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Electrically Induced Plasma

Nate Ashby

Mentor: Dr. Ajay Singh

November 6, 2015

My research project, under the mentorship of research professor Ajay Singh was to prove that the plasma he was creating was lasting longer than the electrical current data indicated. He decided that if the plasma was still there, it would be producing light. So we set out to prove that the light emitted from his plasma lasted longer than the current draw measurements.

My project consisted of two major parts. The creation of a photodiode array, and creating a serial interface with an oscilloscope to digitize the data measured by the photodiode array. We decided that we needed a photodiode array to measure multiple locations around the experiment. This allowed us to verify the integrity of the components and the entire system in general.

I started with the creation of the photodiode array. After searching we found the VTP1188SH. We selected this diode for the following reasons:

1. It was affordable at about 10\$ a unit.
2. The spectral wavelength range was 400 nm to 1100 nm, giving us a range from ultraviolet to infrared light. All of which was being produced by the plasma.
3. The Junction Capacitance was .18 nF. This would allow the photodiode to give accurate readings at very small time intervals.
4. The diode had a low sensitivity at .55 Amps per Watt.

After receiving a number of these diodes I began to test their output with different light intensities. Because the light output we were attempting to measure was a broad spectrum, we used white light for all of these tests. The results were underwhelming. The output between bright lights and dim ones was within the error on the oscilloscope, this did not give our data enough differential voltage. We decided that I needed to make a voltage multiplier to create a substantial signal easily measureable.

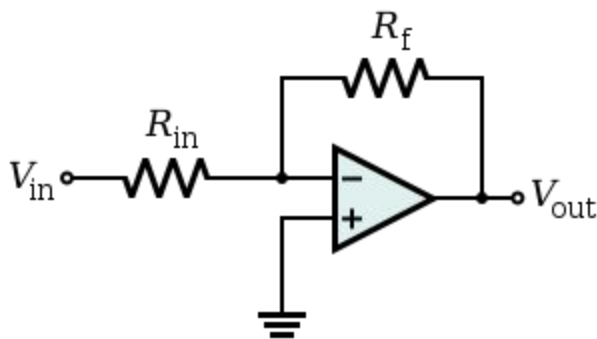


Diagram 1.

Diagram 1 shows a basic OP Amp voltage multiplier. I needed to find suitable components to create a similar circuit across the array. I ended up with an OP Amp that was lying around where I work. It would run up to 8 of these circuits at the same time, without interfering with each other too much. I ended up using a 1k resistor for R_{in} and a

15k resistor for the R_f . The signal created from the diode had a gain of 15. After making the circuit we hooked it up to a DC voltage supply, this had some unexpected results. The signal from the array had a secondary signal on top of it. It was 60 hertz, coming from the AC to DC conversion done by the supply. After figuring this out, I made a battery voltage equivalent DC power supply, fixing the issue and providing accurate data.

This provided a very clean way of creating easily measured signals from each photodiode in the array. To verify the system and its components, we used all 4 photodiodes in the same place. We then ran the experiment and verified that all of the photodiodes produced almost the same waveform.

Then I had to create the program to interface with the oscilloscope. The greatest reason for interfacing with the oscilloscope was to digitize the analog data generated by the photodiode array. Once we digitized this data, we could compare it with the electrical power data generated by the system already being collected and digitized.

Diagram 2 shows the high level architecture of the system. This would take the analog data measured from the photodiode array and convert it into digital data, analyzable by the computer.

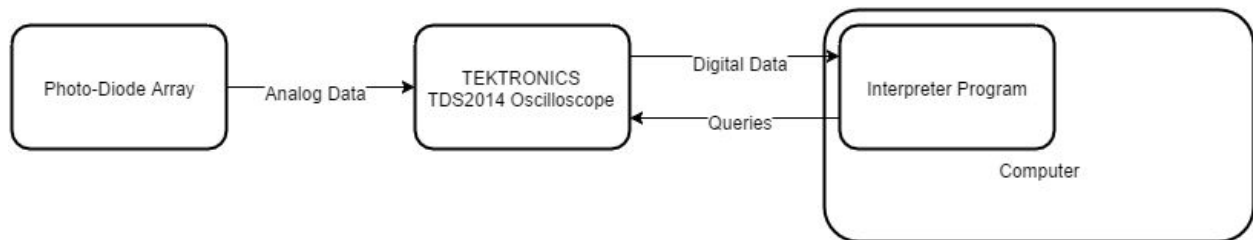


Diagram 2.

The program would interface with the oscilloscope using old RS-232 serial communication protocols. I found the Programmer Manual for the series oscilloscope, a 350 page document containing all of the documentation for the interface. The oscilloscope would receive ASCII based commands via the RS-232 interface, and then return the command's output back through the RS-232 interface.

First we would test the connection by sending an IDN? query, this would return some information about the oscilloscope. We used this information to verify that we were connected and properly communicating with the oscilloscope. It needed a number of setup commands to work correctly for our application. First we needed to set the data format to ASCII and set the resolution for the data to a 2 byte signed integer format.

The simple CURVE? query would return the a comma separated ASCII data for the waveform currently displaying on the oscilloscope. The problem with this, is that there is no indication of voltage units, time units, or the selected channel. The ASCII data returned was an integer multiple of the voltage scale setting on the oscilloscope. Similarly the time between each integer was the current setting of the time scale on the oscilloscope.

Using the WFMPRE? query I was able to acquire all of the other information that I needed. I had to parse and determine the values for the voltage multiplier, time multiplier and voltage offset. The voltage multiplier and offset would be applied to the ASCII data, and the time multiplier would be used to generate timestamps for each of the data points. I had to iterate through each of the 4 channels and keep track of the current channel because the CURVE? and WFMPRE? commands did not return the current channel.

This data was saved in a CSV format containing the timestamps in the first column, and each channel's value in the following columns. This made it easy to analyze using tools like Matlab. The data was also displayed using a graphing library that I downloaded.

Later I found that the WAVFRM? query did both of these queries, and would have saved me time developing. But I never implemented the program with the new, simpler query.

After making the program work initially, Dr. Singh wanted me to make it user friendly and open source so other scientists could use this as a general way of retrieving data from this series of oscilloscopes. I added a graphical user interface(GUI) allowing the user to scan and connect to available COM ports, select the channels they wished to query, set the voltage and time scales, and even set the trigger voltage. All of these were done with a command dictionary created from the programmer manual. Using this dictionary other scientists could use this code to programmatically do virtually anything that compatible oscilloscopes can do physically.

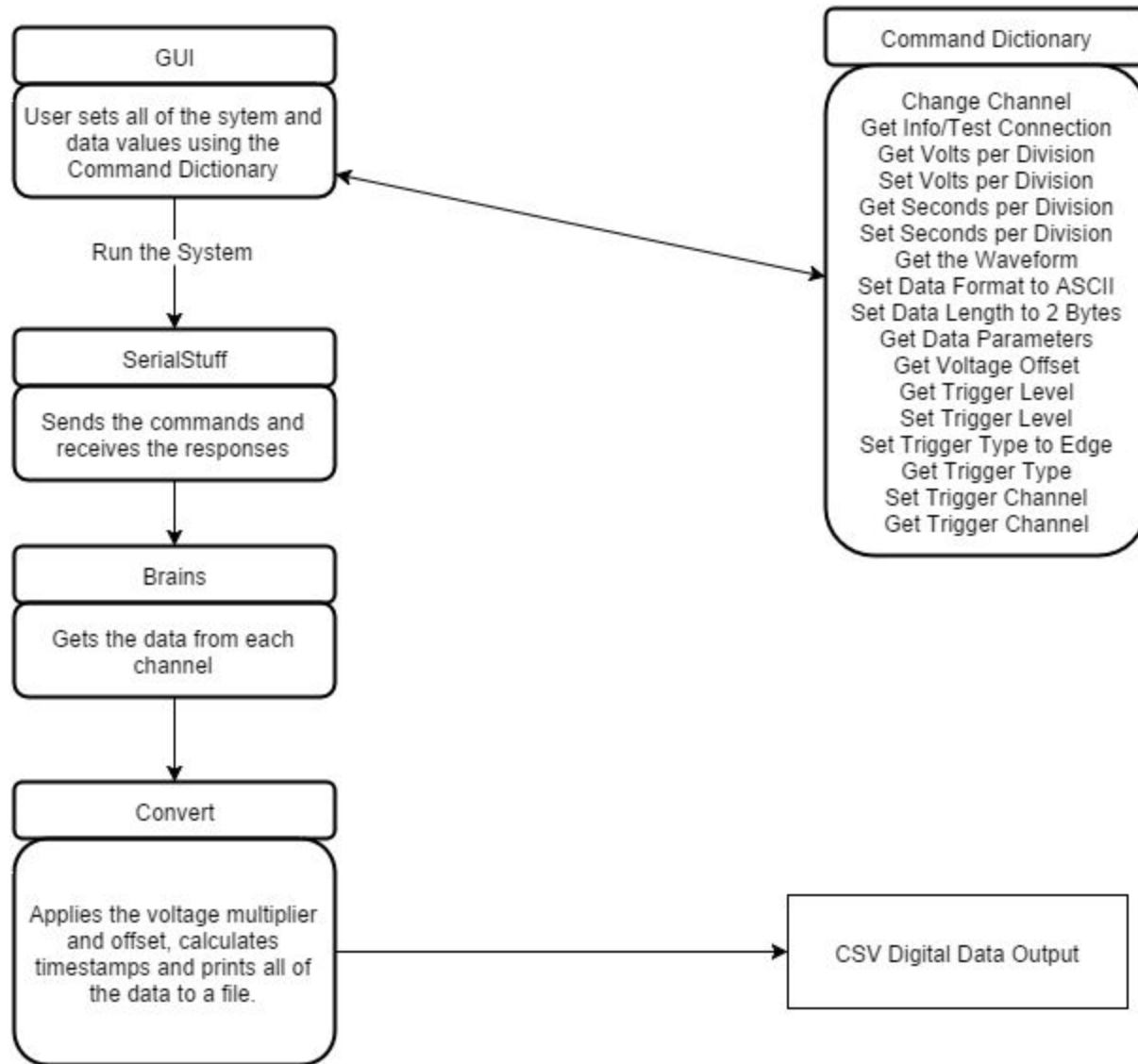


Diagram 3.

The end architecture is shown in Diagram 3. There was and still are many bugs in this code. Dr. Singh was laid off while I was developing this part of the project, and I never finished and polished this part of the program. Which is why I said I only deserved a B. This was the last part of the project before completion. Honestly I'm a much better programmer now, and would just rewrite the entire thing, and have the system be much better.

After acquiring the data, we were able to confirm some of Dr. Singh's hypotheses: The light lasted longer than the current, and we were able to see some interesting waveforms and patterns in the light data to create an analysis between the two sets of data. One of the ways we were able to verify the integrity of the prototyped system was

to compare the waveforms of the two sets of data, seeing that they were very similar. Light and electricity are just forms of energy, and it makes sense that there is a correlation between the amount of light created, and the amount of electrical power pushed through the plasma.

In conclusion, I built a photodiode array to measure the amount of light coming from high energy plasma in his experiment, I then wrote a program to pull this data from the oscilloscope. We analyzed this data and proved Dr. Singh's assumption. I learned so much about plasma physics, but still have much to learn. We were lucky to have a third party allow us to use an ultra high speed camera to even film the plasma, its filamentation and other properties. I wish I still had those photos, but I was unable to find them.

I was able to complete most of this research with the help of Dr. Singh. We proved that the light did last significantly longer than the electrical current in the experiment. I know this wasn't the most conventional physics research project, but many of the problems in science lie in the realm of engineering. As engineering processes become more precise and available, science leaps forward with new tools and ideas, and in turn creates new engineering processes and tools. This relationship builds and moves us toward a better understanding of ourselves and the universe.