Wiimote Lab

Introduction

After receiving feedback from students we found that they really wanted to learn how engineering relates to real-world devices. With over two million units sold by December 2008, the Nintendo Wii is currently the best selling game system on the market and we felt that this platform would be a good choice for our "Hack Lab," which was later renamed to the "Wiimote Lab." The controller that the Wii uses, also known as the Wiimote, has been popular for hacking among electronics hobbyists and is fairly simple to disassemble so we decided to use it as the focus of our lab to discuss sensors and communication buses. The Wiimote contains an MEMS accelerometer, an infrared camera, and a Bluetooth communication system. This provided us a good base to talk about sensor technologies and data interpretation. After learning about the Wiimote we hope that students will show off their knowledge to friends and hopefully use the techniques learned in this lab to learn about other devices they use in their homes. Warning: Caution should be given when handling electric devices in case of electric shocks. Always remember to unplug the device before trying to prop open the device. Avoid direct touch to the metallic components of the equipment for safety reasons and also situations that may create static electricity.

In this lab you will learn about sensors and communication buses by hacking a Wii remote controller (Wiimote). You will then use the Wiimote and interpret its sensor data to determine how the sensors are being used so that you can determine other potential uses for the sensors. If you are not familiar with the Wii, it is a gaming console released by Nintendo in 2006 that uses a motion sensitive remote control instead of the more generic joystick control of other popular consoles like the Sony Playstation or Microsoft's xBox.

Figure 1-Wiimote

Wiimote Lab: Sensors and Buses
Procedure:
First you will start out by hacking a broken Wiimote (marked **with black tape)** so that you can see what the layout of the PCB (Printed Circuit Board) looks like and see where the sensors are located.

1. Remove the battery cover and the two batteries. Then remove the four screws as pictured below, figure 2. (**Be careful not to turn the screw too tightly it could result for the screws not to hold anymore (stripping)**).

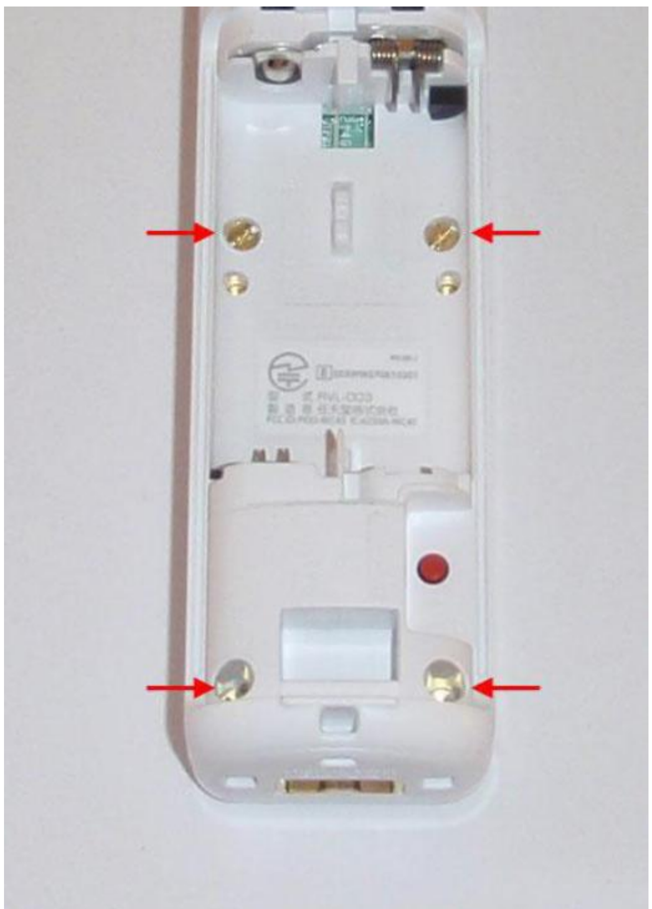

Figure 2-location off four screws

2. Carefully pull the two pieces of the case apart. Be sure to keep the button side of the case facing down so that all the buttons don't fall out of place and don't misplace the screws so you can reassemble the controller.

Figure 3- After the two pieces of the case pulled apart (Note: that in this picture, one of the cases is flipped)

3. You can now take the green PCB board out of the case for examination. Accelerometer Locate the accelerometer as shown below. The accelerometer is used to measure acceleration in three axes and is the sensor that is used to determine how you are swinging the remote in Wii games. In particular the accelerometer used in the Wiimote is the ADXL330.

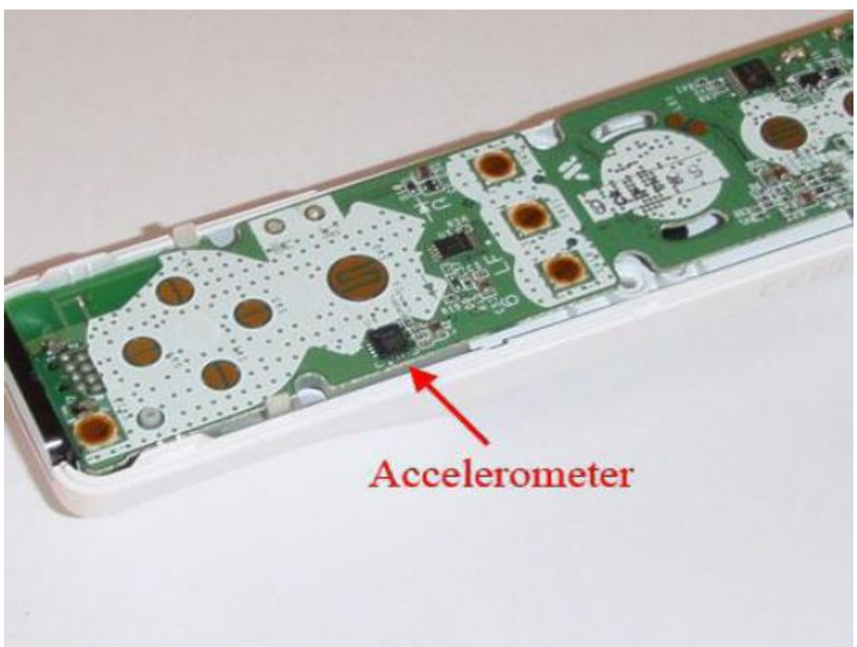

Figure 4- locating the accelerometer

Accelerometers are manufactured using a relatively new technology called "MEMS Technology." MEMS stands for MicroElectroMechanical System. In the image below you can see a micro machined MEMS three axis accelerometer under a microscope. The average human hair is about 80 micrometers* in diameter and you can see that this accelerometer is roughly 200 micrometers* wide or three hair widths! (Figure-5) The four maze-looking parts in the corners are actually springs and as the device is moved the center part of the accelerometer moves, expanding and compressing these springs. Meanwhile, electricity is flowing through these springs and as the springs expands or compresses the spacing changes, this in turn changes the capacitance which is an electrical property that can then be detected and outputted on the wires you see coming out of the chip. As you can imagine the device is quite fragile so a micro machined cover is placed over the accelerometer and then it is encased in the black plastic case you see on your PCB. *

*1Micrometers = 10^{-6}meters =$\frac{1}{1000,000}$ meters.

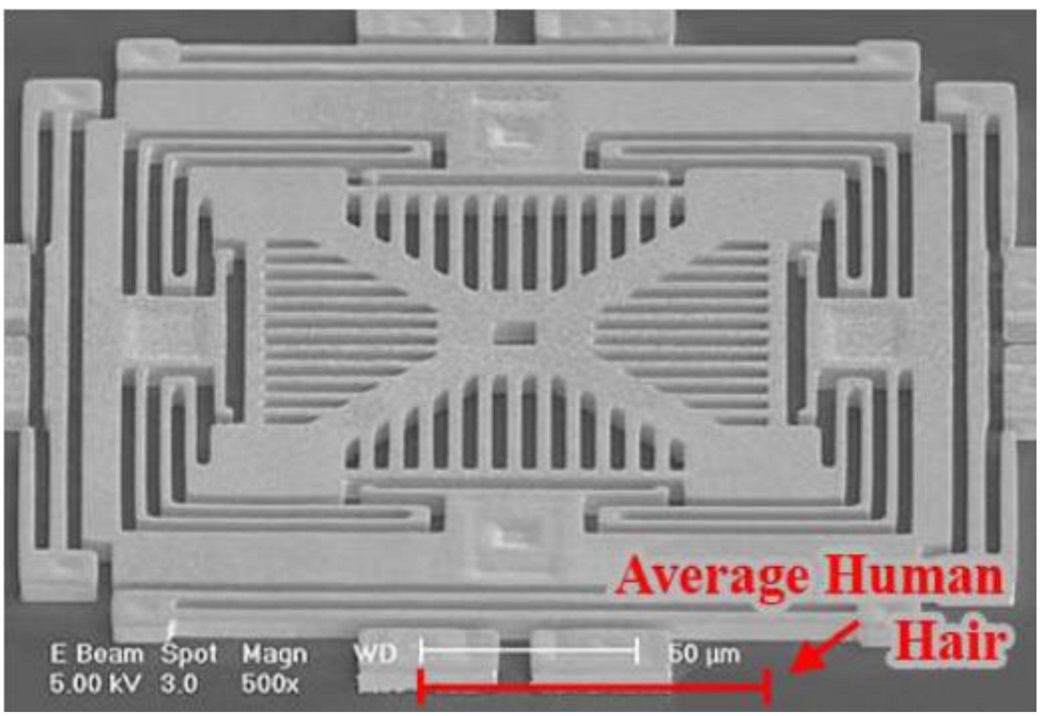

Figure 5-Image from: http://archives.sensorsmag.com/articles/1203/20/main.shtml

Camera One thing most people don't realize is that there is actually a small infrared camera on the end of the Wiimote. Locate the camera as shown in the picture below, figure 6.

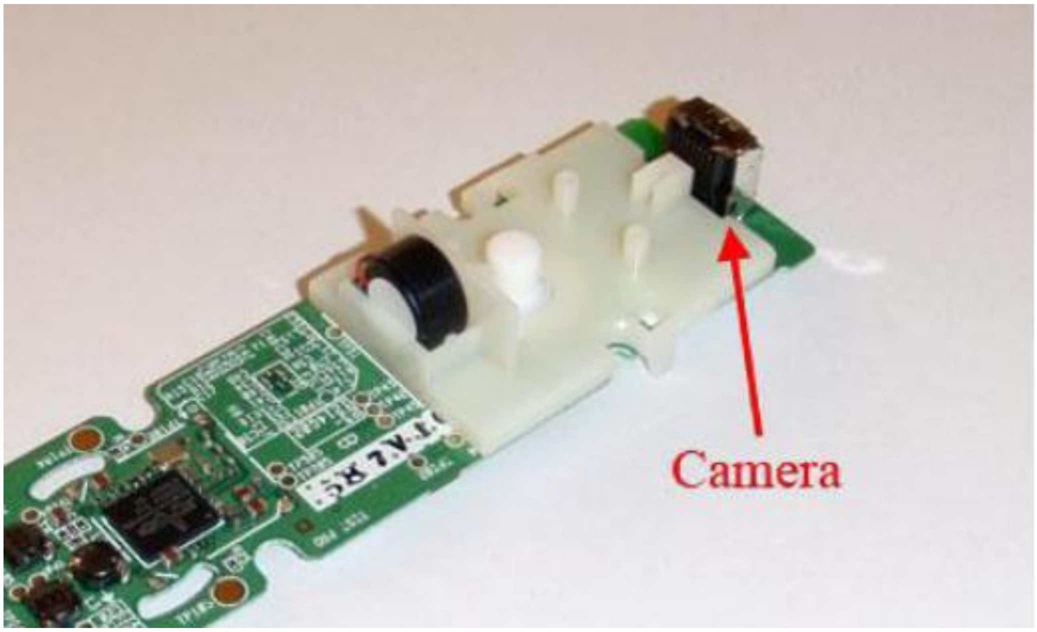

Figure 6- locating the infrared camera

You might be wondering what the camera is for and the answer relates to the "sensor bar" that you place on top of your TV. The sensor bar is really not a "sensor" but in fact two infrared LED lights. When you point the Wiimote at your TV the infrared sensitive camera picks up the lights and uses this data to determine where you are pointing the Wiimote, rather than using the accelerometers. The reason for this is because accelerometers are good at detecting motion in the X, Y, and Z directions but they can't detect rotational acceleration (as when you rotate the remote to move the cursor around on the screen). In order to detect rotational accelerations you need what is called a gyroscope (also based on MEMS technology).

Gyroscopes are devices that measures or maintain an orientation of an object using the principle of angular momentum. Unfortunately gyroscopes are pretty expensive so engineers at Nintendo came up with the camera/sensor bar idea to reduce the price of the controllers to an affordable level.

Part identification
In some of your other labs you may have been working on prototypes of components that don't look like the parts you see on the Wiimote PCB. This is because most devices, especially small devices like the Wiimote, use what are called SMD (Surface Mount Devices). These parts are much smaller than the ones you use in your lab but the functionality is the same as their larger versions, only the packaging has changed. To see a photo comparison click HERE. On integrated circuits the part number is usually a letter or set of letters followed by a set of numbers. This is then followed by more letters and numbers that give the exact model of the chip but aren't necessary when trying to determine what it does. *Question:* Locate the "Broadcom" chip and try typing in the part number to determine what the chip does. The part number you type in should look something like the form of the accelerometers "ADXL330" part number.

Reassemble Follow the above steps in reverse to reassemble the Wiimote. If any buttons fell off, carefully place them back in the correct spots before placing the case back together. Again, be careful not to over tighten and strip the screws.

Data Interpretation Now that you have reassembled the Wiimote you are now ready to see how the sensors work.

If you have Mac please follow these Instructions otherwise please skip to the next step:
If it is not already loaded on your computer you will need to download an application called "DarwiinRemote" which you can get HERE. Once it is loaded on your computer open the application as shown below in figure 7 by clicking on the DarwiinRemote button.

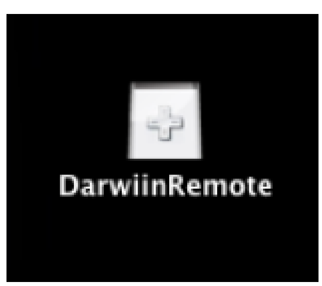

Figure 7

Under the "Window" menu select "Show IR Info" shown in figure 8.

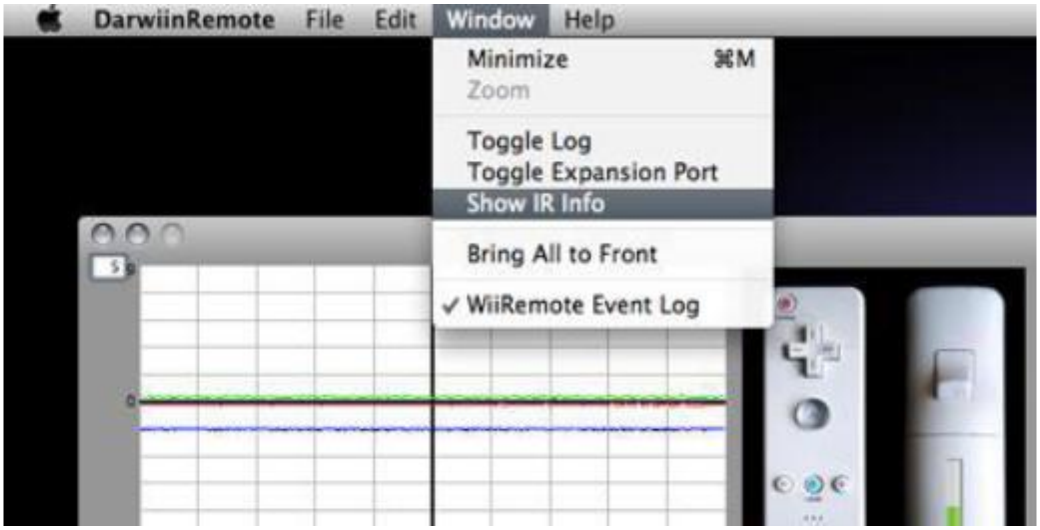

Figure 8

Now click the "Find Wiimote" button and then press the "1" and "2" buttons on the actual Wiimote. Please refer to figure 9

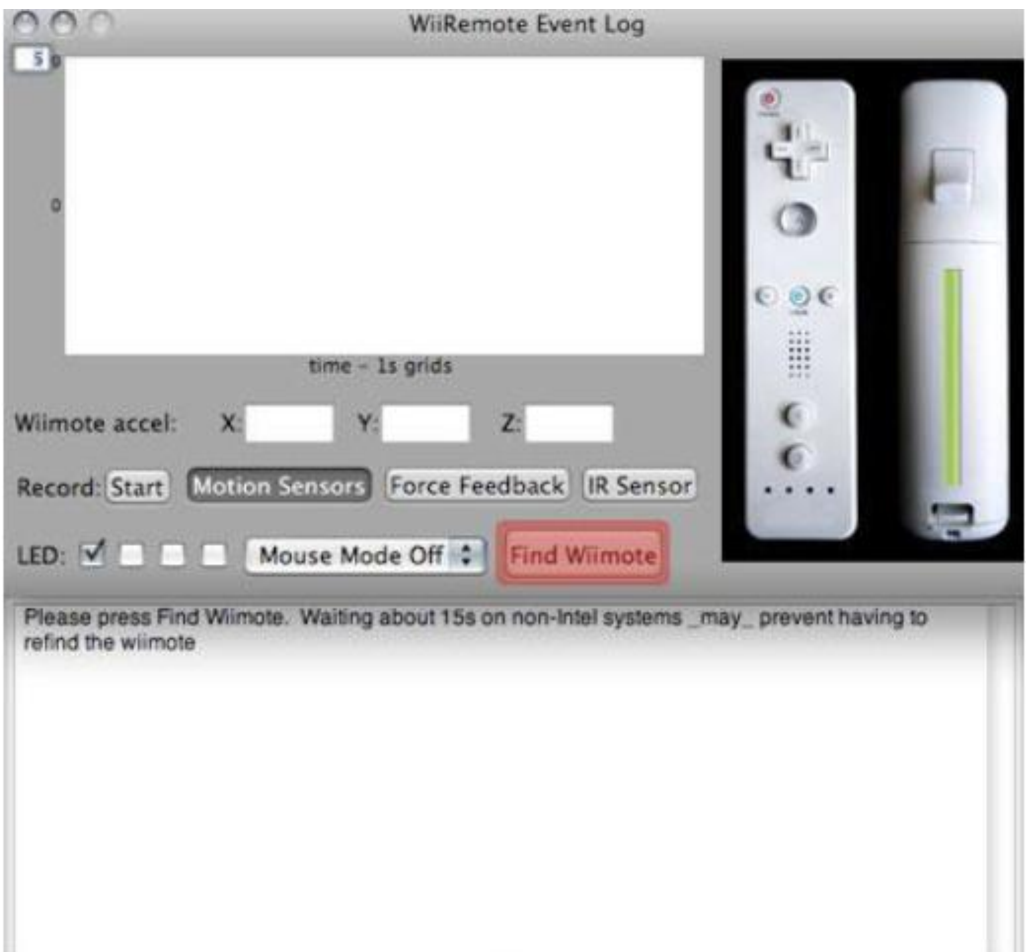

Figure 9

Finally click the "IR Sensor" button that's right above the "Find Wiimote" button.

Figure 10

You should now see a graph of the accelerations of the remote and the view of what the infrared camera sees. Wave the remote around and you should see the graph change.

Question*:* Set the remote down flat on your table. Why does the "Wiimote accel." section report an acceleration value of about -1.0 on the Z axis?

Question*:* With the Wiimote still flat on the table note the values of the X, Y, and Z accelerations. Slowly tilt the Wiimote to about) angle. What happens to the X, Y, and Z values? Finally tilt it all the way up on its side. What are the values now?

In order to interpret sensor data you need to scale it. When the remote is sitting flat on the table we will say the remote is at 0 degrees. If you tilt it all the way to one side () you will get a value of 1 for that axis. Multiplying the acceleration by 90 will now give you 90 for an acceleration of 1. So: Degrees remote is tilted = Acceleration * 90. This is the same for both the X and Y axis.

Side-to-side Tilt Angle (degrees) = X Accel. * 90

Front-to-back Tilt Angle (degrees) = Y Accel. * 90

Question*:* If the Wiimote's acceleration values read X: 0.5 Y: 0.6, how is the Wiimote oriented in degrees? Work this mathematically before testing your results. Show your work.

To demonstrate the IR camera you will need an infrared source such as a TV remote control or a lighter. Point the end of the TV remote directly at the end of the Wiimote and hold down a button. You should see a flashing white spot. You can also point the Wiimote at a lit lighter and you should also see a white dot. Flame emits a lot of light in the invisible infrared light spectrum as well as the visible spectrum.

Question*:* What is another use for an infrared camera?

Conclusion: Now that you have learned how the Wiimote works you can use the internet to learn how other devices you own work. If you want to see what else can be done with the Wiimote check out these links:

http://www.youtube.com/watch?v=Jd3-eiid-Uw

http://www.youtube.com/watch?v=0awjPUkBXOU

Or some more advanced projects:

http://blog.makezine.com/archive/2008/11/hacking_the_wiimote_ir_ca.html