# **The Piezoelectric Vibration-Sensing Shoe: A Novel Device for Aiding the Audibly and Visually Impaired**

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**Background:** Snakes are fascinating animals which have developed outstanding adaptive strategies over the course of their existence. One important characteristic about snakes is that they do not have any ears, and therefore cannot hear. To compensate for this loss of hearing, snakes contain special nerves known as ***mechanoreceptors*** located within their skins. These nerves pick up vibrations produced along the ground by moving animals or objects, convert them into electrical signals, and send them to the brain to be processed. Thus, this adaptive strategy allows snakes to safely identify and navigate their surroundings despite their lack of hearing.

Currently, there are over 70 million people who are deaf and over 285 million who are visually impaired in our world. Although aids such as walking dogs and “smart-canes” do exist, they are not too effective. Therefore, drawing from what is known about the adaptive strategies of snakes, a device could be used to mimic mechanoreceptors and aid those who are impaired.

**Purpose:** The purpose of this device is to aid the audibly and visually impaired to better sense their surroundings and avoid incoming threats. A piezoelectric sensor will be used as a technological equivalent to mechanoreceptors, and will detect vibrations produced in the near proximity caused by moving people or objects.

**Hypothesis:** It is hypothesized that this device will effectively detect vibrations produced by people and/or objects moving along the floor and will accordingly notify the user.

**<u>Procedure:</u>** First, research was conducted on existing technologies in order to ensure that the current device would be a novel take on the issue.

*<u>GPS Navigation Shoes:</u>* GPS Navigation shoes have been introduced as a good solution for the visually impaired travelling from one location to another; however, they don't fully protect the user from incoming threats (their object detecting range is very small). Accordingly, these shoes require the user to have a smartphone with access to Bluetooth or Wi-Fi, which can be very expensive and inaccessible to users in some parts of the world.

*<u>Close-Range Object Detection Shoes:</u>* This technology uses ultrasonic range detecting sensors to detect objects in the proximity and warn the user. These shoes, however, tend to be very heavy due to all the sensors mounted on to them, and only have a detection range of around 1 foot, whereas with just one piezoelectric sensor the current project aims to detect moving objects from over 10 meters away.

***After acknowledging current shoe-devices being used to aid the audibly/ visually impaired and checking international patents, the current project was confirmed as a novel device.***

In order to test the aforementioned hypothesis, 3 prototypes were built.

<u>PROTOTYPE I (Constructed between **April 2015** and **July 2015**)</u>

In the first prototype, an Arduino Uno Microcontroller was utilized as the main control unit for the device. The circuit was created on a 3” by 2” breadboard, with the aid of jumper wires to connect the required components. A piezoelectric sensor was mounted underneath the shoe, a vibration motor was mounted to the side, and 6 AA batteries were used to power the entire system.

<u>Initial Results:</u> This device worked with decent accuracy in terms of detecting vibrations within a static phase (detection of vibrations with no movement of shoe). The device, however, didn't work as properly within a dynamic phase (detection of vibrations with walking movement of shoe) as it reacted to various false triggers.

*<u>Obstacle 1:</u>* The acceleration motion caused during walking was detected by the piezoelectric sensor and provided false triggers. In order to overcome this obstacle, the piezoelectric signal was split into two parts within the operational amplifier. One signal was used to detect vibration and the other signal was used to detect acceleration.

*<u>Obstacle 2:</u>* The piezoelectric sensor reacted differently on different surfaces, providing varied values to the microcontroller. In order to test this, trials were conducted on 3 different surfaces.

| | **Piezo Element Response on Multiple Surfaces** | |
|---|---|---|
| | Soft Knock Range | Hard Knock Range |
| Oak Hardwood | 10-12 meters | 20 meters |
| Leather Cushion | 12-13 meters | 22-24 meters |
| Asphalt Road | 1-2 meters | 5-6 meters |

The best results were found when the shoe was placed on a leather cushion; however, the results from the hardwood floor are the most accurate representation of the device's capability, as hardwood floors are more commonly found in households. Asphalt didn't respond too well due to external factors such as blowing wind triggering the sensor.

***Limitations included:*** *Bulkiness of device, uncomfortableness of wearing device, often false triggers from piezoelectric sensor, and overall unreliability of piezoelectric sensor.*

These limitations made it necessary for the device to be improved through the implementation of a new design plan and second prototype.

PROTOTYPE II (Constructed between **December 21, 2015** and **March 31, 2016**)

In the second prototype, many significant improvements were made to the device. Through these improvements, the device was made more efficient and convenient for use.

Improvements:

-The Arduino Uno Microcontroller (68.6 mm x 53.4 mm) was replaced with the much smaller Adafruit Trinket Microcontroller (27mm x 15mm) to reduce the overall size of the device.

-The main circuit was condensed into half of its original size.

-A ***Force Sensitive Resistor*** was used to differentiate between acceleration and vibration rather than using the previous method of signal-splitting. This proved to be a more effective method.

- A Lithium-Ion battery (3.7 V, 1000 mAh) replaced the 6 AA batteries. This change to the power supply reduced the size of the overall device and increased convenience as it can be recharged.

PROTOTYPE III (Constructed between **April 5, 2016** and **April 15, 2016**)

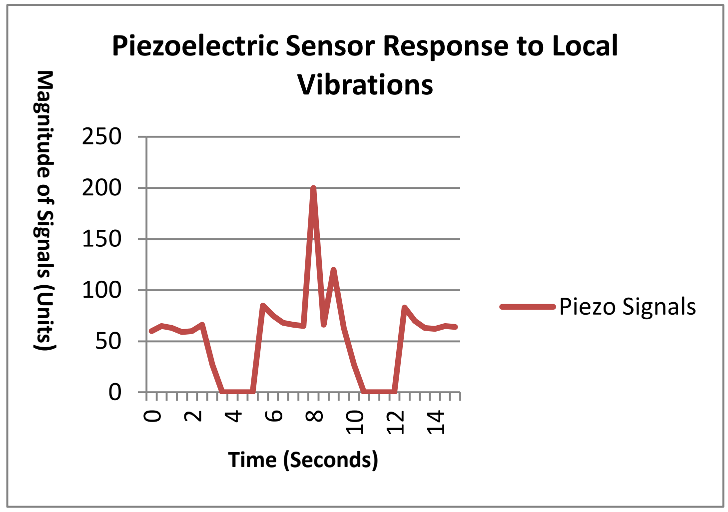
***Prototype III – Right Side View***

This final prototype was the most efficient design out of all other prototypes. The original hypothesis was fully validated and the purpose was served.

***Prototype III – Left Side View***

Improvements: A PCB (Printed Circuit Board) was implemented into the final prototype instead of the breadboards used in prototype I and II. A Toggle Switch was also added in order to create a convenient on-off system as found in almost all current electronic devices.

**Results and Observations:** Prototype III brought very promising results. Vibrations were sensed from moving objects and people within the proximity with great accuracy.




The graph (right) shows the change in the signals produced by the piezoelectric sensor as per the vibrations in the local environment. The initial values show equilibrium output without any vibrations (around 58-68 units). The drop to 0 shows the short time period during which the shoe is in the air. As there is no force applied onto the force resistor, the piezo signals are not sensed by the device and the values are therefore "0". Once the user's foot returns to the floor, the values quickly return to their equilibrium state of around "58-68". During the time interval of 7-9 seconds, an external vibration by a moving object or person is being sensed by the sensor. These signals are the only important signals as they are used to trigger the vibration motor and alert the user about the incoming threat.

**Conclusions:** Overall, the "Piezoelectric Vibration Sensing Shoe" validated its original hypothesis and was a great success. All aspects of design and application worked out accurately and successive improvements were made throughout the build to further enhance the device. Based on the results of this project, it can be concluded that by using a piezoelectric sensor, a vibration motor, and software; vibrations in the proximity can indeed be detected within a dynamic environment. Furthermore, with a few more improvements, this device can be very helpful to those who are audibly or visually impaired to better sense their surroundings.

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