SENIOR DESIGN I

UV-Vis Spectrophotometer

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Design Document Draft

Group 29

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Project Narrative

Biomedical research is responsible for an increasingly significant portion of innovation in medical technology. Many modern drugs and procedures are made possible with the knowledge and manufacturing methods produced in these laboratories. One of the growing sectors of biomedical research is molecular biology, which studies the structures and behaviors of cellular structures using advanced machinery. Scientific endeavors such as the Human Genome Project rely on molecular biological research to understand the genetic information of lifeforms and how they correspond to traits and behaviors. These studies are made possible by increasingly sophisticated machinery to interact with the microscopic material, and one of the most important tools is the spectrophotometer.

Spectrometry is used in the lab to answer questions related to sample concentration, purity, and reactivity. This information is vital to understanding what is happening on the molecular level, and almost every protocol performed in a molecular lab uses a spectrometer of some kind to identify or verify experimental results. Many labs will contain several types of spectrometers, but the most common is a spectrophotometer capable of single-wavelength measurements with a minimum amount of sample usage. Often several of these devices will be available in a research laboratory due to their popularity in modern scientific protocols.
This project aims to create a spectrophotometer specifically tailored for molecular biology labs that study proteins and genetic information. This device aims to be a low-to-moderate cost model suitable for fast sample readings with a specific focus on ease-of-use and clear data presentation. The end product will have good portability and easy user configuration, resulting in simple benchtop installation with a low profile. The goal is to provide researchers a quick and easy solution to running optical spectroscopic protocols without significantly impacting overall workflow or lab efficiency.

This is not a unique concept in the market, and several products exist that try to satisfy this audience with various resolutions, price-points, and interface options. Some companies exist only to produce these instruments and related supporting material. While many of these products are adequate for lab use and embraced by the scientific community, there is room for increased specialization and more features thanks to improvements in both biology and electronics. Embedded devices are cheaper and more powerful than ever before, and manufacturing refinements have brought many high-quality parts into an affordable domain. The market is ripe for a new product to appeal to biology researchers at a time when more studies and laboratories are being established every day. With so many studies requesting funding and so many devices required for state-of-the-art research, budgets are tight and any quality low-budget product is a welcome sight.

One of the most valuable things to a researcher is their time, as many tasks need to be completed in short order to produce good data and meet the deadlines of their investors. Many common tests done using a spectrophotometer, such as a kinetic assay for measuring enzyme activity, require collecting data points over 5-10 minute periods, but current budget models on the market only display one data point at a time. These points can be 30 seconds apart, requiring a researcher to manually sit by the device to record measurements for some simpler devices. More advanced devices may include some automation steps, but often do so via disorganized printouts that must be manually recreated for statistical analysis at a later time. These steps add up to time lost in the lab that could be put to better use elsewhere. Even a few minutes saved per assay could translate to an extra procedure performed by that researcher, improving the quality of their research and reducing mental fatigue from repetitive simple tasks.

One feature that has been requested by researchers is a combination of real-time and discrete measurements when running assays, which was not possible on older devices. Using a modern display screen and a more powerful processor will enable real-time graph generation for desired applications. This information can provide more detailed understanding of reaction kinetics and reduce the chance of outliers affecting the data. Another significant improvement is compatibility with modern computer interfaces. Several models on the market only supply RS-232 output for data exports, which is considered obsolete and not featured on many computers. Upgrading to standard communication ports will improve the integration of this device into the lab environment.

Overall this project hopes to produce an attractive product for newly-established laboratories aiming to work in molecular biology or older labs seeking to upgrade their equipment. It also serves as an excellent educational tool, providing an easy-to-use measurement device with quality results that reflect good technique in the lab.

Specifications

- USB compatibility
  - .csv output and printer-ready readout
- Weigh less than 30 pounds
- Input light via xenon lamp
- Functions at room temperature
- Output detection via sensor array
- Power
  - 90-260 VAC, 47-63 Hz
- Low heat transmitted to sample < 250W
- Small form factor within 2 ft. by 2 ft.
- Ability to use wavelengths from 200 nm to 800 nm
- Wavelength accuracy: < 10 nm
- Spectral bandwidth: < 10 nm
- Organized Display
  - Graphs of spectra captured
  - Simple user interface
  - Low setup time

Block Diagram

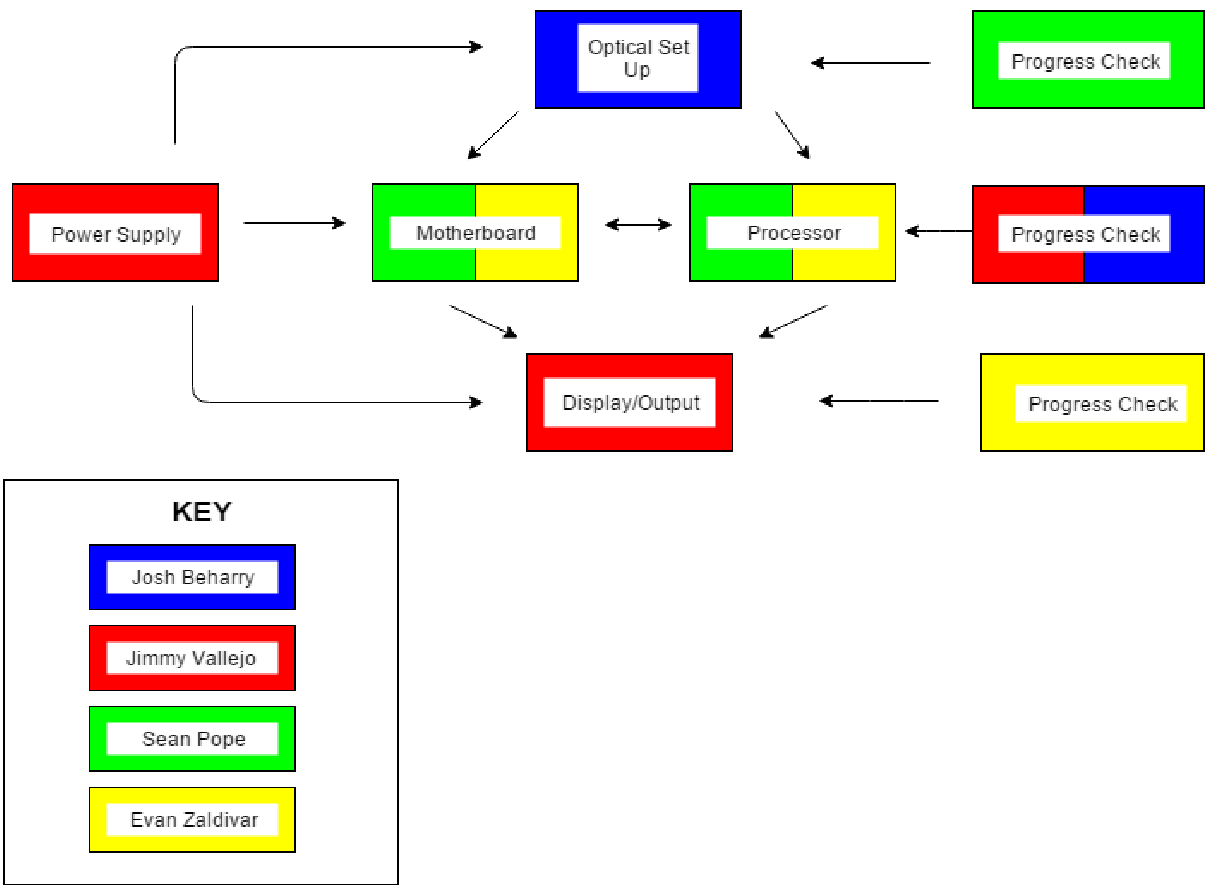

Figure 1

Block Status				
To Be Acquired	N/A			
Acquired	Light	Optical Setup		
Research	Power	Motherboard	Software	Display
Design	N/A			
Prototype	N/A			

Table 1

The Marketing-Engineering Tradeoff Matrix is to develop an idea to be able to correlate the requirements needed for the project. By developing the Marketing-Engineering tradeoff chart will help us overcome situations encountered while creating the project. The following chart will show correlations of “The UV-Vis Spectrophotometer” project.

I. Marketing Requirements (▼)
II. Engineering Requirements (▶)

- ↑ = Positive correlation
- ↑↑ = Strong Positive correlation
- ↓ = Negative correlation
- ↓↓ = Strong Negative correlation
- + = Positive Polarity
- - = Negative Polarity

(▼) (▶)		Bandwidth	Power	Speed	Weight	Compatibility	Resolution	Cost
		+	+	+	+	+	+	-
Install Ease	+	↑			↑↑	↑↑	↑	↓↓
Speed	+	↑↑	↑			↑	↑↑	↓
Heat	+	↑	↑				↑↑	
Ease of Use	+		↑	↑↑		↑	↑↑	↓
Resolution	+	↑↑	↑	↑↑		↑		↓↓
Weight	-	↑				↑		↓
Cost	-	↓↓	↓↓	↓	↓		↓↓	↓↓
Goals for Engineering Requirements		≤ 10 nm	< 250W radiated	< 5s read time	≤ 30lbs	USB	≤ 10 nm	≤ $6000

Table 2

Initial Project Milestones

Description	Duration	Dates
Project Brainstorming	2 weeks	August 22 – September 5
Finalize Project Idea	1 week	September 5 – September 12
Initial Project Documentation		September 9
Research Individual Subsystems	2 weeks	September 12 – September 26
Design Individual Subsystems	2 weeks	September 26 – October 10
Integrate/design subsystems	4 weeks	October 10 – November 4
Table of Contents		November 4
Writing	1 week	November 4 – November 11
Senior Design I Draft		November 11
Order and organize parts for prototype	3 weeks	November 11 – December 6
Continue research and design	2 weeks	November 11 – November 21
Breadboard test of parts	2 weeks	November 21 – December 6
Finalize the design + Writing	2 weeks	November 21 – December 6
Final Senior Design I Documentation		December 6
Begin prototype creation	4 weeks	December 6 – January 9

Table 3

Senior Design II – Spring 2017

Description	**Duration**	**Dates**
Begin prototype construction	1 week	January 9 – January 16
Confirm all parts are correct working	1 week	January 9 – January 16
Design and test software	3 weeks	January 16 – February 6
Assemble prototype hardware	6 weeks	January 16 – February 27
Prepare and test for midterm demo	2 weeks	February 27 – March 13
Midterm demo		TBA
Integrate and construct final product	4 weeks	March 20 – April 17
Test final product	1 week	April 17 – April 24
Writing	2 weeks	April 10 – April 24
Final presentation and demo		TBA

Table 4

Budget Estimation

Item	Cost	Quantity	Total Cost
PCB	$100	1	$100
Xe light source	$200	1	$200
Output display	$200	1	$200
Servos and motors	$15	4	$60
Monochromator	$1500	1	$500
Breadboard	$10	1	$10
Detector	$50	1	$50
Electrical components	$50	Various	$50
Microcontroller	$50	1	$50
FINAL TOTAL			$1220

Table 5