Operator’s Manual
Virtual Reality System for Visual and Auditory Stimuli

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Important Safety Instructions

WARNING!

THOROUGHLY READ ALL WARNINGS BEFORE USING THIS DEVICE. IF YOU FAIL TO DO SO, YOU WILL EXPOSE YOURSELF TO THE RISK OF ELECTRICAL SHOCKS, DAMAGE TO EYES, AND ALSO TO OTHERS.

This device is intended as a portable device for people to test if they have suffered a mild traumatic brain injury - the parts of the device should be handled with care, but do not have a large potential to cause bodily or environmental harm, however they must still be used correctly.

You must follow the safety guidelines listed below to prevent injury:

- All parts may electrocute user if used around water or moisture. To ensure proper safety all users must wipe their face dry with a towel before using the device.
- DO NOT test voltages with electrodes on your face, you will get electrocuted!
- Do not immerse device in water or any liquids
- Device is intended for indoor and outdoor use
  - Do not use when it is raining or snowing in order to keep parts away from moisture
- Keep device away from humid conditions
- Do not leave parts powered on for extended lengths of time,
  - Sleep computer when not in use and unplug glasses
- Ensure all electrodes are secured properly on user’s face before powering on device
  - Particularly the ground electrode, located in the middle of the forehead
- Use the correct plugs and sockets for all parts
  - If you do not know how to plug in glasses or any other components please refer to set-up instructions, located below
- Do not touch PCB circuit r any components in the PCB when device is powered on
  - Turn Power OFF to handle circuit
- Handle device with care when transporting
- Do not attempt to disassemble or rewire any circuitry or other components used with the device
- Glasses may be too heavy for younger users
  - Please follow age guidelines listed below
- Long hair should be moved to the side when using device
- Adhesive may cause mild skin irritation
  - If this persists for several days, consult a physician
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<td>Wrap Lightshield</td>
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Features

- This device is portable and can be used in a variety of settings including, but not limited to, professional sports, the military and in the emergency room.
- This device tests for mild traumatic brain injury with no invasive procedure to the user
- Real time EOG data is shown to the user on the portable Toshiba Ultrabook computer
- Calibration is unique to each user and is done before each test session
- Device simulates virtual reality for the user
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1. Introduction

1.1 General Overview

Via the Toshiba Ultrabook computer this portable device uses the Vuxiz 1200VR virtual reality glasses, to run visual and audio stimuli to tests, and the NI-USB 6008, to gather EOG signals via electrodes, to test for mild traumatic brain injuries (mTBI). The glasses’ screen serves as a computer screen for the user to see the visual stimuli tests and the headphones enable the user to hear the audio stimuli. A LabVIEW program, run on the portable Toshiba Ultrabook laptop computer, runs the tests and records all of the data.

Through the LabVIEW program the test taker will select the type of test they would like to run from the drop down menu. There are three classes of tests that can be run, visual stimuli only, audio stimuli only, and audio and visual stimuli combined. Within these classes there are three different degrees: four, eight, and twelve, that the user can select, making a total of nine test to chose from in the menu. Before the first test is run the user must go through a calibration for the glasses in order to convert the millivolt reading of the electrodes to degrees in order to be viewed more easily by the user on the laptop, this is a slightly different calculation for each user.

All visual stimuli are a Microsoft Powerpoint slide set where each slide has a blue background and a yellow dot which is either placed to the left, right or center of the screen. The dot is either 4, 8, or 10 degrees away from the center depending on the test type the user selected. The slides run continuously 3-5 seconds apart, determined at random, creating the effect that the dot is moving for the user. The user is expected to follow the dot in reasonable time and with reasonable accuracy with their eyes. The audio stimuli is similar, however, it is a constant frequency that plays in these respective locations which the user must follow.

The calibration is a unique Powerpoint of five slides with visual stimuli moving in a variation of 10 degrees. After the calibration, the test selected previously will run and the user will be expected to move their eye to the visual or audio stimuli as it appears on the screen. As the test is running, real time electrooculography (EOG) data is being gathered via the electrodes. When the user moves their eyes left or right, respectively, a potential difference occurs between the electrodes and this reading is recorded. The signal needs to be amplified and filtered before it can be read clearly, so the signal passes through a small circuit, contained in the PCB circuit board. After passing through the circuit the EOG data is shown in real time on the laptop computer in the LabVIEW program. This data is recorded and stored for later use where it will be analyzed. Furthermore, the LabVIEW program displays the head movement and records and saves that data from the Wrap 6TC. From this data the patient is diagnosed for an mTBI, this process is illustrated and described in more detail below in section 1.2.
1.2 Step-By-Step Instructions

1) Set up the device.
   a. Open the laptop to the position shown below in figure 1.

![Figure 1: Open laptop position]

b. Plug the glasses in to the USB port and the VGA ports using the respective connections as shown in figure 2-4, below.

c. Plug the NI-USB 6008 in to the second USB port.
**Figure 2:** Location of connections on laptop

**Figure 3:** USB Port on Laptop

**Figure 4:** VGA Port on laptop
2) Wipe the user’s face dry with a towel. Take an alcohol wipe and clean the user’s right temple, left temple, and center of the forehead to prepare for the application of the electrodes.

3) Place a small drop of the electrode gel on each of the electrode pads, as shown below.

![Figure 5: Electrode with a Drop of Electrode Gel in Center](image)

4) Place the electrodes on the user’s face in the sequence shown in figure 5-7, below.

![Figure 5: Right Electrode Placement](image)  ![Figure 6: Left Electrode Placement](image)
5) Attach the electrode lead wires to each of the electrodes using their respective colors. **Red** for right, **Black** for left, and **Ground** for ground, or the center of the forehead. Be sure that the wires are not crossing and they are out of the way of where the glasses will rest. Refer to the figure 8, below.
6) Make sure that the glasses fit comfortably on the user’s face by asking the user to put on the glasses. Adjust the head strap so it fits securely and the user does not feel much discomfort.

7) Ask the user if they are able to clearly see the image on the screen. If they cannot, please refer to the trouble shooting section below to check the screen resolution. Be sure they are in a seated position. They should look like figure 9, below.

Figure 9: Complete Set- Up on User

8) Turn on the battery power unit for the PCB board before running any tests. The power button is located on the side of the black box.

9) On the front panel of the LabVIEW program select the type of test that you wish to run from the drop down menu, shown below in figure 10.
10) Operator should click the START arrow for the LabVIEW program in the top left corner.

11) Operator should move the mouse to the user’s screen, click ONCE, to remove the start menu at the bottom, and move the mouse back.

12) The calibration tool should run before the test runs, if the calibration tool is not running, refer to the troubleshooting section below. The user should move their eyes to the respective stimuli, audio, visual or both, as it flashes on the screen.

13) After the calibration tool runs the test the warning to “Please Zero the Head Tracker” will pop up. The operator should press “Zero Head Tracker” on this warning. It looks like the figure shown below.

14) Next the test the operator selected should run automatically. The user should move their eyes to the respective stimuli, audio, visual or both, as it flashes on the screen just like the calibration.

15) As the user is moving his/her eyes the real time EOG data should appear in the LabVIEW program, as show in figure the below.
16) If you wish to run another test select a new test from the drop down menu and repeat steps 6-15.

17) Once all tests are complete turn off the power unit connected to the PCB. Remove the glasses from the user and each of the electrode leads. Then carefully remove each of the electrode pads from the user’s face.

18) To view the text file for the calibration data, you can find the text file called “CALIBRATION” in “Calibration and Tests” folder on the desktop; similarly the test file will be labeled “EYE MOVEMENT TEST DATA” and “HEAD ROTATION TEST DATA”. **Note:** These files will overwrite every time a new test is run. If the client wishes to change this, it can easily be done by adjusting the file paths on the “Write to Measurement File VI”.

19) Once the user is unwired disconnect the VGA and USB cords from the computer used to power the glasses. Shut the lid of the laptop computer and place each part back in the box.
2. Maintenance

This device is fragile and requires a particular level of care. Therefore, below, lists the maintenance one should do on the device in order to keep it running smoothly.

2.1 Electrical

- Do not drop any parts of the device. If the laptop falls from a height greater than one foot it may damage the electrical components inside as well as the screen. The PCB board cannot withstand a drop much more than one foot because the electrical components may also become dislodged. The glasses are also very fragile and cannot be dropped at all. The screen and other parts of the glasses are small and fragile; they are intended to be handled with care. If any part of the device is accidentally dropped, please refer to the troubleshooting section to see if it is still working properly.

- The wires of the each component of the device should be checked every 2-3 months for fraying. If any wire is frayed or one can see the bare wire, this needs to be taken care of immediately and one should discontinue use. A bare or frayed wire could cause a fire and serious damage. Please refer to the troubleshooting section on how to fix this if it should occur. A frayed or bare wire could look like the one below, this wire is an extreme example, if any fraying occurs, stop use.

![Figure 13: Frayed Wired](image-url)
• Be sure to wrap all wires in a loose coil when storing the device. If wires are bent too much or shoved in to the storage box they could become easily damaged and in need of replacement.
• Be sure to use a surge protected outlet or surge protector when using an extension cord when plugging in the computer. If the power goes out of there is a shortage it is bad for the computer to suddenly turn off and could permanently damage the parts.

2.2 Mechanical

The parts of each component are quite fragile and need to be handled carefully. Below is a list of the components and the maintenance required for each one:

• **Vuzix 1200VR Glasses**

  - There are many small parts and screws attaching the parts to these glasses, if any of the parts feel loose check to see that the screws are screwed tightly, to do this use a small screwdriver intended for tightening eyeglasses

  - The screens of the glasses are removable and need to be secured in properly before use, they will not come loose very easily, but once every few uses, push each side in unison, as shown below, to secure the screen in tightly.

![Figure 14: Secure screen of glasses](Figure 14: Secure screen of glasses)
- The nose piece is also removable, so if it comes loose push it in to secure it, if it comes completely out push nosepiece back in as shown in the figure below.

Figure 15: Secure Nosepiece

- The strap on back of the glasses is attached to either temple tip, the part that goes around the ear. If that comes loose slip it back in to the holes, as shown in the figure below.

Figure 16: Hole to Secure Head Strap on Glasses
- Close your frames before placing them on any surface, and never lay them lens-side down. To prevent accidental scratching, store your glasses in a case whenever they are not being worn. Never put them in a purse or bag without proper protection.

- **Toshiba Ultrabook Laptop Computer**

  - Be sure to clean the case. Wipe the case and clear its ventilation ports of any obstructions. Compressed air is great for this, but don't blow dust into the PC or its optical and floppy drives. Detach all cables before cleaning.

  - Keep the keyboard clean. Periodically turn the computer upside down and gently shake out any crumbs that may be in the keyboard. Try not to eat around the device or computer.

  - Store your PC in an area free from direct sunlight or moisture. It is very bad for the computer to be in any extreme weather conditions and storing the laptop and entire device properly is essential.

  - **System maintenance:** It is important to do system maintenance on the computer every few months. This includes updating the computer when it prompts you to do so and cleaning any unwanted files off of the hard drive. Furthermore, make sure that the computer is restarted as least once per week because restarting the computer allows it to be reset and therefore, it will run faster.

- **NI-USB 6008**

  - Each port on the NI-USB is secured with a screw, it is important that these screws stay very tight, every two years it would be good to check that the screws are tight to ensure that the wires are in place.

  - As the unit sits without being moved much it will gather dust and dust is not good for the connections. Every year wipe down the hardware with a cloth and try to clear out any dust that may have built up. Be sure that the device is OFF before cleaning.

- **PCB Board**

  - It is possible for connection to come loose in the PCB board. In order to make sure that the device is running optimally it is god to check the voltages of the board every year or two. To do this, please refer to the troubleshooting section on the PCB board.

  - The PCB board may gather dust or other unknown particles since it may sit in one place for a very long time. In order to avoid any of the pieces being damaged and
optimal use of the device it is important to wipe down the hardware, very gently, with a cloth to clear out any dust that has built up. This should be done once a year. Be sure that the device is OFF before cleaning.

- **Battery Pack**
  - Store the battery in a cool place out of the reach of children.
  - When charging the battery do the following:
    - Do not charge battery pack outside. This may cause issues with moisture, the temperature, or any unwanted precipitation may occur.
    - When charging the battery pack make sure the polarity of connections are correct or the battery will NOT charge. (Ex: Red goes to Red)
    - Do not charge battery in the enclosure due to heat generation during charging.
    - As a precaution, don’t over charge the battery.
    - Make sure to connect battery to the charger BEFORE plugging into the wall.
    - DO NOT charge battery during use of PCB and system.

- **Electrodes**
  - Store electrodes in a cool dry place out of reach of children or any serious dirt or dust. They need to be applied very firmly to the face and any dust or dirt could compromise the adhesive quality of the electrodes

**2.3 Environmental**

- Keep the device free from moisture of any kind. If the electrical components of this device get wet they will likely short and be irreparable. Water damage is a common cause for electrical devices to malfunction. The device should not be used outside when it is raining or snowing, furthermore, it should not be placed on the user’s face without he/she wiping their face dry with a towel. Most importantly, it is dangerous to the user to place the electrodes and glasses on the face when it is wet.

- Keep the device in temperatures between 40 Degrees Fahrenheit and 100 Degrees Fahrenheit. The device cannot be in temperatures around or below freezing or the parts will not work as well.

- Clean all of the screens on a regular basis. The screens of the glasses and the computer will naturally become dirty from dust in the air and people touching them. Please take care to clean the screens with a clean, soft, lint-free cloth every few months. Do not use paper towels, silicone tissues, facial tissues, or old rags that may have embedded dirt. These materials may scratch your lenses. If the screens on the glasses become too dirty
the user may not be able to see the stimuli as clearly and the results could be skewed. Furthermore, be sure that the device is completely OFF when cleaning any part of it.

3. Technical Description

3.1 Introduction

The design described is capable of acquiring an electrooculography (EOG) signal from a subject, and convert the voltage readings into degrees of the eye movement. It is comprised of data acquisition hardware that acquires an EOG signal from a subject, and data analysis software for the attained EOG signal.

3.2 Subunits

There are several components that work as one system in order to create the eye movement data. Electrodes and a National Instruments USB-6008 are connected to a printed circuit board (PCB) in order to acquire the EOG signal from the subject. The USB-6008 is connected to a USB port on the Toshiba Portégé laptop. The created LabView program displays the specified visual and auditory tests on the Vuzix 1200VR glasses, runs a calibration test, and acquires the eye movement data in degrees.

3.2.1 Electrodes

A critical part of the system is the electrodes which are attached to the user’s face. Electrodes are conductive interfaces between a patient’s skin and the electric circuitry that is used to amplify and filter any signals that are picked detected. In this application, the electrodes pick up the voltage differences between the two eyes, which make up the EOG signal. The EOG signal is more specifically the measurement of the natural resting potential that exists in the retina of the both eyes. The retina is light sensitive and lines the inner surface of the eye as seen in Figure 17 below. When looking at a visual stimulus off to the right side of the head, the side of retina of the right eye facing the right electrode is positively charged. Inversely, the side of the retina of the left eye facing the left electrode is negatively charged. This creates a voltage difference between the two electrodes and this difference is what is known as an EOG signal.
The placement of the electrodes on the face is very significant when trying to acquire an EOG signal. The areas where the electrodes are to be placed must be dried and wiped with alcohol swaps. The electrode gel must be applied to the electrodes in order for them to be conductive and send the signal from the eyes down the lead wires. Electrodes with insufficient amounts of gel produce smaller noisier signals and sometimes no signals at all. The placement of the electrodes to detect horizontal eye movements is as follows: one electrode must be placed on either side of the face as close to each outer corner of the eye, known as the canthus, as possible. The third electrode must be placed on a neutral site, such as the forehead, in order to act as a reference ground. An example of the placement of the electrodes can be seen in Figure 18 below.
Figure 18: Example Placement of Electrode for Horizontal Eye Movements

The normal voltage difference created between the two electrodes on both canthi is in the microvolt range. Any loose connections of the electrodes to the face or lead wires to the electrodes, often introduces additional noise into the EOG signal. Signals in this voltage range are often hidden by noise produced by other resting potentials present in the tissue surrounding the electrodes as well as surrounding electronic devices. Small voltages, such as with the EOG signal, cannot be detected without sufficient amplifying and filtering of the signal first.

3.2.2 Power Supply

The EOG circuitry implemented onto the PCB is powered by a Tenergy 12 volt 3800 mAh NiMH DC power supply as seen in Figure 19 below. This power supply is constructed of 10 rechargeable 1.2V AA batteries connected in series. Its maximum discharge rate is 30 A, and can discharge 2280 mA constantly for one hour. This was computing using equation (1):

$$\frac{\text{Battery's Output (mAh)}}{\text{Current Being Drawn (mAh)}} \times 0.6 = \text{Battery life (hours)}$$ (1)

“Current Being Drawn (mAh)” in equation (1) is the amount of current being drawn, in the design’s case, by the PCB. “Battery’s Output (mAh)” in equation (1) specifies the batteries mAh output, which the manufacturer defines by testing discharging the max current the battery can put out in an hour. In this case, this battery is rated to put out 3800 mAh. This means that the battery will be able to put out 3800 mA for an hour before dying. This is deceiving, however, because the manufacturer doesn’t actually test the battery for an hour. This is why the output to current drawn ratio is multiplied by 0.6, to take into account any discrepancies about the actual value of the battery’s amp hour rating. Using the information known about the current being drawn by the PCB (20 mAh) and the output of the battery (3800 mAh) and applying it to equation (1) you get:
The value used for the current being drawn by the PCB (20 mAh) is conservative, since the operational current being drawn by the PCB is around 12mA.

\[
\frac{3800 \text{ (mAh)}}{20 \text{ (mAh)}} \times 0.6 = 114 \text{ (hours)}
\]

One of the desired features of the battery pack is that it has separate charging and discharge wires. This is necessary to our design because the discharge wires are permanently soldered to the PCB board and the charging wires are available to recharge the battery with the charger. The Tenergy Smart Universal Charger for NiMH/NiCD 7.2v-12v Battery packs is the charger that is used with this battery pack. Seen in Figure 20 below, the charger comes with extra wires that have plastic connections on either side. The output connection is cut off and the wires are soldered and wrapped in electrical tape to the charging wires from the battery pack. This improves safety and simplicity of connecting the charger to the battery pack. The user needs to connect the output connection from the charger to the input connection on the battery pack.
Figure 20: Tenergy Smart Universal Charger for NiMH/NiCD 7.2v-12v Battery Packs

The charger can be used worldwide because it accepts input voltages from 120 – 240V AC. The output setting in use is the 1.8A, since the battery pack is about 3000 mAh. At this input the battery should fully charge within a little over 2 hours. It also has safety features including a temperature sensor to make sure the battery doesn’t overheat during charging, automatically stops charging once and the LED turns green at 100% charge, and has a fuse in case of reversed polarity, short circuiting, or a current surge. When charging the battery it is important to take the battery out of the enclosure due to the generation of heat during the charging cycle. This heat could be detrimental to the PCB and its components.

3.2.3 PCB

Working with such small and noisy signals from the EOG required hardware circuitry to be designed before being able to acquire any meaningful data. The signal needed to be amplified and filtered before entering the USB-6008. The schematic shown in Figure 21 below is the EOG circuit that was built in order to amplify and filter the signal. As previously stated, the circuit is driven by a 12V source. This voltage is then sent through two LM7805 voltage regulators. Voltage is regulated to 10.2V out of LM7805 U4, and 5.3V out of LM7805 U5. The 10.2V is used to power all of the op-amps in the circuit. And the 5.3V is used at the reference voltage along with the reference electrode for the INA118P. The INA118P takes in as input the two positive and negative electrodes leads and amplifies them by a gain of 501. The output is then sent through a notch filter centered at 60 Hz. This filters out only the 60Hz frequency because this is the frequency at which a lot of noise is introduced into the signal. This noise comes from power sources, fluorescent lights, computer monitors, and most electronic devices. The signal is then sent through the LM358N op-amp. From here the signal is filtered through a 2nd order passive low pass filter that has a cut-off frequency of 15.9 Hz. The EOG signal produces almost no useful data from frequencies above 15 Hz. The signal is then sent through the non-inverting input of the LM741 along with the reference ground. A feedback loop through the inverting input of the op-amp is feed from the output pin 6. The USB-6008 input wire is then attached to the output, pin 6, of the LM741CN and the ground wire is attached to the ground source.
The circuit designed on the breadboard and PCB have the same expected voltages at all locations. The steady state current (mA) and voltage (V) values for important sections of the circuit design are laid out below in Table 1 and Table 2. The steady state values were taken under the following conditions: the power supply was on, the LabView data acquisition program was not running, the USB-6008 was connected to the laptop and the PCB, and the wires coming from the PCB were not connected to the electrodes or in contact with any tester. It is important to point out that testing the voltages and or current values at any pin on the PCB while wearing the electrodes and having them connected to the PCB may result in shock to the user. While 11.7mA is not life threatening, introduction of the multimeter leads into the circuit can cause larger amounts of current to be pulled.

<table>
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<th>Component</th>
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<th>LM7805 (U5) pin 1</th>
<th>LM7805(U4) pin 1</th>
<th>LM7805(U4) pin 3</th>
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<th>INA118 P (vout) pin 6</th>
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<td>Current</td>
<td>11.4 mA</td>
<td>4.4mA</td>
<td>7mA</td>
<td>5.5mA</td>
<td>0.46mA</td>
<td>0.4mA</td>
<td>11.7mA</td>
</tr>
</tbody>
</table>

**Table 1: Expected Current and Voltages at Steady State**
## Table 2: Expected Current and Voltages at Steady State Continued

The PCB in use is a dual layer board with solder-mask on both the top and bottom surfaces. What are not shown in this 3-D depiction of the board are the through holes that were drilled in order to mount the board to the enclosure. The holes are placed on all four corners and have a radius of 1.5 mm. The board is designed exactly from the MultiSim circuit schematic seen in Figure 21. All connections, voltages, and currents are the same as described above.

<table>
<thead>
<tr>
<th>Component</th>
<th>LM358N (v+) pin 8</th>
<th>LM358N (vout) pin 1</th>
<th>LM741CN (v+) pin 7</th>
<th>LM741CN (vout) pin 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>10.2V</td>
<td>6.4V</td>
<td>10.2V</td>
<td>6V</td>
</tr>
<tr>
<td>Current</td>
<td>0.5mA</td>
<td>11.7mA</td>
<td>0.5mA</td>
<td>11.7mA</td>
</tr>
</tbody>
</table>

**Figure 22: 3-D PCB Design of EOG Circuit**

The difference between the PCB and the circuit on the breadboard is that the breadboard was powered by a wall power supply and the PCB is powered by the Tenergy 12V battery pack. The battery is connected to the PCB where it says “V1” in Figure 22 above. The location of the wires that connect to the electrode leads and USB-6008 are shown in the above picture by the golden rods protruding from the PCB. From left to right: negative wire (left electrode), positive wire (right electrode), virtual ground (reference electrode), and signal output (USB-6008). This set up assures that when the subject looks to the right the spike in voltage will be positively, and inversely, when they look to their left the spike in voltage will be negative.

### 3.2.4 Enclosure

The PCB, battery, and USB-6008 are housed in a hard plastic flame retardant enclosure seen below in Figure 23. This enclosure has screw holes on the top lid that allows a PCB to be fastened to it. The max size PCB that fits inside the lid, or bottom, is 3.898”x2.323”. The PCB designed had dimensions of 3.85”x2.31”, with 1.5 mm radius through holes placed 0.252” from
the sides and 0.082” from the top and bottom. These holes match up with the screw holes on the lid of the enclosure, and the PCB fits snug inside the lid. The PCB is screwed into the lid with the components facing the bottom of the enclosure. The Tenergy battery pack is attached to Velcro on the bottom and on the side of the enclosure to keep it from moving around and possibly destroying the PCB.

The USB-6008 is attached to the top of the box with Velcro and the input and ground wires are wired through a small hole on the side of the enclosure. These wires are then soldered onto the PCB to acquire the EOG signal. The heat dissipation hole is drilled opposite of the hole for the USB-6008 wires. This holes was drilled in order to allow for any heat created by the PCB or battery pack to dissipate out of the enclosure. The battery pack is also situated as close to the hole as possible to increase heat dissipation, and decrease noise being introduced to the signal coming out of the PCB going to the USB-6008 on the opposite side of the enclosure. Situating the battery pack close to these wires can introduce 60 Hz noise into the EOG signal.

![Hammond ABS Plastic 4.8”x3.3”x2.1”](image)

**Figure 23:** Hammond ABS Plastic 4.8”x3.3”x2.1”

The last component on the enclosure is the On/Off switch that controls the power to the PCB and can be seen in Figure 24 below. The switch has a designated on and off position to allow the user to easily identify whether the power is on or not. This is situated on the wide side of the enclosure close to the battery and battery input of the PCB. It is mounted vertically to reduce accidentally turning on the system while sliding one’s hand onto the enclosure to pick it up.
3.2.5 National Instruments USB – 6008

The data acquisition task of the design is achieved using the National Instruments USB-6008 hardware shown in Figure 25 below. This device has 8 analog inputs, 2 analog outputs, and 12 digital I/O’s. For the design, only two analog inputs on the hardware are being utilized. Analog input 1 is connected to the ground wire, and analog input 2 is connected to the EOG signal. The input terminals rise up when the screw for that terminal is turned to the right. The wire is sandwiched between this lower part of the terminal and the upper part of the terminal. The screw is screwed until it is tight, but not tightened to the point where the screw starts to strip.

The wires connected to the USB-6008 have just enough insulation stripped off to allow contact to the metal terminal. Wire with excess insulation stripped off allows for unwanted noise to get into the EOG signal. An example of the appropriate amount of insulation to remove is shown in Figure 26 below.
### 3.2.6 Vuzix 1200VR with Wrap 6TC

The Vuzix 1200VR glasses function as the virtual reality display for the visual and auditory stimuli tests. They connect to the laptop via a VGA output, and USB port on the back of the laptop. These virtual reality glasses provide 720p (1280x720) resolution, and simulate a 75” widescreen display as seen from 10 feet away. As seen in Figure 27 below, the display on the glasses are two miniature LCD screens. These screens are customized to optimally fit the subject. The interpupillary distance (IPD), distance between the two eyes, is adjusted to best fit each subject. After adjusting the IPD the focus of each individual screen can be adjusted to better suit each subject. In order to better differentiate images on the screen the display resolution on the extended glasses is set at 800x600, which is closest to the native screen resolution of each individual LCD display (852x480).

![Figure 26: Stripped Input Wire Example](image)

![Figure 27: Vuzix 1200VR with Wrap 6TC](image)

Each time the glasses are plugged into the laptop they should be calibrated using the Vuzix supplied VR Manager. The user interface, as seen in Figure 28, shows the progress of the calibration process. The user zeros the sensors, and then proceeds to rotate the glasses through
the three degrees of freedom (yaw, pitch, and roll). The progress bars don’t fill, but they proceed until they get to about ¾ of the way done. At this point the user presses “Lock Calibration” and closes out the calibration program. If the tests being require audio then the user must connect the Vuzix supplied head phone that connect to the top of the glasses as seen in Figure 27 above. They are not right and left specific, and just plug into place. If audio is not being used, disconnecting the headphones makes connecting all necessary components much more simple.

![VR Manager Calibration User Interface](image)

**Figure 28:** VR Manager Calibration User Interface

Once the glasses are on the subjects head, use the tether strap seen in Figure 27 to tight the glasses to their face so it does not move around during the tests. The LCD display controller, shown in Figure 29 below, is used to control the brightness, contrast, hue, and color saturation of the LCD displays. This also allows choosing options such as 3-D, for 3-D videos, and screen aspect ratios. The controller is poorly made and it is suggested that the settings are not changed constantly. The default settings are optimal for view the test slides. In the case of 3-D, the glasses should automatically switch to a 3D mode when they detect the film format.
When not in use for an extended period of time the VGA and USB connection of the glasses are disconnected from the laptop. This is to prevent any potential LCD burn in of images. This seems to be a problem with these glasses, so it is important to be meticulous about leaving the glasses plugged in unattended for extended amounts of time. Unplugging the VGA port is a good idea when doing data analyses between tests. This prevents the user from having to calibrate the glasses again, since the USB is never disconnected. It also cuts down on the likeliness of image burn in.

The glasses contain a tracker which extends their abilities from three degrees of freedom, to six degrees of freedom. The Wrap 6TC tracker, as seen in Figure 30 below, adds capabilities of detecting motion along the X-Y-Z axes. The current software development kit (SDK) for the Vuzix 1200VR, does not support and functions that provide meaningful X-Y-Z data. Future releases of the SDK are said to be in the works that provide functions that return meaningful data. The Wrap 6TC increases the accuracy of the yaw, pitch and roll data. After testing the capabilities of the glasses, it seems that the yaw is accurate to around 70 degrees in either direction, the pitch is accurate to around 50 degrees in either direction, and the pitch is accurate to around 60 degrees in either direction. It should be noted that when tilting one’s head (roll), the yaw can become very inaccurate. This is not a calibration error or zeroing error, but a problem with the gyroscopes themselves.
3.2.7 Toshiba Portégé Z830

A Toshiba Portégé Z830 ultrabook, as seen in Figure 31 below, interfaces all of the components of the system together. This laptop weighs slightly over 2 lbs, has a solid state drive, VGA output, and spill resistant keyboard. The project requirements defined the system be portable. This laptop is the best of both worlds; it is portable without sacrificing any functionality. The two USB ports on the back of the laptop are used for powering and transferring data from the USB-6008 and Vuzix 1200VR glasses. The VGA output is used to extend the laptop display onto the glasses in order to display the visual and auditory tests. While running all components of the system to run tests, the battery lasts for around 4 hours. The solid state drive, small monitor, and new series of processors allows for the long battery life. To ensure that the battery life stays as long as possible, the laptop is unplugged and used until the battery must be charged again.
3.2.8 LabView Program

Two programs have been created in LabView to acquire and analyze the EOG signal from the PCB. The first program is very basic, and is meant mainly for troubleshooting. For times when it seems as though there is no signal coming into the DAQmx, when the voltage is unexpectedly low, or any other problems that may arise. The second program runs a calibration test and then runs the specified eye movement test using the calibration to convert the voltage data into degrees. This second program also utilizes the head tracking capabilities of the Vuzix glasses and saves the data to a separate head tracking file.

3.2.8.1 Diagnostic LabView EOG Acquisition VI

The program uses the DAQmx Assistant to communicate with the USB-6008. As seen in Figure 33 below, after acquiring the signal it is sent through a series of filters to further clean up the EOG signal. This cascade of filters is modeled after the internal hardware filters used in the BioPac EOG acquisition system. There is a low pass filter with a cut off at 38.5 Hz, a low pass filter with a cut off at 66.5 Hz, and a notch filter with a bandstop at 60-61 Hz all of which are Butterworth 4th order. This is meant as a final cleanup of the EOG signal that has been acquired from the PCB board.
Figure 32. Diagnostic EOG Acquisition Block Diagram

The front panel of the program displays the filtered, on the left, and unfiltered, on the right, data in chart form. This front panel, seen in Figure 34 is intended to be used for diagnostic purposes, as evident by the large graph displays. The only feature on the front panel is the stop button, which terminates the program when pressed.

Figure 33: Diagnostic EOG Acquisition Front Panel

3.2.8.2 Calibration and Eye Movement Test VI

As the diagnostic program, this program also uses the DAQmx Assistant to communicate with the USB-6008. This program first runs a calibration test in order to set up a conversion from voltage to degrees during the actual eye movement test. The calibration test consists of displaying a PowerPoint presentation with 10 degree saccade movement slides on them. The timing between these slides is four seconds, and the stimuli always moves back to the center after a saccade to either side. The calibration is set up to run visual stimuli in the center of the screen, 10 degree saccade right, move back to center, 10 degree saccade left, back to center, test complete. During this test the DAQ is acquiring the EOG signal from the USB-6008 and writing
the voltage data to a measurement file. The rate of acquisition is 1,250 Hz, and the data written to file is the filtered data. A header containing relevant time and date information is included as well as a time column for troubleshooting and future reference. The block diagram seen in Figure 35 below shows the flow of control. First the PowerPoint application is initiated. A prep slide is displayed saying “Calibration Test Starting”. After four seconds the EOG acquisition is started and the slide is changed. This continues until the slideshow stops, which at what point the data acquisition stops. The DAQ task is stopped, and its resources are released in order to start another DAQ task later on in the program without encountering an error.

![Figure 34: Calibration Data Acquisition and Slideshow Presentation](image)

When the slideshow ends, or is stopped, the application throws an expected error code that causes the presentation to close. This occurs in the left sequence in Figure 36 below. The next step is to open the EOG data calibration file and cut out the header and time column information and print this chopped data to a standard txt file. This is being done in the right sequence in Figure 36 below. Next the data is mined for relevant data points during each eye movement. The program specifies to take data after the slide has been shown for half a second, and average a seconds worth of data after that time point. This can be done because the length of each slide is known, and the amount of data points per second is known. This is done for all five calibration points in the tests and then put into a five column array. Another five column array is created with the known degrees of the five calibration points. These two arrays are used to plot the calibration points on an X-Y graph and create a best fit curve.
The calibration tab of the front panel looks like Figure 37 below after running the calibration test and calibrating the data. This is continuously visible to the operator during the test, as the slideshow is being displayed solely on the glasses. Charts of the filtered, top left, and unfiltered, bottom left, EOG data are displayed. An X-Y graph of the calibration points, and each calibration point itself (see below X-Y graph), from the test is displayed on the right side of the front panel.
Along with the calibration points, the best fit, y-intercept, and slope of the best fit line are displayed on the front panel in Figure 37 above.

In the next (middle sequence) shown in Figure 38 below, the Vuzix head tracking device is started. This is done by importing the Vuzis SDK, which is a standard .dll file, into LabView. This loads the necessary functions under the User Libraries options on the block diagram. The first function starts the head tracking device. An error is thrown based on the function return call if the function is called and the glasses are not connected. This is a user generated error warning meant to let the operator know that the glasses are not connected and that head tracking data will not be saved if the program continues. The two options are to stop the program, or continue without head tracking. The next sequence forces the operator to zero out the sensors in the head tracker before the test begins to get the most accurate results. This is done by pausing the program and popping up a notification which says “Please Zero Head Tracker” and the click button says “Zero Head Tracker”. Upon pressing the button, the sensors are zeroed and the program moves into the next sequence.
The next sequence can be seen in Figure 39 below. This runs much like the calibration part of the program, except the PowerPoint that is opened is the one specified by the user in the drop down menu. If no specific PowerPoint is chosen, the default is to open the 12 degree visual only stimuli test. The preparation slide is presented and on completion the EOG data acquisition is started, the head tracking is started, and the slide is changed. The \( y \)-intercept of the line of best fit is then subtracted from all voltages in the filtered EOG signal to create a base line from the reference (zero degree saccade movement). The signal is then divided by the slope of the best fit line in order to convert voltages to degrees. This effectively brings the signal to a point relative to the average of the zero degree voltages during the calibration test and then scales the voltage to its relative eye movement degree. This value is then saved to a measurement file with the same kind of header produced by the calibration test, and includes a time column.

**Figure 37:** Voltage to Degree Set Up and Vuzix Set Up
The head movement data acquisition loop, seen in Figure 40, is started at the same time as the EOG signal acquisition. This is done by connecting the error out from the preparation slide to the slide show viewer, the EOG acquisition, and the head tracking loops. The imported .dll file did not bring all needed functions into the user library. In order to access the six degrees of freedom head tracking data the call library function VI is used. The .dll is chosen, and then the specific output parameters are created and given the correct data type based on the function call in the .dll. The last step is to change the “Pass” parameter to “Pointer to Value”, since it’s a pointer. This must be done for all the parameters created. At any point during the eye movement tests the operator may zero out the head tracking sensors by pressing the “Set Zero” button of the “Tests” tab of the front panel. This does not affect functionality of the program in anyway, and simply sets the sensors to a new zero.

The next step is to change the returned value into degrees. The Wrap 6TC returns values from -32768 to 32768 for the yaw, pitch and roll parameters. Each of the yaw, pitch, and roll values are then divided by 32768 in order to get a number between 0 and 1. This number is then multiplied by 180 (degrees) in order to get the value for the yaw, pitch and roll in degrees. In the case of the yaw parameter, left is positive as default. Since, for the EOG looking right is positive, the yaw is multiplied by -1 in order to have right rotations be positive. Looking up returns positive degrees for pitch and tilting the head to the right returns the positive values for roll. These values are then merged into one signal and written to a measurement file with the standard header and time column present. The file output has the following format: first column is time, second is yaw in degrees, third is pitch in degrees, and fourth is roll in degrees.
During the eye movement tests the slide timing is randomized. This is controlled in the slideshow while loop, as seen in Figure 41 below. A random value between zero and one is generated, multiplied by 2, and then multiplied by 1000. This gives a random value between 0 and 2000 milliseconds. This value is then added to a baseline of 3000 ms, in order to have a random slide change time between 3 and 5 seconds.

The slideshow loop itself runs a total of 34 times. In order to stop the EOG and head tracking acquisition a local variable needed to be created called “loopstop”. This is a basic LED true or false indicator. It only gets a value of true if the loop iteration is equal to 33. It is equal to 33 and not 34 because the for loop is zero indexed, meaning that it starts counting from zero instead of one. Thus 33, means that the loop has executed 34 times. This indicates that the slideshow is done and tells the EOG and head tracking loops to stop. As in the calibration test the presentation error code closes PowerPoint.

After the sequence structure has completed there are only two tasks to complete before stopping the program. The “loopstop” local variable needs to be reinitialized to its default value of false. This is so that the next time the program is run, the value of “loopstop” is still not true. If this was the case the EOG and head tracking acquisition would not start because the loop conditions of both loops are to stop if the value wired to the stop function is true. The other task that needs to be completed is to close the head tracking and release its resources.
The “Test” tab of the front panel looks as seen in Figure 42 below. The two charts on the left are the filtered, top, and unfiltered data, bottom. On the right is a chart of the eye movements in degrees after the conversion using the calibration data. Below the chart are the head tracking indicators showing yaw, pitch, roll, xtrn, ytrn, and ztrn, along with the zero head tracking button. The slide delay indicator is just a reference for the operator to know the delay that is being applied to each slide in the eye movement slide show.
4. Troubleshooting

There are several problems that could arise when using the device. Below is a list, separated by possible issues, that gives step by step instruction so how you might correct the problem. Please use this list as the troubleshooting guidelines before doing anything else to fix the device.

4.1 Cannot See Any Image on Glasses

If you cannot see any image on the Vuzix glasses your projector setting may be wrong. Please follow the step by step instruction below to correct this:

1) Plug in the glasses as described in the instruction in section 1, Introduction.
2) Go to Start → Control Panel (located on the right side)
3) Locate the Hardware and Sound icon and click on it
4) Click on Display → Connect to a projector (located on the left) and a box should pop up that looks like the image below.

![Figure 42: Connect to a projector screen](image1)

5) Use the right arrow on the keyboard and scroll over until the “Duplicate” box is highlighted, as shown below, when it is hit enter.

![Figure 43: Connect to a projector screen with Duplicate highlighted](image2)

6) Place the glasses on the user’s face again; they should see the same screen as the one that appears on the laptop.

4.2 Trouble Viewing Content on Vuzix Glasses

If you are having trouble viewing the images or words on the glasses then the screen resolution may not be set correctly. To do this please follow the step by step instructions below to set the computer to the correct screen resolution.
1) Plug in the glasses as described in the instruction in section 1, Introduction.
2) Go to Start → Control Panel (located on the right side)
3) Locate the Hardware and Sound icon and click on it
4) Click on Display → Change display settings (located on the left) and a box should pop up that looks like the image below.

![Display Settings Box](image.png)

**Figure 44: Display Settings Box**

5) In the drop down menu labeled Display make sure that the glasses are the main display.
6) Select the Glasses, labeled “Generic Non PnP Monitor”, from the drop down menu next to Display.
7) In the drop down menu labeled Resolution click on the arrow and move the bar down so that the resolution is 800x600, as shown in the figure below.
8) After selecting the resolution click “Apply” in the bottom right corner of the box and then click OK allowing the computer to keep these settings.
9) You may notice the computer screen jumping around, looking smaller than before, or the text may have gotten much larger, do not worry, this is normal.
10) Put the glasses back on and the words and images should appear clearer than before.

4.3 Calibration or EOG Data Displays Poor Results

If the calibration displays poor results, stop the test and restart the calibration. Before proceeding, do the following:

1) Check to make sure that each electrode is hooked up to the proper lead, they should be as follows:

   **RED** = RIGHT
   **GREEN** = CENTER (GROUND)
   **BLACK** = LEFT

   If this is was not correct, retry the tests. If it was correct, proceed to step 2.

2) Make sure that all of the electrodes are securely on the user’s face. If need be take the electrodes off, dry face, and re apply electrodes following the proper steps. Furthermore, if the center electrode, also known as the ground electrode, is constantly peeling off remove that electrode and place a new electrode behind one of the user’s ears. As shown in the figure below.

3) If the graphs do not display data and the text files are empty after eye tests have run make sure that the loop stop indicator on front panel is not lit when the test starts.
The results should appear cleaner and more accurate.

4) Check that the scale of the graph is reasonable.

With these steps the signal should look cleaner and easier to read.

**4.4 PowerPoint Slides Are Not Showing on the Screen**

It is important to note that every time a test runs you NEED to click the screen to ensure Powerpoint is in the foreground of the running programs, clicking the screen once will also allow the slides to appear in the foreground and the task bar to disappear at the bottom of the screen.

If the PowerPoint slides are not appearing on the screen for the user please refer to section 4.1 and make sure that the projector settings are correct. If the PowerPoint slides are still not appearing on the screen check to see that the PowerPoint program is running. When the test begins the PowerPoint program should start and the program icon should appear on the taskbar, as shown below:

![Taskbar Showing PowerPoint Icon](image)

The taskbar on the computer is hidden, but when you move the mouse to the bottom of the screen it will appear.
If the icon is flashing orange, but the slides are not appearing, click once on the icon and the program should open so you can view the slides. This is probably because the slides are running in the background, behind the LabVIEW VI. The LabVIEW VI should minimize when Powerpoint begins and open back up when the slide show is finished.

If the slideshow is not appearing at all, please refer to section 4.3, calibration does not run, and follow those steps, the same problem may be occurring.

**4.5 DAQ Assistance**

If the following error was thrown:

```
Error: 201003 at DAQmx, this error means that the NI hardware is not connected. To solve connect the hardware to a laptop USB port. If problem persists, connect hardware to USB port on the backside of the laptop.
```

Make sure the DAQ is plugged in to the USB port on the computer!

Make sure the light is blinking which means it is being powered!

If the following error was thrown:

```
Error: 501103 DAQ index error (The specified resource is reserved)
```

You have more than one DAQ running at the same time. You cannot have more than one DAQ running at a time. Make sure that the resources from the first DAQ are being released. Make sure that the DAQ has stopped recording. Make sure you have no other LabVIEW programs open.

**4.6 Electrodes Will Not Stick to User**

The electrodes may not stick to the user’s face very securely the first time. If this occurs or they seem like they are falling off, remove the electrode that is not sticking and throw it away. Dry the side of the face with a cloth or paper towel where the new electrode will be placed. Then, clean the area where a new electrode will be placed thoroughly with an alcohol swab and let it dry before proceeding. This may take up to a minute. Get a new electrode from the box and place a small drop of the electrode gel in the middle. Make sure not to add too much so when the electrode is placed on the user’s face it does not smear over to where the adhesive is.
4.7 Frayed Wire

Having a frayed wire is extremely dangerous and needs to be taken very seriously. A frayed wire may cause the device to not run as well, but can also be a serious fire hazard. If any part of the device has a frayed wire it may need to be replaced, but there are a few easy ways to try to fix the wires in the event that the wire is difficult to replace. To replace a wire please contact the manufacturer of the part to find a replacement.

To fix a frayed wire you can do one of two things:

1) For a quicker, but less permanent repair take a piece of electrical tape or duct tape and roll it over the frayed wire. Be sure that the entire device is powered off before doing this repair.

2) A more time consuming, yet more permanent and safer fix is to seal the wire with a silicone sealant. This can be found at most grocery stores or hardware stores. The sealant will insulate and protect the wire. You can use clear or black to match the color of the wire. To do this follow these instructions:

   1) Lay a thick strip of painter’s tape on the surface of the table, the sealant will not stick to the painter’s tape. This will protect the table and make it easier to lift the wire off the table. The painter’s tape will peel right up off the table
   2) Lay the frayed wire on the painter’s tape to prepare to seal it
   3) Squeeze a bit of the silicone sealant on to the area that needs fixing. Rub the gooey paste in to place, covering the damage with a nice thick coating. You may want to wear gloves during this part. Refer to the images below.

   ![Sealing a frayed wire](image)

   **Figure 48:** Sealing a frayed wire

4) Let the sealant sit for an hour or two until it is firm and complete dry before use.
4.8 PCB Board is Malfunctioning

If the PCB board is malfunctioning try the following:

1) Make sure unit is ON!
2) Using a standard voltmeter check voltages from the power source to the components, specifically the output. To do this refer to technical section which lists the proper voltages.
3) Make sure no wires are touching for some reason.

4.9 The Device was Dropped

If the device was dropped it is important to check that all of the parts are running correctly depending on what was dropped. Below is a list of parts and how to treat each one if they were dropped.

**Toshiba Ultrabook Laptop Computer**

1) After the computer is dropped turn on the computer and listen to the noises it makes, if you hear any suspicious noises such as grinding or clicking your hard drive may be damaged and it is necessary to take the computer to a computer technician to get it fixed.
2) If your do not hear noises and your computer turns on but displays an error message of any kind or your programs will not open, the hard drive may be damaged and you will need to take it to a computer technician.

If either of these issues occurs and the hard drive has lost all data, the files can be retrieved again from the student user’s drive at the University of Connecticut in the “Team 7” folder.

If there seems to be no issues and the computer is running fine, the computer has survived the fall, but keep a close eye on it and handle it with care in the future.

**PCB Board**

1) Check to see that no parts came loose and everything is still connected inside the PCB board.
2) Check that all wires are still connected.
3) Check all voltages, as listed in the technical description using a standard voltmeter.

If any part has come loose and it can be repaired take the device in to a professional to solder back the pieces to the PCB. If you think you are able to fix the device on your own, please handle with care and be sure to refer to the technical description to ensure that the device is put together properly.

**NI-USB 6008**

If the NI hardware is dropped be sure that it still works by running a mock visual test. Compare the results. If the NI hardware is permanently damaged a new NI-USB 6008 can be purchased online.
**Glasses**

If the glasses are dropped you need to check each part of the glasses to make sure there was no permanent damage.

1) Check the screens to make sure they are not cracked or broken and that the image shows up clearly.
2) Carefully examine each edge and part of the glasses, focusing on the area that was hit first, to check for any scratches or dents. If you do find a scratch or dent and it is not in an area that disrupts the use of the glasses you can continue to use them, but handle them with care.
3) Check the wires to make sure that the connections were not bent.

If the glasses do not work properly anymore or the damage found after the check prevents you from using them well, please contact the manufacturer for a replacement.

**4.10 Wires are Dislodged or Any Parts are Dislodged**

If for some reason any part of the device comes dislodged or looks out of place do the following:

1) Check that all components are in the proper place. The battery and PCB should be in the casing. The NI hardware should be fastened to the top of the casing. The glasses and computer should be in tact.
2) Check that all wires in the proper place. Make sure that the electrode leads have some give and are not being pulled too tightly.
3) If any of the components seem out of place refer above to some of the troubleshooting on “Dropped Parts” or the “Maintenance” section on the glasses and computer.
4) Refer to technical section to check voltages using a standard volt meter of the components on the PCB board.
5) If there are irreparable parts take the device to an expert to fix.
5. References


