

# Working and Learning in PSEC

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April 12, 2017

## 1 Overview

I worked in the PSEC group at The University of Chicago during the academic quarters of Autumn 2016 and Winter 2017. In this report, I discuss the projects I worked on as a laboratory assistant in the group. Over the course of two quarters, I learned a lot about applying classroom physics knowledge to real life circuitry. The goal of this report is to describe the projects I worked on as well as to relay useful standard procedures to future PSEC research assistants. For more technical descriptions of these projects, please refer to reports "Monitoring Sound Levels" and "Monitoring AC Wall Voltage in the HEP Building." Both of these can be found in the LAPPD Document Library.<sup>1</sup>

## 2 Projects

During my time in PSEC, I worked on projects designed to measure and monitor the laboratory environment.

In each, we began with a **planning stage**. This required determining the measurement we intended to make, drawing a circuit diagram, calculating values (for example, an RC time constant), and gathering necessary parts (resistors, capacitors, diodes) from the UChicago Electronics Shop.

Next, we **built** and **calibrated** our circuit. This involved soldering circuit components, connecting the circuit to a data acquisition device (we used a LabJack U6, which interfaced with a Raspberry Pi) and determining how to calibrate the measurements.

The final step of each project was **data collection** and **analysis**. We plotted the recorded data and drew conclusions that we shared in our reports.

### 2.1 Sound Monitoring Project

The first project I worked on was a project to monitor the sound levels in the laboratory. Having a record of sound levels over time in the laboratory allows identifying external disturbances. We built a system that can accurately detect entry in and out of the laboratory, as well as noisy events within the laboratory (items falling or breaking, janitorial work, etc.).

To build the laboratory sound monitor, we used a powered indoor microphone that outputs an AC signal. After rectification and low-pass filtering, the signal is readable by a LabJack U6 data acquisition device. The circuit diagram for the sound monitor is shown in Fig. 1. In Fig. 2, I have included a picture of the first version of our circuit. The soldering job is clearly messy, and soldering is something I address in section 3 of this report.

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<sup>1</sup>LAPPD Document Library: <http://lappddocs.uchicago.edu/>

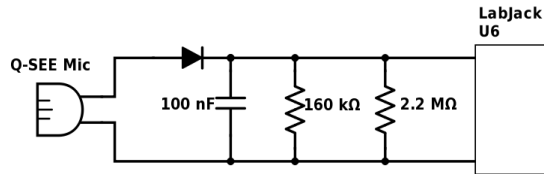


Figure 1: Circuit diagram for our sound monitoring circuit.



Figure 2: Photo of an early rendition of the circuit we used for the sound monitor. The soldering is not clean, as this was a first attempt at soldering.

We used a Raspberry Pi Model B to run a script recording data that the LabJack U6 collected. To plot this data, we pushed files from our Raspberry Pi to the Margherita system. From there, LivePlotter plots our data and displays it on <http://psec.uchicago.edu/margdata/plots.png>.

A more detailed description of this project is presented in the report "Monitoring Sound Levels".

## 2.2 AC Voltage

A second project I worked on involved monitoring the AC wall voltage in HEP room 321. Monitoring fluctuations in the building power supply was important to determine whether or not the HEP building's power supply was having an effect on Large-Area Picosecond Photodetector (LAPPD) production in the laboratory.

We found that the building power fluctuates as much as 4.1 V (3.2%) over the course of a single day. However, we did not find any correlation between these fluctuations and malfunctions in other laboratory devices.

The circuit we built to monitor the wall voltage contained an AC-to-AC wall wart, a full-wave rectifier, a low-pass filter, and a simple voltage divider to produce a varying DC signal. This signal was readable on a LabJack U6<sup>2</sup>. The schematic for our circuit can be seen in Fig. 4.

A fuller account of this project is in the report "Monitoring AC Wall Voltage in the HEP Building".

## 2.3 Capacitively measuring tile impedance

Large Area Picosecond Photodetectors (LAPPDs) consist of a window with an interior photocathode coating, spacers, microchannel plates, and an anode layer. It would be useful to have a way to measure the impedance of the film in the LAPPD window. Because the film is not

<sup>2</sup>LabJack U6 product information: <https://labjack.com/products/u6>

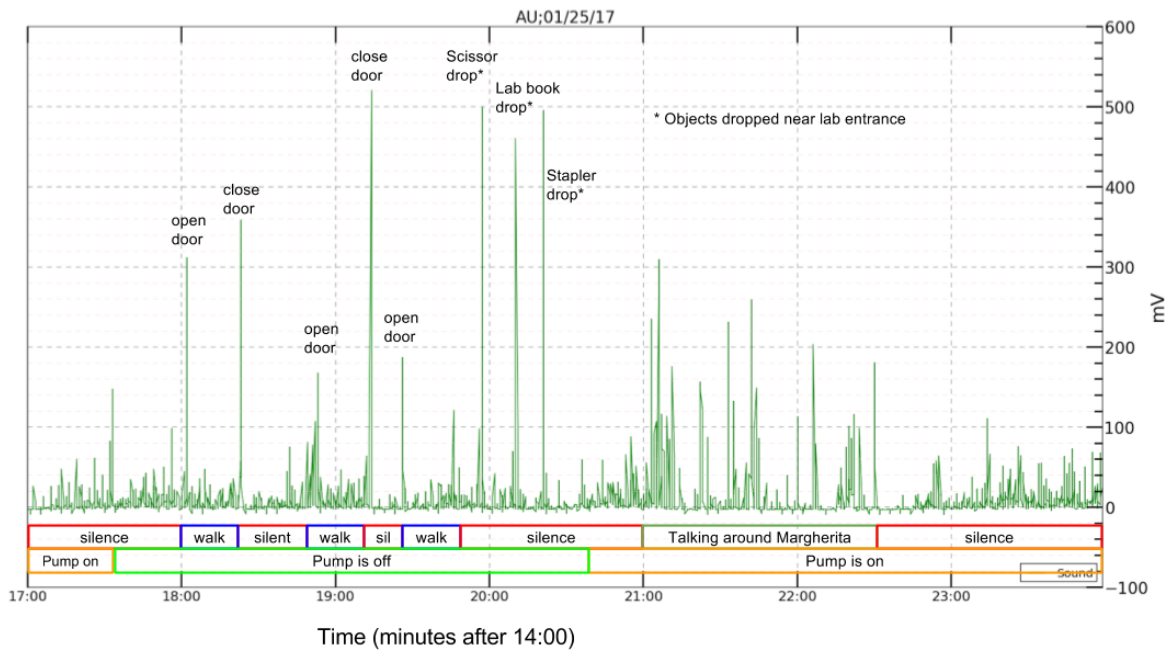


Figure 3: Sound monitoring calibration. We performed various actions in the laboratory to see what the sound monitor would detect.

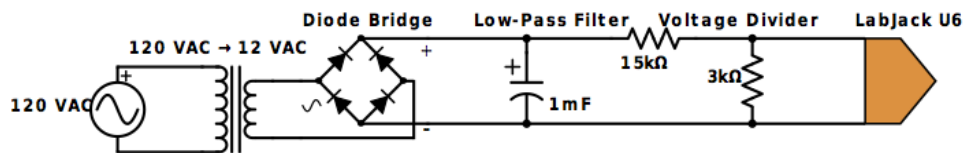


Figure 4: Circuit schematic for the Wall Voltage monitoring project.

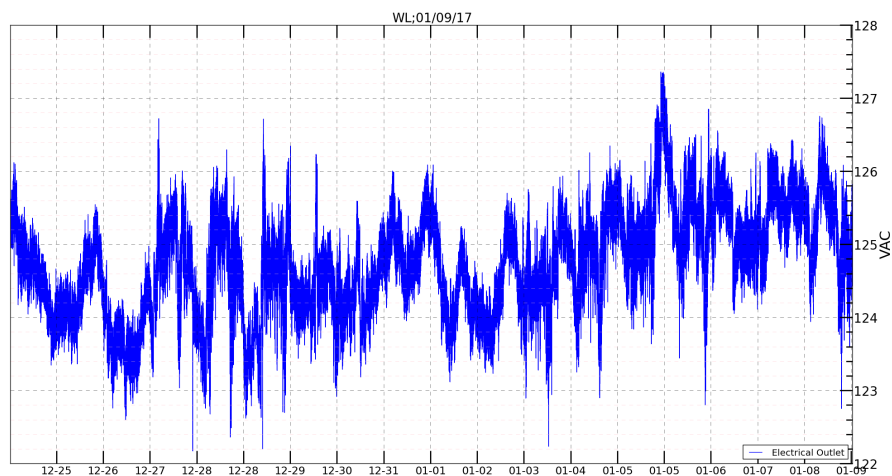


Figure 5: Wall AC voltage levels over the winter break. The wall voltage is clearly more "noisy" during active hours, and less so during the night and on vacation days.

accessible through the outer glass window of the LAPPD, we need to develop a way to calculate impedance indirectly. To do this, we are in the process of building a circuit that capacitively measures the impedance of the tile.

The circuit will consist of two plates on the outside of the tile that act as capacitors with the film behind the glass of the tile. We will use a function generator to send different frequencies through the film, and by measuring the current in the circuit, we will determine the impedance of the film.

## 2.4 Thermocouples

A thermocouple is a device used to measure temperature. It consists of two wires of different material (in our case, one of Alumel and one of Chromel) that meet at a point and send different signals back to a measurement device. For Margherita 2, we need devices that will be suitable for the vacuum environment. To make the thermocouples suitable for the vacuum we used ceramic insulation instead of rubber insulation. Rubber outgasses in vacuum conditions, making it unsuitable for that environment. Using ceramic insulation fixes this problem since ceramic does not outgas.

During my time in PSEC, we assembled thermocouples that will be used in Margherita 2. The assembly process is straightforward: it involves feeding Alumel and Chromel wire through ceramic insulation. Assembly is occasionally tricky due to the thinness of the wires.

# 3 Advice for new Lab Assistants

## 3.1 Learning on the Job

As a lab assistant there are many topics and skills that will require refreshing or learning in order to do certain tasks. Any time a new piece of equipment is introduced, it is important to learn about it and read product specifications. Wikipedia is a good general starting point for most devices, but reading individual product manuals is necessary to actually understand how to use a device. In most cases, these product manuals can be easily found online.

A particularly useful resource for building basic circuits is Horowitz & Hill's textbook *The Art of Electronics*, available online as a [PDF](#).<sup>3</sup> *The Art of Electronics* is not only a textbook, but it is also a reference book of sorts. It has plenty of advice and information about building all types of passive and active circuits.

Relying on online electrical engineering forums is often not the most fruitful strategy. Instead, troubleshooting pages from product manufacturers themselves are more useful.

Learning to solder is essential to lab work because building any circuit requires soldering components together. There are many online tutorials to learn how to solder. In particular, Sparkfun has a helpful [introduction to soldering](#).<sup>4</sup>

## 3.2 Skills to Review

To begin with, reviewing basic principles from Electricity & Magnetism classes will be very useful: Ohm's law and Kirchhoff's rules are indispensable when building or analyzing circuits. Horowitz & Hill's textbook *The Art of Electronics*, is a great place to review this information, as I mentioned earlier.

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<sup>3</sup>*The Art of Electronics, 2nd Edition* pdf is available for free online: <http://www.maerivoet.org/website/software/arduino/manuals/electronics/the-art-of-electronics.pdf>

<sup>4</sup>Sparkfun soldering introduction: <https://learn.sparkfun.com/tutorials/how-to-solder-through-hole-soldering>

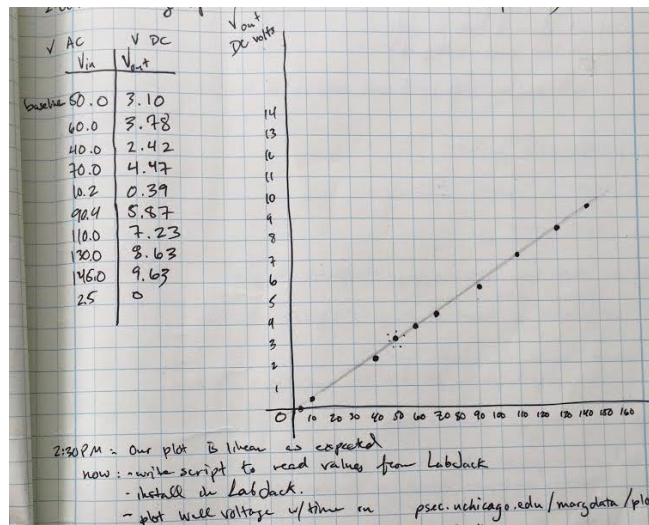


Figure 6: Example of plotting data points by hand instead of afterwards on the computer. In this page of my lab notebook, I plotted input voltage vs output on the voltage monitoring circuit in order to make sure our circuit was sensitive to fluctuations in voltage. We record data points manually to get a sense of what is happening as we go.

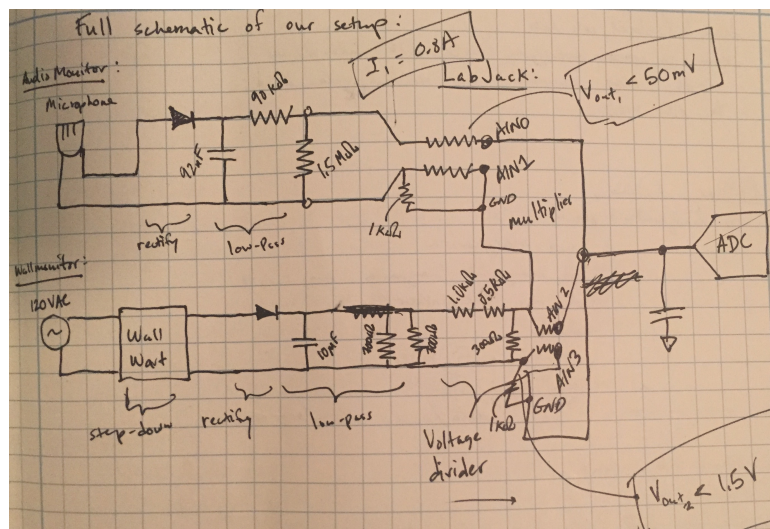


Figure 7: This is a page of my lab notebook depicting the complete circuit diagram, with certain important values labeled.

In order to interact with a Raspberry Pi, you will have to operate in a Linux command-line environment. If you are new to Linux or Raspberry Pi, there are plenty of tutorials online to learn. In particular, RaspberryPi.org has an active and helpful online community.<sup>5</sup> RaspberryPi.org has a basic review of Linux commands [here](#).<sup>6</sup>

In addition to Linux commands, a review of basic principles of coding in Python is essential to writing scripts on Raspberry Pi. [Python.org](#) has resources for learning basic aspects of the Python language as well as resources for more advanced topics.

### 3.3 Organization

It is important to keep the lab clean and organized. However, this means more than just cleaning workstations after use.

Maintaining an intelligible lab notebook is important. Make notes of everything that happens in the lab: who is there, what time, and what problem you are trying to solve. That way, you don't ever have to waste lab time trying to remember what you did last time, or worse, redoing something you have already done.

Before building any part of a circuit, draw a schematic. Calculate the values the circuit needs before soldering anything, otherwise you risk wasting a lot of time building circuits that will not work. Always start by drawing the circuit diagram by hand in a lab notebook. When you need to include a diagram in a report, there are plenty of online resources to draw circuits. I have used [SchemeIt from DigiKey Electronics](#).<sup>7</sup>

If you are in the process of taking two measurements and plotting them against each other, do this by hand first. Instead of recording all of your data points, entering them into a spreadsheet and generating a plot on a computer, simply record data points in your lab notebook. This will get you to your result faster and will let you know if the relationship you are measuring is how you expect it to be. An example of this method is in Fig.6.

When working with a new piece of equipment, write all important product specifications (voltage output, current, frequency, etc.) in your lab notebook to serve as reference later. This way you can avoid a careless mistake like providing the wrong voltage to a device.

## 4 Acknowledgements

Before my work in PSEC, I had effectively no understanding of basic circuitry or applied electronics. I didn't know how to use a Raspberry Pi or a LabJack or work within a command line environment. Thanks to the guidance (and patience) of Professor Henry Frisch, Evan Angelico, and Eric Speiglan I have developed these skills. Also, thank you to John Judge and Bala Chockalingam, undergraduate partners in the laboratory.

## 5 References

1. Horowitz, Paul, and Winfield Hill. 1989. The art of electronics. Cambridge [England]: Cambridge University Press.

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<sup>5</sup>Raspberry Pi Forums: <https://www.raspberrypi.org/forums/>

<sup>6</sup>Useful Linux commands to remember: <https://www.raspberrypi.org/documentation/linux/usage/commands.md>

<sup>7</sup>SchemeIt is free from DigiKey Electronics: <http://www.digikey.com/schemeit/project/>