuronal tissue. Thus, in future applications of this project, the use of multiple or multi-function accelerometers to measure both linear and rotational accelerations of the head during impact is suggested.

Another limitation of this method is that it measures the acceleration only at the location of the accelerometer, which may hinder understanding of the acceleration of the entire head. A method of overcoming this would be to embed this device into a mouthguard or use multiple devices on subject and gather data accordingly.

7.2 Future Applications

The intended “next step” for this project after a more thorough validation is to have the device used *in vivo* on younger test subjects in high impact sports and contribute to the research being done on MTBIs. Possible factors being addressed for the future application of using this device on test dummies and live test subjects would be the exact

placement of this device on the test subject and the choice of biocompatible adhesive for holding the device as close as possible to the subject's skull, if direct application is chosen versus the use of a mouthguard. This would allow for investigation into head acceleration measurement in both helmeted and non-helmeted sports.

Ch 8. Conclusions

Mild traumatic brain injuries are prevalent, under-reported, and under-documented. Of the population, it has been proven that the elderly and younger persons are at the highest risk for experiencing MTBI. For younger persons, one of the most common causes of MTBI is participation in high-impact sports.

Even with recent technological advances and increased public awareness of the individual and societal effects of these injuries, the true cause and cure are still unknown. The only current method of circumventing MTBIs is through preventative methods. In order to put into place effective preventative measures against MTBIs, a better understanding of the cause is needed.

The objectives of this project were to first better understand the current status of understanding MTBIs in younger persons. The next was to design and fabricate a device that could possibly be used in order to aid researchers in collecting more data on youth in high-impact sports. Both objectives were completed successfully, though there are many improvements that could be made. With thorough validation and increased sensing capabilities, this device could possibly be used in the future on test subjects participating in high-impact sports.

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Appendix

Calibration Data

Voltage Sweep Data

MIC Ch1		ACC Ch2	
X	Y	X	Y
Vrms	Vrms	Vrms	Vrms
0.001	0.0008962	0.001	0.0001342
0.0010798	0.0008997	0.0010798	0.0001296
0.001166	0.0008632	0.001166	0.0001664
0.001259	0.0008974	0.001259	0.000023
0.0013595	0.0009303	0.0013595	0.0001378
0.001468	0.0009174	0.001468	0.0001249
0.0015851	0.0008969	0.0015851	0.0001398
0.0017116	0.0008834	0.0017116	0.0001505
0.0018482	0.0009328	0.0018482	0.0001364
0.0019957	0.0008852	0.0019957	0.0001719
0.002155	0.0008896	0.002155	0.0002549
0.0023269	0.0008856	0.0023269	0.0001435
0.0025126	0.0009003	0.0025126	0.0001327
0.0027131	0.0009029	0.0027131	0.0001887
0.0029296	0.0008736	0.0029296	0.0001592
0.0031634	0.0009697	0.0031634	0.0001884
0.0034159	0.0009179	0.0034159	0.000154
0.0036884	0.0008733	0.0036884	9.133E-05
0.0039828	0.0009035	0.0039828	0.0001492
0.0043006	0.0008701	0.0043006	0.0001076
0.0046438	0.0008778	0.0046438	0.0001326
0.0050144	0.0008791	0.0050144	0.0001355
0.0054145	0.000895	0.0054145	0.0001777
0.0058466	0.0008802	0.0058466	0.0001956
0.0063132	0.0009325	0.0063132	0.0001263
0.006817	0.0008962	0.006817	0.0001251
0.007361	0.0008572	0.007361	0.0001205
0.0079484	0.00089	0.0079484	0.0001139
0.0085827	0.0008937	0.0085827	0.0001752
0.0092676	0.0009221	0.0092676	0.0001222
0.0100072	0.0009189	0.0100072	0.0001285
0.0108058	0.0008771	0.0108058	0.0001306

0.0116681	0.0009037	0.0116681	0.0002707
0.0125992	0.0009101	0.0125992	0.0001449
0.0136046	0.0008674	0.0136046	0.0001712
0.0146903	0.0009052	0.0146903	0.0002003
0.0158626	0.000897	0.0158626	0.0001488
0.0171285	0.0008924	0.0171285	0.0001498
0.0184953	0.0009187	0.0184953	0.0001347
0.0199713	0.0008875	0.0199713	0.000167
0.021565	0.0009154	0.021565	0.0001313
0.0232859	0.0009152	0.0232859	0.0001781
0.0251442	0.0008803	0.0251442	0.0001446
0.0271507	0.0009211	0.0271507	0.0001236
0.0293173	0.0009032	0.0293173	0.0001238
0.0316569	0.0009121	0.0316569	0.0001061
0.0341831	0.0009219	0.0341831	0.0001252
0.036911	0.0009237	0.036911	0.0001387
0.0398565	0.0008715	0.0398565	0.0001652
0.0430371	0.0008858	0.0430371	0.0001667
0.0464715	0.0008787	0.0464715	0.0001454
0.05018	0.0009164	0.05018	0.0002163
0.0541844	0.0008635	0.0541844	0.0001322
0.0585084	0.0009129	0.0585084	0.000158
0.0631774	0.0008952	0.0631774	0.0001945
0.068219	0.0009297	0.068219	0.0001656
0.073663	0.000932	0.073663	0.0002446
0.0795414	0.0009215	0.0795414	0.00026
0.0858888	0.0009633	0.0858888	0.0001495
0.0927429	0.0009351	0.0927429	0.0001399
0.1001438	0.0009642	0.1001438	0.0001601
0.1081354	0.000931	0.1081354	0.0004776
0.1167647	0.0009899	0.1167647	0.0001922
0.1260827	0.0009579	0.1260827	0.0004838
0.1361442	0.0009767	0.1361442	0.0001759
0.1470087	0.0009972	0.1470087	0.0001466
0.1587401	0.0010577	0.1587401	0.0001303
0.1714077	0.0010335	0.1714077	0.0001122
0.1850862	0.0010816	0.1850862	0.0001182
0.1998563	0.0010999	0.1998563	0.0001065
0.2158051	0.0011624	0.2158051	0.0001225
0.2330265	0.0011595	0.2330265	0.0001456
0.2516223	0.001241	0.2516223	0.0001327
0.271702	0.0011647	0.271702	0.000121
0.2933841	0.0012902	0.2933841	0.0001066

0.3167964	0.0013677	0.3167964	0.0001725
0.3420771	0.0013784	0.3420771	0.0001749
0.3693752	0.0014048	0.3693752	0.000124
0.3988518	0.0015529	0.3988518	0.0001886
0.4306805	0.0016151	0.4306805	0.0001807
0.4650493	0.001756	0.4650493	0.0001819
0.5021607	0.001742	0.5021607	0.0001681
0.5422336	0.0019293	0.5422336	0.0001624
0.5855044	0.0019484	0.5855044	0.000106
0.6322283	0.0020724	0.6322283	0.000106
0.6826808	0.0021882	0.6826808	0.0001497
0.7371594	0.0022893	0.7371594	0.000131
0.7959855	0.002489	0.7959855	0.0001494
0.8595059	0.0025259	0.8595059	0.0001184
0.9280954	0.0027605	0.9280954	0.0001533
1.0021584	0.0027715	1.0021584	0.0001521
1.0821316	0.0028933	1.0821316	0.0003458
1.1684869	0.0030791	1.1684869	0.0002272
1.2617333	0.0032103	1.2617333	0.0001896
1.3624209	0.0032317	1.3624209	0.0001375
1.4711435	0.0033376	1.4711435	0.0001521
1.5885423	0.0035413	1.5885423	0.0001373
1.7153096	0.00354	1.7153096	0.0001509
1.8521931	0.0036889	1.8521931	0.0001198
2	0.0039086	2	0.0001655

Frequency Sweep Data

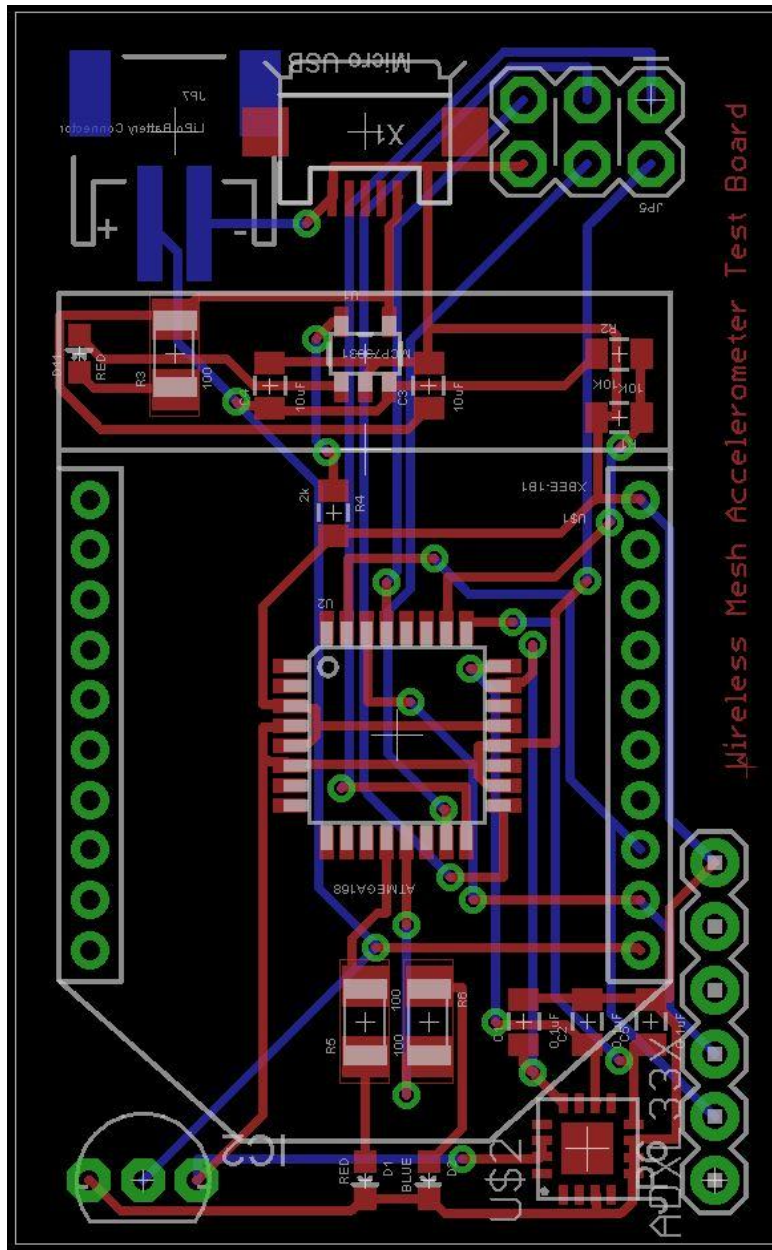
Ch1 (MIC)		Ch2 (ACC)	
X	Y	X	Y
Hz	Vrms	Hz	Vrms
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2.4090071	0.000906	2.4090071	0.0006921
2.6438823	0.0009	2.6438823	0.0006748
2.9016576	0.000896	2.9016576	0.000627
3.1845656	0.0009014	3.1845656	0.0006319
3.4950568	0.0009014	3.4950568	0.0006898
3.8358205	0.0009023	3.8358205	0.0005799
4.2098083	0.0009257	4.2098083	0.0005377

4.6202594	0.000925	4.6202594	0.0006301
5.070729	0.0009176	5.070729	0.0006407
5.5651188	0.0009167	5.5651188	0.0005737
6.107711	0.0009272	6.107711	0.0006376
6.7032053	0.0009149	6.7032053	0.0005555
7.3567595	0.0009257	7.3567595	0.0006455
8.0740345	0.0009133	8.0740345	0.0005393
8.8612429	0.0009121	8.8612429	0.0005129
9.7252032	0.0009039	9.7252032	0.0006526
10.673398	0.0009135	10.673398	0.0006126
11.714042	0.000914	11.714042	0.0005322
12.856146	0.0009043	12.856146	0.0005737
14.109605	0.0009084	14.109605	0.000794
15.485274	0.0009331	15.485274	0.0006843
16.995069	0.0009328	16.995069	0.0005975
18.652067	0.0009764	18.652067	0.0004757
20.47062	0.0010322	20.47062	0.0004303
22.466481	0.0011071	22.466481	0.0005084
24.656935	0.001228	24.656935	0.0003034
27.060955	0.0013318	27.060955	0.0005032
29.699365	0.0016081	29.699365	0.0003969
32.595017	0.001434	32.595017	0.000686
35.772991	0.0014291	35.772991	0.0001937
39.260813	0.0016102	39.260813	0.0003162
43.088694	0.0021471	43.088694	0.000345
47.289788	0.0033911	47.289788	0.0003019
51.900484	0.0040066	51.900484	0.0003404
56.960717	0.0032693	56.960717	0.0004118
62.514317	0.0025464	62.514317	0.0002182
68.609386	0.0024663	68.609386	0.0002707
75.298716	0.0026513	75.298716	0.000259
82.640248	0.002597	82.640248	0.0002253
90.69757	0.0020035	90.69757	0.0001683
99.540471	0.0014643	99.540471	0.0002874
109.24554	0.0019109	109.24554	0.000193
119.89685	0.0024443	119.89685	0.0002262
131.58664	0.0024179	131.58664	0.0001985
144.41618	0.0018681	144.41618	0.000174
158.49658	0.0023536	158.49658	0.000168
173.9498	0.0024886	173.9498	0.0001539
190.90969	0.0023389	190.90969	0.0001368
209.52315	0.0023908	209.52315	0.0001774
229.9514	0.0023359	229.9514	0.0001574

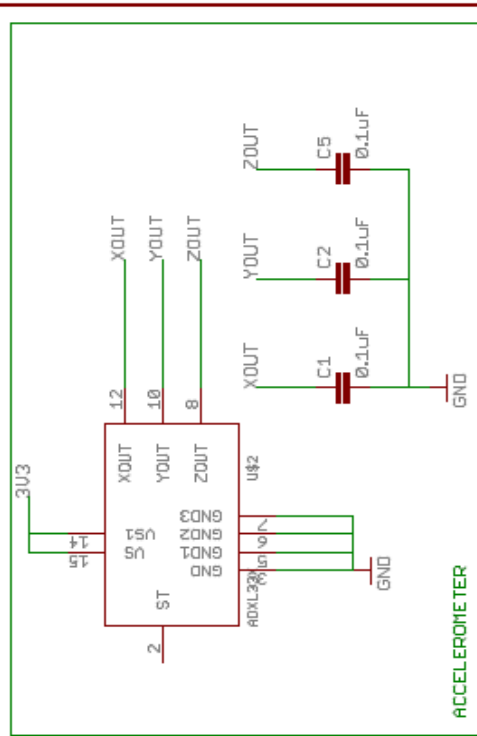
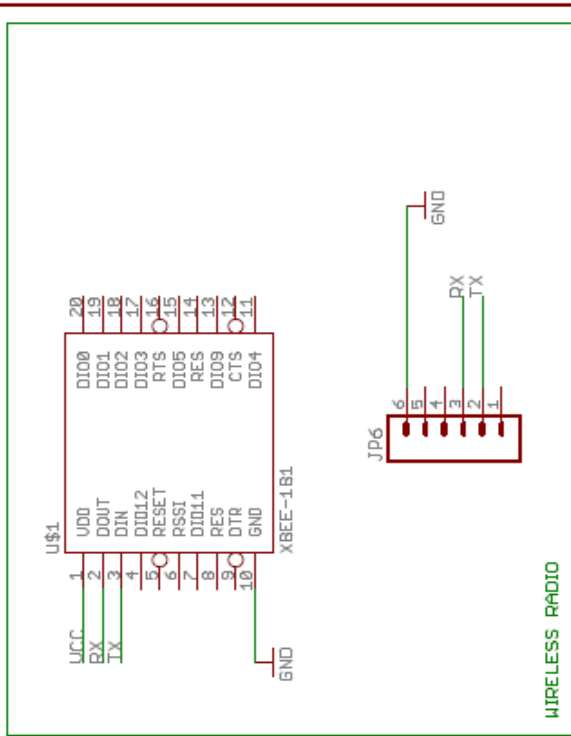
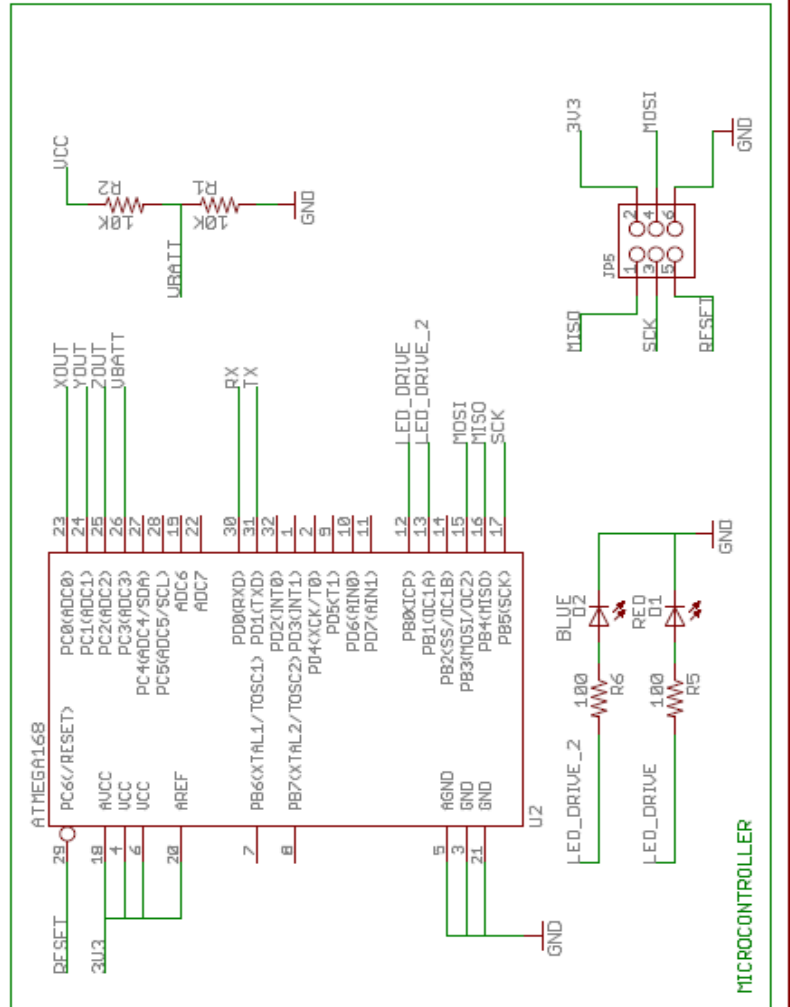
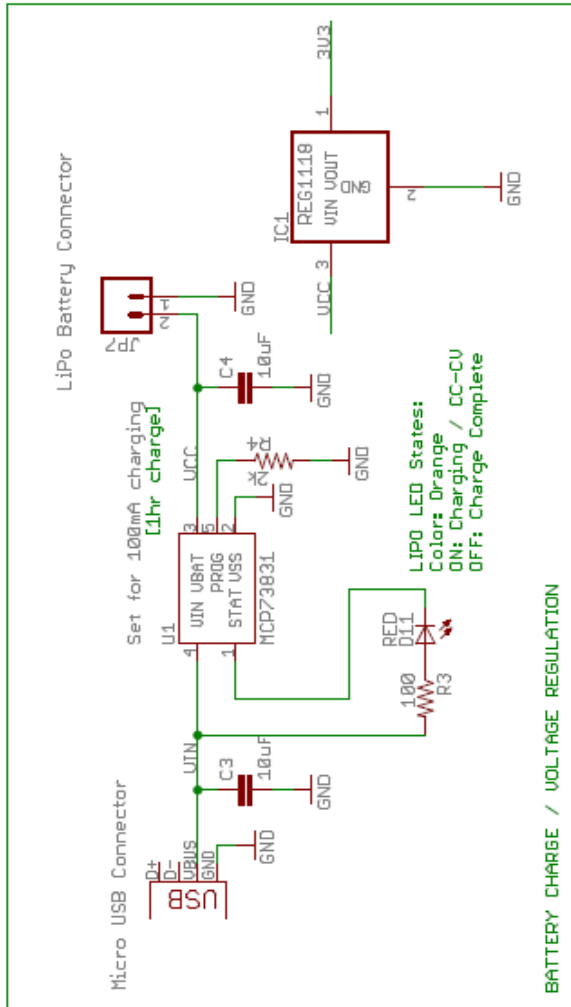
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303.98222	0.0020056	303.98222	0.0001657
333.62011	0.0019726	333.62011	0.0001325
366.14766	0.0018682	366.14766	0.0001493
401.8466	0.0018957	401.8466	0.0001551
441.02615	0.0017861	441.02615	0.0001908
484.02565	0.0020291	484.02565	0.0001343
531.21756	0.0018232	531.21756	0.0001134
583.01061	0.001435	583.01061	0.0001991
639.85343	0.0010484	639.85343	0.0001327
702.23835	0.0012602	702.23835	0.0001414
770.70572	0.0023598	770.70572	0.0001879
845.84857	0.0049489	845.84857	0.0002437
928.31777	0.0102312	928.31777	0.0003856
1018.8276	0.0149897	1018.8276	0.0004527
1118.162	0.0164657	1118.162	0.0007877
1227.1815	0.0157345	1227.1815	0.0012137
1346.8301	0.010369	1346.8301	0.0018049
1478.1444	0.0073033	1478.1444	0.0014869
1622.2617	0.005222	1622.2617	0.0017103
1780.4302	0.0033166	1780.4302	0.002064
1954.0199	0.001933	1954.0199	0.0021481
2144.5344	0.0017576	2144.5344	0.0022844
2353.6239	0.0020635	2353.6239	0.0021107
2583.0993	0.0011696	2583.0993	0.0014388
2834.9483	0.0011978	2834.9483	0.000215
3111.3523	0.00097	3111.3523	0.0009986
3414.7053	0.0008871	3414.7053	0.0012119
3747.6348	0.0008939	3747.6348	0.0014271
4113.0246	0.0009082	4113.0246	0.0018142
4514.0394	0.00093	4514.0394	0.0029731
4954.1527	0.0009201	4954.1527	0.0028832
5437.1765	0.0009286	5437.1765	0.0014029
5967.2945	0.0008874	5967.2945	0.0023873
6549.0983	0.0008815	6549.0983	0.001697
7187.6273	0.0008691	7187.6273	0.0015027
7888.4121	0.0008822	7888.4121	0.004208
8657.5226	0.0008727	8657.5226	0.0025288
9501.6203	0.0009054	9501.6203	0.0017134
10428.017	0.0009278	10428.017	0.0012136
11444.735	0.0009028	11444.735	0.0005322
12560.583	0.0008721	12560.583	0.0003178

13785.224	0.0009013	13785.224	0.0006715
15129.267	0.0008941	15129.267	0.0004375
16604.351	0.0008835	16604.351	0.0003168
18223.255	0.0008906	18223.255	0.0003173
20000	0.0008831	20000	0.0002402

Circuit Layout

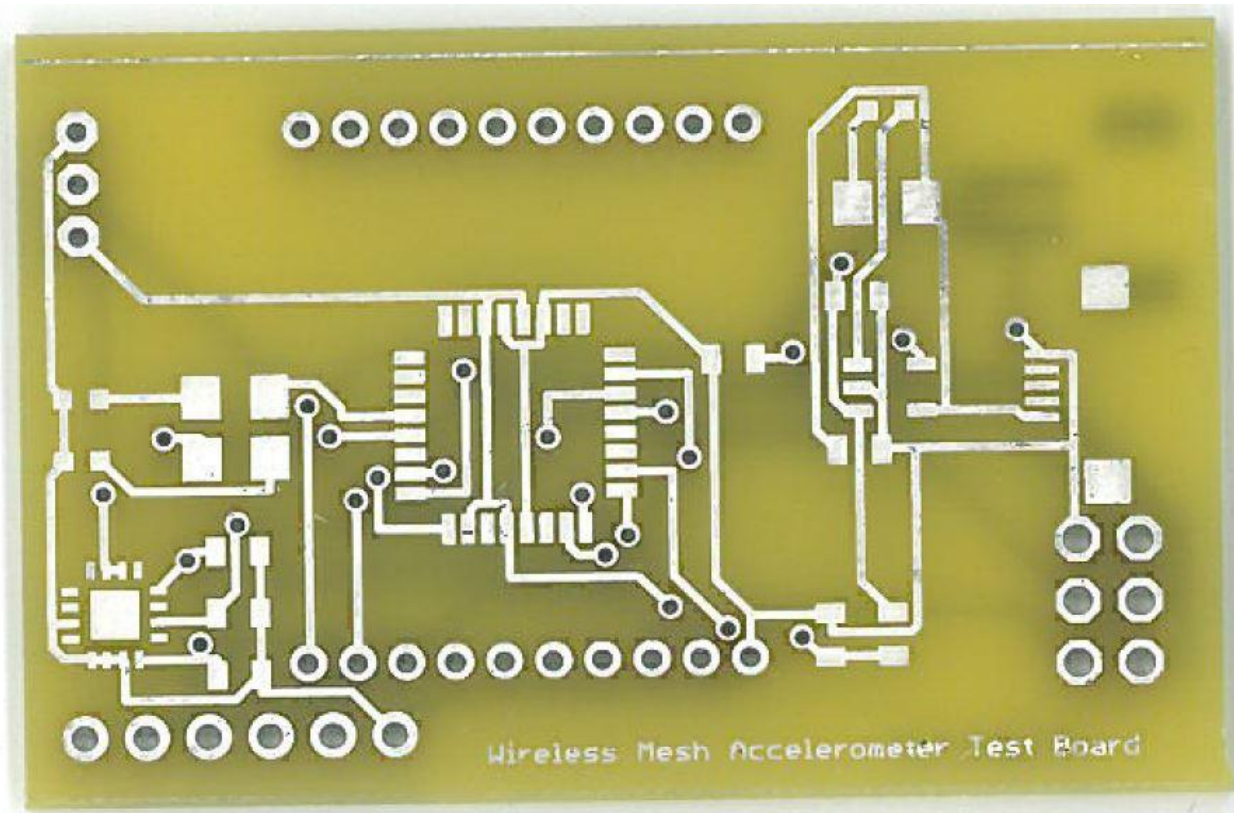


Circuit Schematic



	
TITLE: accel_schematic	
Document Number:	REV:
Date: 12/19/2013 10:15:59 AM	Sheet: 1/1

Printed Circuit Board



Bill of Materials

Item	Function / Description	Supplier	Distributor Link
Polymer Lithium Ion Battery	system power supply	sparkfun	https://www.sparkfun.com/products/731
enable/disable switch		digikey	http://www.digikey.com/product-detail/en/200USP9T1A1M2RE/EG4914-ND/2498451
input cap		digikey	http://www.digikey.com/product-detail/en/CL21A106KOQNNNE/1276-1096-1-ND/3889182
accelerometer	0.01uf	digikey	http://www.digikey.com/product-

filter cap			detail/en/CC0805ZRY5V9BB104/311-1361-1-ND/2103145
current limit led resistor	100 ohm	digikey	http://www.digikey.com/product-detail/en/RC1206FR-07100RL/311-100FRCT-ND/731438
accelerometer pullup	4k ohm	digikey	http://www.digikey.com/product-detail/en/RC0805FR-074K22L/311-4.22KCRCT-ND/730860
accelerometer	main mems accelerometer, +/-200G	digikey	http://www.analog.com/en/mems-sensors/mems-accelerometers/adxl377/products/product.html
microcontroller	atmega168	digikey	http://www.digikey.com/product-detail/en/ATMEGA168-20AU/ATMEGA168-20AU-ND/735450
micro jtag connector	for programming board	digikey	http://www.digikey.com/product-detail/en/67996-406HLF/609-3218-ND/1878478
battery connector	battery -> board connector	digikey	http://www.digikey.com/product-detail/en/B2B-PH-SM4-TB%28LF%29%28SN%29/455-1734-1-ND/926831
micro-usb connector	lipo charging	digikey	http://www.digikey.com/product-detail/en/1981584-1/A97799DKR-ND/1786251
linear regulator	3.3v supply onboard	digikey	http://www.digikey.com/product-detail/en/MIC5210-3.3YMM/576-2373-ND/1030467
lipo charge-control ic	safe lipo charging	digikey	http://www.digikey.com/product-detail/en/MCP73831T-2ACI%2FOT/MCP73831T-2ACI%2FOTCT-ND/1979802
lipo regulator resistor	2k	digikey	http://www.digikey.com/product-detail/en/ERJ-6ENF2001V/P2.00KCCT-ND/119044
Orange LED	indicator led onboard (0603)	digikey	http://www.digikey.com/product-detail/en/LNJ812R83RA/P11476DKR-ND/1846157
Blue LED	indicator led onboard (0603)		http://www.digikey.com/product-detail/en/LTST-C194TBKT/160-1837-1-ND/2356236
Red LED	indicator led onboard (0603)	digikey	http://www.digikey.com/product-detail/en/LTST-C194KRKT/160-1835-1-ND/2356232
clear heat shrink tubing	system enclosure	igikey	digikey

zigbee -> computer interface board	wireless data transfer	sparkfun	https://www.sparkfun.com/products/8687
zigbee tx/rx board	wireless data transfer	sparkfun	https://www.sparkfun.com/products/8665
micro usb cable		amazon	http://www.amazon.com/AmazonBasics-Male-Mini-Cable-Meters/dp/B00E9IF9RI/ref=sr_1_2?ie=UTF8&qid=1387179437&sr=8-2&keywords=mini+usb+cable

Device Test Code

```
// These constants won't change. They're used to give names
// to the pins used:
const int analogInx = A0; // Analog input pin that the x axis is attached to
const int analogIny = A1; // Analog input pin that the y axis is attached to
const int analogInz = A2; // Analog input pin that the z axis is attached to

int sensorValuex = 0; // value read from the accelerometer
int sensorValuey = 0; // value read from the accelerometer
int sensorValuez = 0; // value read from the accelerometer

int TripThreshold = 400; // threshold to start pummeling data over rs232 link

int cycles = 1000; // Number of cycles to push out data after an a TripThreshold event occurs
int cycleCount = 0;

int sensor_delta= 0; // average accelerometer value

void setup() {
  // initialize serial communications at 115200 bps:
  Serial.begin(115200);
}

void loop() {
  // read the analog in value:
  sensorValuex = analogRead(analogInx);
  sensorValuey = analogRead(analogIny);
  sensorValuez = analogRead(analogInz);

  // Basic trip point: If sensor average is greater than threshold begin sending data
```

```

sensor_delta = sensorValuex+ sensorValuey + sensorValuez;
sensor_delta = sensor_delta / 3;

if (sensor_delta > TripThreshold)
{
do{
    // read adc's
    sensorValuex = analogRead(analogInx);
    sensorValuey = analogRead(analogIny);
    sensorValuez = analogRead(analogInz);
    // print the results to the serial monitor:
    Serial.print("x=" );
    Serial.print(sensorValuex);
    Serial.print(",y=" );
    Serial.print(sensorValuey);
    Serial.print(",z=" );
    Serial.print(sensorValuez);
    Serial.println();
    cycleCount = cycleCount +1;
}
while (cycleCount < cycles);
cycleCount = 0;
Serial.print("event complete");
delay(1000);
}
}

```

Device Testing Raw Data

```

==~==~==~==~==~==~==
~==~==~== PuTTY
log 2014.01.09
18:47:28
==~==~==~==~==~==~==
~==~==~==
x=329,y=337,z=554
x=335,y=341,z=568
x=326,y=351,z=572
x=320,y=344,z=579
x=323,y=326,z=599
x=319,y=316,z=615
x=314,y=316,z=627
x=315,y=325,z=643
x=319,y=310,z=662
x=304,y=312,z=674
x=308,y=290,z=674
x=300,y=295,z=674
x=283,y=295,z=674
x=286,y=297,z=674
x=277,y=306,z=675
x=266,y=302,z=674
x=262,y=318,z=676
x=256,y=339,z=675
x=236,y=343,z=674
x=239,y=350,z=674
x=237,y=363,z=675
x=222,y=358,z=675
x=205,y=352,z=674
x=191,y=373,z=675
x=184,y=371,z=675
x=154,y=383,z=674
x=134,y=389,z=675
x=112,y=373,z=674
x=84,y=374,z=675
x=76,y=344,z=674
x=43,y=335,z=674
x=26,y=317,z=675
x=1,y=91,z=112
x=649,y=19,z=655
x=101,y=642,z=9
x=40,y=363,z=105
x=19,y=0,z=22
x=108,y=582,z=669
x=0,y=576,z=217
x=0,y=320,z=429

x=0,y=248,z=300
x=264,y=527,z=199
x=669,y=626,z=45
x=673,y=351,z=135
x=664,y=301,z=197
x=351,y=323,z=207
x=361,y=351,z=255
x=367,y=313,z=234
x=339,y=361,z=210
x=347,y=357,z=235
x=328,y=366,z=243
x=307,y=323,z=227
x=303,y=329,z=227
x=334,y=342,z=232
x=325,y=336,z=240
x=322,y=328,z=280
x=325,y=333,z=261
x=340,y=359,z=281
x=335,y=353,z=244
x=341,y=351,z=212
x=331,y=351,z=203
x=334,y=339,z=225
x=344,y=350,z=240
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x=337,y=347,z=257
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x=339,y=349,z=235
x=347,y=347,z=238
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x=351,y=339,z=229
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x=335,y=345,z=227
x=345,y=337,z=231
x=342,y=346,z=244
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x=341,y=347,z=233
x=337,y=343,z=229

```

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x=324,y=346,z=233	x=343,y=353,z=247	x=344,y=344,z=241	x=340,y=345,z=233
x=333,y=343,z=246	x=341,y=346,z=242	x=337,y=352,z=229	x=339,y=341,z=248
x=327,y=342,z=232	x=345,y=348,z=234	x=329,y=347,z=242	x=338,y=340,z=243
x=340,y=354,z=242	x=333,y=349,z=239	x=333,y=343,z=247	x=344,y=345,z=235
x=332,y=341,z=226	x=332,y=349,z=244	x=343,y=341,z=245	x=350,y=338,z=232
x=347,y=345,z=229	x=332,y=351,z=234	x=341,y=351,z=233	x=338,y=346,z=228
x=346,y=346,z=239	x=336,y=343,z=240	x=338,y=345,z=235	x=347,y=344,z=237
x=338,y=345,z=229	x=338,y=350,z=239	x=336,y=342,z=243	x=339,y=358,z=236
x=340,y=339,z=228	x=337,y=350,z=233	x=341,y=350,z=233	x=341,y=352,z=229
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x=335,y=347,z=234	x=339,y=354,z=236	x=339,y=343,z=233	x=334,y=344,z=231
x=336,y=339,z=243	x=348,y=353,z=240	x=342,y=344,z=244	x=337,y=331,z=240
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x=354,y=344,z=235	x=338,y=342,z=241	x=335,y=351,z=247	x=335,y=354,z=232
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x=327,y=343,z=236	x=343,y=345,z=235	x=343,y=353,z=234	x=336,y=338,z=234
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x=329,y=344,z=242	x=338,y=347,z=242	x=333,y=345,z=234	x=345,y=354,z=232
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x=334,y=352,z=240	x=344,y=349,z=233	x=338,y=339,z=238	x=341,y=343,z=245
x=340,y=346,z=230	x=333,y=350,z=232	x=337,y=348,z=242	x=328,y=347,z=234
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x=341,y=345,z=226	x=344,y=342,z=240	x=339,y=344,z=227	x=339,y=341,z=237
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x=335,y=341,z=233	x=337,y=342,z=239	x=337,y=343,z=226	x=348,y=344,z=233
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x=340,y=343,z=243	x=337,y=354,z=238	x=330,y=345,z=229	x=332,y=349,z=241
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x=339,y=351,z=240	x=340,y=338,z=234	x=339,y=347,z=243	x=331,y=351,z=239
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x=341,y=344,z=241	x=351,y=357,z=229	x=344,y=350,z=245	x=328,y=362,z=229
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x=343,y=348,z=238	x=327,y=349,z=244	x=333,y=353,z=239	x=336,y=347,z=243
x=344,y=343,z=240	x=335,y=347,z=236	x=334,y=353,z=239	x=329,y=338,z=247
x=343,y=333,z=240	x=344,y=342,z=237	x=326,y=336,z=237	x=338,y=337,z=247

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x=330,y=349,z=230	x=332,y=346,z=241	x=335,y=340,z=239	x=339,y=337,z=236
x=335,y=349,z=231	x=336,y=349,z=226	x=340,y=347,z=236	x=334,y=342,z=236
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x=341,y=347,z=240	x=328,y=343,z=244	x=338,y=347,z=233	x=348,y=349,z=237
x=340,y=350,z=244	x=344,y=342,z=235	x=323,y=349,z=243	x=341,y=341,z=242
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x=338,y=339,z=234	x=332,y=343,z=247	x=334,y=350,z=235	x=341,y=341,z=244
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x=341,y=343,z=241	x=336,y=346,z=235	x=328,y=345,z=238	x=338,y=345,z=244
x=336,y=342,z=222	x=345,y=339,z=243	x=335,y=341,z=235	x=346,y=350,z=230
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x=348,y=343,z=239	x=340,y=348,z=224	x=338,y=352,z=237	x=327,y=349,z=223
x=333,y=342,z=242	x=331,y=349,z=238	x=343,y=345,z=226	x=332,y=350,z=237
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x=335,y=342,z=240	x=334,y=346,z=238	x=341,y=346,z=237	x=333,y=351,z=243
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x=333,y=335,z=238	x=330,y=348,z=237	x=340,y=343,z=228	x=338,y=348,z=231
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x=347,y=339,z=239	x=319,y=674,z=412	x=299,y=255,z=222	x=336,y=259,z=366
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x=345,y=349,z=232	x=333,y=675,z=415	x=342,y=256,z=401	x=345,y=260,z=348
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x=342,y=351,z=244	x=299,y=674,z=392	x=329,y=278,z=328	x=332,y=251,z=330
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x=335,y=339,z=229	x=238,y=674,z=411	x=322,y=260,z=372	x=341,y=259,z=319
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x=347,y=348,z=242	x=174,y=673,z=445	x=329,y=263,z=335	x=339,y=266,z=313
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x=338,y=341,z=227	x=123,y=673,z=458	x=349,y=249,z=331	x=345,y=265,z=313
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x=333,y=347,z=233	x=359,y=24,z=240	x=345,y=255,z=331	x=331,y=262,z=326
x=339,y=337,z=235	x=0,y=233,z=3	x=331,y=257,z=332	x=352,y=266,z=330
x=321,y=342,z=234	x=540,y=488,z=657	x=339,y=252,z=338	x=335,y=260,z=330
x=343,y=349,z=237	x=69,y=604,z=676	x=335,y=247,z=351	x=342,y=256,z=335
x=337,y=348,z=229	x=1,y=11,z=673	x=348,y=254,z=347	x=327,y=250,z=330
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x=341,y=344,z=237	x=0,y=431,z=148	x=335,y=252,z=366	x=341,y=264,z=343
x=343,y=353,z=224	x=459,y=510,z=1	x=352,y=264,z=369	x=336,y=248,z=345
x=328,y=352,z=239	x=673,y=69,z=0	x=351,y=258,z=359	x=336,y=256,z=334
event	x=673,y=26,z=0	x=336,y=253,z=371	x=341,y=251,z=332
completex=314,y=57	x=674,y=61,z=121	x=340,y=249,z=354	x=339,y=254,z=337
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x=305,y=591,z=336	x=677,y=334,z=677	x=336,y=252,z=370	x=351,y=248,z=349
x=302,y=604,z=351	x=322,y=322,z=403	x=342,y=247,z=370	x=343,y=249,z=344
x=307,y=615,z=347	x=389,y=321,z=269	x=346,y=262,z=364	x=343,y=262,z=343
x=307,y=637,z=359	x=453,y=204,z=231	x=339,y=263,z=361	x=335,y=262,z=331
x=306,y=651,z=359	x=495,y=304,z=180	x=338,y=276,z=351	x=337,y=255,z=340
x=311,y=666,z=371	x=405,y=219,z=192	x=339,y=256,z=361	x=341,y=247,z=342
x=312,y=671,z=385	x=329,y=238,z=209	x=337,y=255,z=361	x=336,y=247,z=334
x=313,y=675,z=379	x=298,y=258,z=196	x=332,y=252,z=372	x=344,y=258,z=348

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x=341,y=263,z=327	x=337,y=253,z=334	x=342,y=251,z=328	x=339,y=256,z=320
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x=338,y=257,z=323	x=340,y=256,z=325	x=343,y=256,z=329	x=336,y=259,z=322
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x=344,y=264,z=323	x=345,y=263,z=332	x=352,y=255,z=325	x=328,y=255,z=330
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x=326,y=263,z=332	x=344,y=268,z=316	x=340,y=249,z=324	x=345,y=249,z=329
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x=346,y=258,z=327	x=343,y=263,z=322	x=330,y=260,z=320	x=341,y=249,z=319
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x=346,y=258,z=324	x=349,y=269,z=326	x=336,y=258,z=327	x=348,y=254,z=329
x=348,y=252,z=327	x=350,y=253,z=324	x=335,y=241,z=327	x=346,y=262,z=321
x=334,y=241,z=336	x=339,y=257,z=335	x=351,y=266,z=329	x=341,y=251,z=329
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x=341,y=248,z=332	x=342,y=246,z=325	x=343,y=253,z=335	x=347,y=249,z=339
x=345,y=251,z=336	x=339,y=253,z=323	x=334,y=260,z=332	x=351,y=253,z=328
x=333,y=251,z=332	x=335,y=253,z=328	x=351,y=241,z=327	x=329,y=261,z=336
x=356,y=258,z=336	x=349,y=262,z=319	x=340,y=257,z=324	x=346,y=259,z=324
x=337,y=253,z=329	x=341,y=249,z=326	x=337,y=251,z=329	x=338,y=258,z=328
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x=344,y=249,z=331	x=341,y=265,z=315	x=335,y=259,z=325	x=333,y=261,z=325
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x=344,y=242,z=324	x=338,y=255,z=326	x=342,y=265,z=331	x=343,y=248,z=324
x=339,y=244,z=321	x=332,y=258,z=327	x=344,y=262,z=333	x=348,y=252,z=325
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x=343,y=253,z=322	x=334,y=257,z=326	x=338,y=255,z=334	x=331,y=259,z=334
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x=337,y=264,z=327	x=349,y=249,z=328	x=344,y=252,z=328	x=332,y=257,z=333
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x=340,y=252,z=321	x=342,y=259,z=328	x=345,y=259,z=334	x=344,y=252,z=330
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x=347,y=252,z=326	x=351,y=250,z=332	x=349,y=256,z=342	x=343,y=245,z=325
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x=323,y=267,z=332	x=336,y=259,z=329	x=335,y=264,z=318	x=340,y=250,z=327
x=349,y=263,z=328	x=339,y=256,z=328	x=337,y=257,z=330	x=344,y=254,z=322
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x=341,y=251,z=330	x=344,y=258,z=336	x=336,y=262,z=333	x=331,y=266,z=329
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x=338,y=251,z=327	x=347,y=249,z=331	x=338,y=255,z=327	x=341,y=262,z=328
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x=341,y=263,z=335	x=342,y=252,z=335	x=342,y=268,z=325	x=343,y=255,z=329
x=345,y=256,z=319	x=336,y=259,z=326	x=343,y=254,z=331	x=328,y=261,z=329
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x=346,y=243,z=328	x=331,y=250,z=324	x=339,y=255,z=330	x=342,y=261,z=329
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x=335,y=268,z=334	x=339,y=248,z=338	x=338,y=246,z=343	x=340,y=247,z=327
x=336,y=247,z=332	x=347,y=257,z=327	x=337,y=256,z=321	x=330,y=256,z=325

x=337,y=257,z=325	x=337,y=241,z=325	x=315,y=359,z=212	x=327,y=335,z=231
x=344,y=257,z=323	x=336,y=263,z=338	x=345,y=335,z=241	x=328,y=336,z=247
x=341,y=261,z=320	x=340,y=260,z=315	x=339,y=340,z=248	x=345,y=339,z=233
x=334,y=256,z=327	x=345,y=245,z=335	x=350,y=354,z=236	x=341,y=341,z=235
x=350,y=258,z=329	x=333,y=256,z=317	x=361,y=353,z=256	x=345,y=340,z=238
x=345,y=258,z=326	x=344,y=256,z=326	x=340,y=341,z=245	x=332,y=331,z=249
x=349,y=249,z=339	x=337,y=254,z=319	x=337,y=327,z=218	x=339,y=345,z=251
x=345,y=259,z=322	x=328,y=262,z=325	x=343,y=322,z=240	x=345,y=355,z=231
x=345,y=262,z=325	x=340,y=252,z=320	x=340,y=327,z=235	x=334,y=345,z=211
x=342,y=244,z=318	x=340,y=253,z=329	x=341,y=345,z=226	x=352,y=335,z=235
x=335,y=252,z=331	x=341,y=265,z=316	x=334,y=339,z=231	x=339,y=347,z=245
x=341,y=259,z=332	event	x=328,y=360,z=233	x=331,y=321,z=236
x=342,y=263,z=328	completex=350,y=50	x=338,y=354,z=227	x=342,y=333,z=221
x=346,y=258,z=325	4,z=336	x=339,y=354,z=241	x=336,y=323,z=228
x=332,y=250,z=334	x=326,y=544,z=340	x=332,y=340,z=225	x=331,y=339,z=236
x=334,y=250,z=333	x=335,y=461,z=353	x=347,y=327,z=266	x=327,y=343,z=237
x=336,y=255,z=339	x=410,y=345,z=427	x=354,y=335,z=282	x=339,y=330,z=231
x=332,y=252,z=335	x=387,y=412,z=382	x=345,y=334,z=262	x=347,y=330,z=232
x=335,y=249,z=329	x=341,y=406,z=297	x=340,y=343,z=235	x=337,y=332,z=247
x=353,y=246,z=332	x=369,y=359,z=313	x=342,y=359,z=242	x=335,y=337,z=240
x=342,y=252,z=325	x=392,y=400,z=342	x=341,y=360,z=234	x=348,y=344,z=226
x=343,y=251,z=332	x=368,y=428,z=313	x=341,y=356,z=232	x=341,y=332,z=246
x=338,y=267,z=319	x=356,y=381,z=301	x=348,y=359,z=233	x=342,y=335,z=222
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x=346,y=256,z=327	x=365,y=392,z=290	x=341,y=356,z=233	x=348,y=336,z=237
x=341,y=245,z=324	x=363,y=369,z=273	x=340,y=352,z=239	x=341,y=353,z=228
x=347,y=259,z=326	x=367,y=356,z=281	x=346,y=343,z=237	x=334,y=339,z=252
x=345,y=252,z=319	x=337,y=373,z=270	x=339,y=348,z=243	x=339,y=342,z=230
x=337,y=261,z=320	x=376,y=306,z=256	x=333,y=346,z=239	x=341,y=338,z=247
x=339,y=260,z=337	x=353,y=360,z=224	x=334,y=348,z=241	x=335,y=339,z=243
x=340,y=251,z=325	x=318,y=285,z=86	x=323,y=338,z=204	x=340,y=331,z=236
x=334,y=256,z=330	x=315,y=372,z=182	x=343,y=334,z=243	x=351,y=349,z=234
x=345,y=262,z=330	x=335,y=283,z=145	x=352,y=356,z=284	x=340,y=343,z=240
x=347,y=254,z=323	x=369,y=304,z=214	x=338,y=342,z=251	x=337,y=344,z=236
x=340,y=260,z=325	x=353,y=355,z=243	x=343,y=331,z=238	x=345,y=345,z=234
x=341,y=253,z=338	x=363,y=362,z=282	x=326,y=345,z=243	x=341,y=347,z=239
x=345,y=260,z=330	x=355,y=368,z=270	x=323,y=318,z=226	x=342,y=347,z=228
x=350,y=263,z=324	x=377,y=346,z=248	x=320,y=315,z=216	x=339,y=341,z=226
x=340,y=260,z=332	x=399,y=214,z=9	x=330,y=324,z=229	x=338,y=343,z=232
x=333,y=247,z=333	x=267,y=373,z=0	x=351,y=352,z=234	x=338,y=336,z=237
x=338,y=270,z=334	x=159,y=353,z=0	x=345,y=355,z=243	x=344,y=336,z=240
x=337,y=251,z=330	x=332,y=329,z=328	x=343,y=349,z=230	x=354,y=342,z=236
x=336,y=256,z=342	x=355,y=279,z=349	x=341,y=336,z=232	x=338,y=336,z=232
x=337,y=263,z=328	x=344,y=270,z=300	x=328,y=348,z=243	x=338,y=336,z=237
x=344,y=253,z=339	x=275,y=211,z=0	x=348,y=339,z=225	x=329,y=342,z=239
x=344,y=252,z=326	x=352,y=342,z=292	x=340,y=358,z=234	x=347,y=339,z=231
x=327,y=263,z=329	x=340,y=313,z=282	x=346,y=345,z=240	x=342,y=342,z=223
x=343,y=267,z=323	x=265,y=394,z=117	x=337,y=343,z=240	x=341,y=344,z=244
x=346,y=256,z=328	x=329,y=348,z=319	x=344,y=349,z=253	x=343,y=341,z=233

x=332,y=353,z=233	x=343,y=345,z=240	x=344,y=340,z=241	x=340,y=345,z=231
x=338,y=349,z=229	x=332,y=342,z=230	x=341,y=345,z=234	x=333,y=348,z=235
x=332,y=355,z=241	x=342,y=347,z=236	x=343,y=341,z=235	x=347,y=345,z=246
x=327,y=357,z=232	x=339,y=335,z=228	x=337,y=356,z=232	x=340,y=335,z=236
x=343,y=340,z=240	x=337,y=344,z=230	x=347,y=337,z=239	x=346,y=344,z=230
x=342,y=331,z=237	x=343,y=343,z=236	x=346,y=345,z=238	x=341,y=338,z=233
x=336,y=337,z=224	x=342,y=337,z=240	x=347,y=349,z=238	x=349,y=336,z=247
x=350,y=343,z=226	x=327,y=346,z=233	x=343,y=352,z=234	x=334,y=345,z=235
x=342,y=327,z=237	x=341,y=352,z=233	x=346,y=346,z=232	x=330,y=347,z=245
x=336,y=340,z=236	x=328,y=339,z=242	x=340,y=346,z=237	x=346,y=345,z=230
x=338,y=344,z=247	x=331,y=350,z=232	x=333,y=342,z=232	x=335,y=338,z=234
x=340,y=346,z=235	x=341,y=341,z=240	x=337,y=335,z=240	x=332,y=341,z=244
x=341,y=352,z=239	x=337,y=341,z=238	x=341,y=348,z=244	x=344,y=339,z=244
x=331,y=342,z=228	x=339,y=343,z=233	x=338,y=338,z=241	x=339,y=341,z=241
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x=344,y=353,z=228	x=338,y=343,z=229	x=340,y=331,z=244	x=336,y=343,z=225
x=341,y=348,z=236	x=335,y=349,z=236	x=330,y=351,z=238	x=343,y=342,z=232
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x=334,y=357,z=239	x=343,y=342,z=229	x=343,y=357,z=251	x=337,y=336,z=232
x=337,y=347,z=240	x=349,y=339,z=237	x=336,y=338,z=231	x=331,y=351,z=229
x=340,y=344,z=244	x=345,y=344,z=228	x=330,y=344,z=237	x=334,y=352,z=233
x=343,y=347,z=223	x=337,y=340,z=232	x=337,y=341,z=248	x=341,y=350,z=235
x=345,y=335,z=249	x=340,y=344,z=246	x=336,y=351,z=237	x=339,y=344,z=230
x=334,y=342,z=242	x=343,y=336,z=234	x=338,y=343,z=235	x=342,y=338,z=246
x=348,y=338,z=239	x=338,y=347,z=242	x=347,y=341,z=239	x=349,y=339,z=229
x=346,y=337,z=233	x=339,y=346,z=239	x=342,y=338,z=240	x=341,y=353,z=239
x=350,y=333,z=228	x=354,y=343,z=234	x=337,y=344,z=234	x=348,y=341,z=240
x=327,y=333,z=236	x=344,y=351,z=236	x=334,y=341,z=237	x=339,y=334,z=239
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x=328,y=339,z=237	x=337,y=340,z=236	x=340,y=352,z=237	x=328,y=342,z=241
x=339,y=343,z=235	x=337,y=341,z=239	x=341,y=346,z=227	x=341,y=350,z=226
x=337,y=344,z=243	x=343,y=341,z=231	x=342,y=342,z=236	x=344,y=347,z=233
x=334,y=339,z=243	x=338,y=340,z=239	x=336,y=345,z=241	x=342,y=348,z=236
x=336,y=344,z=231	x=339,y=351,z=228	x=339,y=340,z=224	x=330,y=348,z=234
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x=352,y=346,z=235	x=347,y=338,z=240	x=338,y=347,z=233	x=345,y=332,z=233
x=341,y=343,z=240	x=336,y=345,z=233	x=344,y=339,z=228	x=342,y=338,z=234
x=340,y=342,z=236	x=343,y=336,z=241	x=339,y=341,z=237	x=336,y=345,z=234
x=334,y=345,z=237	x=349,y=349,z=232	x=341,y=335,z=243	x=329,y=340,z=235
x=338,y=338,z=246	x=341,y=350,z=241	x=335,y=340,z=234	x=341,y=342,z=243
x=351,y=342,z=228	x=341,y=346,z=255	x=337,y=336,z=234	x=345,y=346,z=233
x=344,y=339,z=239	x=347,y=340,z=243	x=336,y=347,z=234	x=351,y=336,z=243
x=339,y=354,z=233	x=343,y=350,z=236	x=351,y=336,z=240	x=341,y=348,z=240
x=345,y=355,z=234	x=337,y=345,z=238	x=339,y=346,z=237	x=339,y=332,z=248
x=337,y=341,z=227	x=346,y=349,z=237	x=340,y=343,z=227	x=336,y=349,z=236
x=331,y=341,z=243	x=341,y=354,z=238	x=340,y=335,z=246	x=336,y=343,z=239
x=337,y=341,z=235	x=336,y=336,z=244	x=338,y=336,z=248	x=333,y=348,z=235
x=337,y=335,z=238	x=334,y=347,z=241	x=339,y=338,z=238	x=342,y=349,z=227

x=345,y=349,z=233	x=334,y=357,z=242	x=335,y=347,z=245	x=345,y=343,z=239
x=347,y=340,z=246	x=340,y=341,z=227	x=341,y=348,z=236	x=351,y=346,z=238
x=327,y=340,z=239	x=345,y=342,z=234	x=343,y=344,z=229	x=333,y=339,z=231
x=329,y=335,z=242	x=337,y=345,z=237	x=344,y=346,z=228	x=347,y=335,z=232
x=341,y=335,z=248	x=334,y=351,z=229	x=342,y=346,z=241	x=334,y=337,z=225
x=331,y=342,z=243	x=343,y=340,z=226	x=342,y=341,z=235	x=341,y=336,z=243
x=336,y=347,z=240	x=339,y=346,z=242	x=332,y=340,z=235	x=343,y=349,z=234
x=327,y=352,z=246	x=343,y=339,z=231	x=341,y=347,z=239	x=339,y=333,z=244
x=334,y=343,z=230	x=338,y=351,z=223	x=339,y=351,z=242	x=339,y=344,z=249
x=332,y=347,z=236	x=341,y=343,z=242	x=342,y=342,z=230	x=329,y=353,z=238
x=341,y=343,z=238	x=345,y=346,z=231	x=350,y=347,z=236	x=346,y=336,z=236
x=342,y=347,z=240	x=325,y=346,z=234	x=341,y=356,z=231	x=337,y=337,z=231
x=341,y=347,z=236	x=333,y=341,z=235	x=341,y=352,z=232	x=336,y=354,z=239
x=338,y=349,z=232	x=345,y=337,z=231	x=339,y=351,z=247	x=333,y=336,z=239
x=337,y=353,z=232	x=336,y=327,z=237	x=340,y=351,z=237	x=342,y=343,z=237
x=345,y=355,z=233	x=334,y=340,z=233	x=344,y=349,z=234	x=341,y=337,z=234
x=340,y=342,z=239	x=340,y=331,z=245	x=345,y=340,z=237	x=333,y=342,z=233
x=340,y=352,z=235	x=338,y=343,z=231	x=348,y=349,z=243	x=348,y=335,z=240
x=343,y=334,z=235	x=329,y=344,z=236	x=340,y=349,z=238	x=339,y=347,z=246
x=338,y=341,z=230	x=344,y=342,z=240	x=337,y=339,z=240	x=344,y=347,z=240
x=337,y=342,z=234	x=329,y=344,z=238	x=339,y=343,z=238	x=333,y=341,z=244
x=345,y=344,z=235	x=328,y=339,z=232	x=341,y=346,z=240	x=333,y=338,z=243
x=342,y=341,z=238	x=325,y=342,z=235	x=336,y=331,z=243	x=336,y=338,z=237
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x=335,y=331,z=234	x=337,y=346,z=233	x=345,y=334,z=234	x=328,y=341,z=241
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x=345,y=359,z=239	x=337,y=336,z=236	x=343,y=343,z=229	x=343,y=345,z=237
x=334,y=339,z=239	x=333,y=347,z=235	x=337,y=342,z=236	x=331,y=331,z=238
x=338,y=340,z=228	x=345,y=331,z=241	x=336,y=350,z=237	x=332,y=342,z=243
x=334,y=339,z=233	x=341,y=344,z=240	x=346,y=333,z=232	x=337,y=336,z=246
x=344,y=346,z=231	x=333,y=336,z=247	x=336,y=344,z=237	x=338,y=345,z=234
x=341,y=342,z=227	x=332,y=344,z=238	x=324,y=339,z=240	x=325,y=340,z=238
x=338,y=347,z=242	x=329,y=345,z=236	x=343,y=348,z=237	x=340,y=340,z=235
x=343,y=347,z=233	x=332,y=339,z=232	x=343,y=346,z=233	x=341,y=342,z=236
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x=338,y=337,z=239	x=339,y=349,z=238	x=336,y=340,z=233	x=347,y=338,z=231
x=333,y=349,z=236	x=341,y=343,z=247	x=335,y=344,z=237	x=349,y=347,z=228
x=341,y=346,z=242	x=331,y=342,z=240	x=348,y=338,z=239	x=340,y=333,z=240
x=337,y=341,z=234	x=344,y=351,z=233	x=332,y=337,z=238	x=337,y=342,z=239
x=336,y=342,z=246	x=345,y=341,z=233	x=342,y=345,z=235	x=339,y=345,z=228
x=339,y=344,z=235	x=347,y=342,z=234	x=348,y=342,z=248	x=340,y=345,z=243
x=345,y=339,z=241	x=335,y=350,z=237	x=338,y=347,z=240	x=335,y=348,z=237
x=342,y=336,z=243	x=338,y=342,z=242	x=346,y=340,z=239	x=337,y=348,z=247
x=334,y=335,z=239	x=345,y=347,z=242	x=337,y=336,z=235	x=337,y=343,z=241
x=337,y=346,z=235	x=337,y=341,z=242	x=331,y=341,z=229	x=336,y=351,z=244

x=350,y=339,z=243	x=339,y=345,z=238	x=341,y=347,z=232	x=339,y=348,z=235
x=338,y=335,z=233	x=339,y=351,z=235	x=350,y=341,z=234	x=334,y=348,z=238
x=342,y=345,z=226	x=333,y=344,z=240	x=339,y=342,z=233	x=334,y=336,z=240
x=344,y=349,z=234	x=328,y=350,z=234	x=346,y=344,z=238	x=341,y=343,z=241
x=340,y=335,z=231	x=339,y=339,z=239	x=335,y=335,z=234	x=338,y=351,z=235
x=342,y=341,z=234	x=337,y=349,z=241	x=337,y=345,z=231	x=334,y=331,z=240
x=335,y=350,z=239	x=347,y=339,z=238	x=338,y=334,z=227	x=337,y=331,z=236
x=330,y=349,z=234	x=343,y=339,z=239	x=340,y=345,z=235	x=336,y=344,z=232
x=343,y=340,z=243	x=334,y=344,z=241	x=340,y=338,z=237	x=333,y=340,z=246
x=331,y=357,z=237	x=334,y=335,z=230	x=337,y=341,z=239	x=336,y=343,z=243
x=334,y=346,z=236	x=341,y=335,z=238	x=343,y=345,z=234	x=338,y=343,z=243
x=337,y=330,z=236	x=340,y=345,z=239	x=337,y=341,z=243	x=336,y=349,z=238
x=342,y=341,z=233	x=344,y=347,z=231	x=338,y=344,z=230	x=339,y=341,z=241
x=343,y=336,z=243	x=346,y=343,z=234	x=337,y=338,z=236	x=332,y=348,z=228
x=350,y=335,z=243	x=345,y=355,z=231	x=346,y=340,z=240	x=349,y=353,z=236
x=348,y=349,z=230	x=341,y=342,z=241	x=348,y=345,z=240	x=341,y=348,z=234
x=343,y=340,z=238	x=341,y=353,z=245	x=342,y=347,z=243	x=335,y=340,z=236
x=341,y=347,z=239	x=330,y=351,z=237	x=340,y=352,z=239	x=330,y=340,z=236
x=338,y=352,z=233	x=342,y=346,z=228	x=339,y=358,z=244	x=330,y=342,z=238
x=337,y=338,z=242	x=332,y=347,z=236	x=348,y=343,z=244	x=339,y=342,z=240
x=337,y=336,z=236	x=334,y=342,z=244	x=337,y=346,z=238	x=333,y=326,z=237
x=334,y=344,z=232	x=345,y=351,z=234	x=338,y=353,z=235	x=343,y=336,z=228
x=339,y=349,z=235	x=339,y=341,z=240	x=344,y=346,z=241	x=338,y=346,z=242
x=338,y=346,z=230	x=335,y=345,z=227	x=333,y=351,z=243	x=342,y=347,z=240
x=341,y=341,z=236	x=346,y=346,z=233	x=347,y=338,z=237	x=342,y=334,z=243
x=339,y=342,z=224	x=335,y=349,z=242	x=347,y=342,z=242	x=331,y=345,z=247
x=343,y=337,z=229	x=333,y=336,z=238	x=347,y=348,z=239	x=344,y=337,z=241
x=340,y=345,z=235	x=342,y=342,z=232	x=339,y=350,z=242	x=336,y=336,z=230
x=343,y=352,z=221	x=336,y=341,z=234	x=344,y=339,z=238	x=340,y=340,z=237
x=339,y=337,z=230	x=330,y=349,z=241	x=339,y=352,z=236	x=350,y=338,z=227
x=340,y=350,z=227	x=351,y=347,z=240	x=340,y=343,z=242	x=338,y=344,z=237
x=341,y=349,z=238	x=343,y=351,z=224	x=352,y=341,z=245	x=334,y=327,z=227
x=332,y=356,z=231	x=341,y=337,z=237	x=341,y=350,z=242	x=344,y=340,z=232
x=343,y=338,z=235	x=347,y=337,z=236	x=347,y=346,z=229	x=340,y=345,z=237
x=341,y=354,z=234	x=346,y=342,z=238	x=342,y=346,z=230	x=336,y=355,z=238
x=343,y=339,z=233	x=342,y=354,z=235	x=345,y=345,z=239	x=334,y=346,z=228
x=334,y=349,z=233	x=340,y=335,z=236	x=342,y=338,z=234	x=335,y=340,z=237
x=342,y=351,z=228	x=343,y=343,z=227	x=334,y=348,z=235	x=336,y=343,z=233
x=329,y=351,z=228	x=345,y=338,z=236	x=339,y=351,z=234	x=336,y=345,z=231
x=343,y=342,z=234	x=332,y=338,z=240	x=342,y=337,z=237	x=347,y=342,z=229
x=345,y=342,z=240	x=348,y=333,z=233	x=343,y=338,z=238	x=341,y=345,z=237
x=340,y=340,z=241	x=353,y=340,z=236	x=343,y=340,z=240	x=337,y=342,z=241
x=328,y=350,z=223	x=331,y=343,z=232	x=350,y=338,z=233	x=342,y=344,z=231
x=347,y=332,z=240	x=337,y=339,z=236	x=339,y=332,z=240	x=333,y=346,z=231
x=341,y=341,z=247	x=341,y=344,z=231	x=334,y=339,z=226	x=334,y=344,z=237
x=332,y=349,z=227	x=334,y=341,z=244	x=341,y=334,z=237	x=346,y=334,z=234
x=337,y=336,z=231	x=339,y=348,z=239	x=337,y=340,z=238	x=339,y=339,z=239
x=335,y=344,z=237	x=332,y=340,z=232	x=334,y=339,z=240	x=335,y=349,z=238
x=342,y=353,z=237	x=339,y=346,z=240	x=345,y=338,z=235	x=341,y=338,z=243

x=342,y=341,z=226	x=342,y=355,z=227	x=334,y=342,z=239	x=339,y=345,z=238
x=332,y=330,z=241	x=344,y=338,z=242	x=344,y=336,z=237	x=344,y=344,z=239
x=345,y=338,z=236	x=344,y=342,z=238	x=326,y=339,z=234	x=338,y=341,z=242
x=345,y=334,z=241	x=332,y=336,z=245	x=331,y=339,z=233	x=351,y=345,z=230
x=342,y=337,z=227	x=339,y=353,z=235	x=340,y=341,z=235	x=342,y=351,z=238
x=347,y=342,z=228	x=337,y=352,z=236	x=345,y=342,z=231	x=344,y=346,z=239
x=336,y=338,z=246	x=341,y=343,z=233	x=348,y=335,z=232	x=340,y=345,z=240
x=339,y=352,z=231	x=339,y=338,z=234	x=342,y=347,z=238	x=336,y=343,z=239
x=332,y=350,z=235	x=336,y=356,z=240	x=332,y=340,z=242	x=346,y=343,z=239
x=340,y=350,z=225	x=341,y=338,z=244	x=332,y=335,z=247	x=329,y=351,z=233
x=347,y=347,z=236	x=339,y=347,z=237	x=344,y=358,z=235	x=341,y=349,z=236
x=342,y=341,z=236	x=331,y=356,z=238	x=340,y=328,z=249	x=338,y=338,z=242
x=342,y=338,z=232	x=338,y=350,z=232	x=333,y=342,z=241	x=348,y=334,z=239
x=338,y=348,z=225	x=337,y=351,z=237	x=341,y=349,z=237	x=342,y=353,z=233
x=338,y=352,z=241	x=328,y=346,z=237	x=342,y=344,z=239	x=337,y=345,z=243
x=339,y=339,z=235	x=336,y=347,z=235	x=331,y=339,z=233	x=339,y=345,z=248
x=340,y=341,z=239	x=338,y=357,z=227	x=335,y=347,z=224	x=339,y=345,z=241
x=344,y=343,z=235	x=333,y=352,z=229	x=344,y=345,z=239	x=345,y=335,z=233
x=348,y=338,z=235	x=335,y=354,z=235	x=338,y=343,z=241	x=327,y=344,z=237
x=345,y=330,z=239	x=337,y=342,z=246	x=342,y=344,z=250	x=333,y=349,z=245
x=342,y=349,z=234	x=333,y=347,z=238	x=343,y=341,z=234	x=336,y=333,z=229
x=339,y=347,z=239	x=348,y=340,z=231	x=343,y=338,z=235	x=330,y=338,z=236
x=347,y=337,z=232	x=336,y=341,z=235	x=336,y=341,z=243	x=329,y=344,z=232
x=331,y=340,z=241	x=340,y=344,z=236	x=334,y=344,z=235	x=343,y=332,z=243
x=342,y=334,z=239	x=331,y=349,z=236	x=334,y=342,z=232	x=332,y=350,z=239
x=337,y=339,z=246	x=341,y=346,z=236	x=339,y=333,z=232	x=341,y=339,z=244
x=334,y=334,z=241	x=336,y=343,z=247	x=333,y=345,z=235	x=333,y=339,z=229
x=346,y=348,z=239	x=334,y=348,z=236	x=336,y=335,z=243	x=338,y=328,z=230
x=344,y=337,z=237	x=344,y=348,z=237	x=332,y=340,z=238	x=345,y=351,z=233
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x=340,y=345,z=237	x=335,y=343,z=240	x=349,y=352,z=231	x=341,y=343,z=231
x=342,y=341,z=227	x=341,y=346,z=241	x=336,y=351,z=233	x=331,y=346,z=235
x=333,y=345,z=234	x=345,y=345,z=232	x=339,y=345,z=244	x=335,y=348,z=245
x=335,y=342,z=243	x=335,y=335,z=227	x=344,y=346,z=240	x=332,y=340,z=229
x=342,y=346,z=240	x=336,y=340,z=228	x=345,y=347,z=237	x=336,y=342,z=235
x=338,y=349,z=231	x=341,y=345,z=240	x=336,y=354,z=235	x=335,y=353,z=233
x=342,y=343,z=237	x=339,y=348,z=226	x=351,y=352,z=237	x=337,y=353,z=233
x=344,y=337,z=238	x=341,y=340,z=233	x=339,y=349,z=235	x=336,y=355,z=241
x=337,y=349,z=231	x=339,y=334,z=243	x=339,y=342,z=237	x=336,y=336,z=239
x=348,y=353,z=232	x=340,y=346,z=246	x=338,y=349,z=241	x=345,y=335,z=236
x=330,y=359,z=242	x=349,y=331,z=245	x=341,y=340,z=239	x=338,y=340,z=237
x=346,y=346,z=238	x=334,y=348,z=232	x=339,y=350,z=240	x=347,y=332,z=227
x=349,y=336,z=242	x=334,y=343,z=228	x=347,y=341,z=244	x=349,y=339,z=229
x=338,y=331,z=243	x=344,y=335,z=235	x=350,y=350,z=230	x=343,y=336,z=235
x=350,y=345,z=237	x=340,y=341,z=249	x=342,y=348,z=242	x=345,y=346,z=241
x=343,y=336,z=239	x=335,y=353,z=232	x=349,y=343,z=231	x=352,y=347,z=234
x=338,y=348,z=240	x=342,y=346,z=239	x=344,y=343,z=234	x=342,y=352,z=228
x=333,y=347,z=247	x=338,y=339,z=231	x=348,y=353,z=234	x=330,y=343,z=232
x=345,y=347,z=247	x=345,y=343,z=239	x=342,y=344,z=241	x=340,y=356,z=229

x=350,y=344,z=226	x=328,y=332,z=254
x=344,y=341,z=242	x=331,y=343,z=233
x=348,y=345,z=233	x=341,y=333,z=229
x=337,y=343,z=241	x=328,y=342,z=246
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x=334,y=347,z=250	x=341,y=344,z=228
x=336,y=346,z=237	x=332,y=349,z=245
x=336,y=347,z=236	x=332,y=339,z=233
x=343,y=348,z=235	x=336,y=343,z=230
x=335,y=347,z=243	x=343,y=348,z=229
x=326,y=344,z=228	x=339,y=343,z=238
x=339,y=351,z=242	x=336,y=338,z=242
x=332,y=345,z=236	x=341,y=336,z=238
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x=336,y=352,z=237	x=343,y=342,z=237
x=332,y=349,z=244	x=330,y=343,z=240
x=340,y=351,z=238	x=333,y=342,z=236
x=335,y=347,z=236	x=336,y=342,z=247
x=337,y=347,z=237	x=334,y=345,z=240
x=344,y=352,z=235	x=328,y=346,z=234
x=346,y=349,z=232	x=348,y=336,z=240
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x=336,y=352,z=245	x=352,y=341,z=230
x=342,y=341,z=237	x=335,y=338,z=237
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x=337,y=352,z=231	x=345,y=348,z=235
x=338,y=342,z=234	x=340,y=350,z=235
x=333,y=345,z=240	x=334,y=345,z=236
x=340,y=352,z=237	x=338,y=341,z=228
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x=334,y=356,z=233	x=339,y=343,z=230
x=341,y=347,z=234	event complete
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x=343,y=348,z=237	
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x=341,y=344,z=241	
x=335,y=340,z=229	
x=346,y=356,z=227	
x=336,y=334,z=231	
x=345,y=341,z=231	
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