Final Report for ECE 445, Senior Design, Spring 2024

TA: Sanjana Pingali

05 May 2024

Project No. 2

[First Author Name (alpha order)]

[Second Author Name]

[Third Author Name]

[Fourth Author Name]

By

Seeing-Eye hat

**Abstract**

The abstract is short (150 words or less) and provides enough of a summary of the report for the reader to decide whether to read the entire document. State very concisely what your device or system does, and the main findings and results of your project. Save background information (e.g., motivation, competitors) for the introduction and design details for the body of the report. Do not give an advertising pitch. Note that the abstract does not appear in the table of contents. (This achieved by stripping out the heading style.)

Note that **you can ignore the TOC on next page because it is generated automatically.** Work on the body of the report, then hit the Update tab on the TOC and *voilà*.

When you double-clicked “ECE 445 Template.dotx,” you opened a new, untitled document in Microsoft Word, which has the main components of your final report set up for you. Save the new document, replace the red text and bracketed section heads with your own, insert carefully prepared graphics, follow the guidelines document (“Preparing Your Final Report for ECE 445”), proofread and revise, and you’ll likely end up with a successful report.

Contents

[1. Introduction 1](#_Toc318193395)

[1.1 Section head 1](#_Toc318193396)

[2 Design 2](#_Toc318193397)

[2.1 [Component or Block] 2](#_Toc318193398)

[2.1.1 [Subcomponent or subblock] 2](#_Toc318193399)

[3. Design Verification 3](#_Toc318193400)

[3.1 [Component or Block] 3](#_Toc318193401)

[3.1.1 [Subcomponent or subblock] 3](#_Toc318193402)

[4. Costs 4](#_Toc318193403)

[4.1 Parts 4](#_Toc318193404)

[4.2 Labor 4](#_Toc318193405)

[5. Conclusion 5](#_Toc318193406)

[5.1 Accomplishments 5](#_Toc318193407)

[5.2 Uncertainties 5](#_Toc318193408)

[5.3 Ethical considerations 5](#_Toc318193409)

[5.4 Future work 5](#_Toc318193410)

[References 6](#_Toc318193411)

[Appendix A Requirement and Verification Table 7](#_Toc318193412)

# 1. Introduction

Briefly describe the science or engineering problem to be addressed in the report, as well as the purpose and usefulness of the device or system you have built. Summarize the contents of the upcoming chapters as well as the main conclusions of your project, to be elaborated in the last chapter.

## 1.1 Block Diagram

To create a section head, go to the Styles gallery under the Home tab and pick Heading 2. It automatically formats as above and creates a table of contents entry (after you click the Update tab). Word will not make the capitalization consistent; you have to do that yourself.

Figure 1 is an example of figure and caption style. Table 1 is an example of table and table title style. A starter table for parts costs is in Chapter 4 of this template.

Use the References🡺Insert Caption tool to generate consistently formatted captions (always *below* the figure), and use the grouping function in Word’s drawing tools to hold figure and caption together. Use picture formatting tools to hold figures in place (preferably at top or bottom of page) and to define text wraps (“top and bottom” is best).

Use Word’s table design and layout tools to format titles, column heads, and borders.

Insert page break at end of every chapter to ensure next chapter starts on new page.

Figure 1 Example of placement and caption for a block diagram. With picture selected, go to References🡺Insert Caption. This creates a neat, consistent caption style that stays connected to the figure. Size the figure so that one-inch margins are preserved. Group the figure and caption to hold them together.

|  |  |  |
| --- | --- | --- |
| **Table 1 Example of a Table and Its Title** | | |
| **Part** | **Electricity** | **Magnetism** |
| Field intensity | **E** | **H** |
| Flux density | **D** | **B** |
| Constitutive factor | **ɛ**b | **µ**c |

# 2 Design

Discuss general design alternatives. Give equations, simulations, general circuits. Describe design in detail, addressing each major component. Include schematics with components, drawings, flowcharts, etc. Some teams may wish to split this chapter in two: 2. Design Procedure, and 3. Design Details. This template will not automatically update numbering systems for chapters, sections, figures, tables, etc., so keep track of them as you develop and revise the text.

Following is a “template” for displayed math. Use the MathType extension of Word to generate your own content, and note the use of the invisible table (no borders) to keep the optional number flush right.

|  |  |
| --- | --- |
| Insert math here using MathType | (number) |

## 2.1 Control Unit Design

To create a section head, go to the Styles gallery under the Home tab and pick Heading 2. It automatically formats as above and creates a table of contents entry (after you click the Update tab).

### 2.1.1 [Subcomponent or subblock]

To create a subsection head, go to the Styles gallery under the Home tab and pick Heading 3. It automatically formats as above and creates a table of contents entry (after you click the Update tab). Even lower level section heads can be created the same way, but they are likely unnecessary.

## 2.2 Imaging and Sensing System Design

## 2.3 Haptic Feedback System Design

The Haptic Feedback system’s purpose is to translate the locational data into sensory feedback for the user. The core design has remained consistent. Haptic Motors, otherwise known as Linear Resonant Actuator (LRA) Motors, are used to convey sensor feedback to the user.

Haptic motors are evenly distributed across the inside rim of the hat. This divides the surrounding area into evenly spaced “zones” extending out from the angles between the motors. For example, the final product uses 12 motors. This places a motor every 30 degrees around the hat. Each haptic motor now represents a 30 degree “slice” of the world surrounding the user.

The strength of the vibration is determined by the Control Unit. The control unit uses a PWM Signal and switching transistors to regulate the power delivered to the motor. These are used to not over-tax the maximum current drawn from the microcontroller. With a sufficiently powerful microcontroller, and a limit on the maximum number of motors activated, the switching transistors may be able to be removed.

We used a 150 CM threshold distance to turn on the motor. We considered having the strength of the signal proportional to the distance to the nearest measured object within the motors zone. Testing showed that this was difficult to perceive by users.

The initial design wanted to have all motors on at one time. When testing, we learned that most test subjects struggled to distinguish the locations of the vibrating motors once more than one was on at a time. Therefore, we limited the scope to only pulse one motor at a time. We also considered using 8 motors instead of 12 if the product became overstimulating.

## 2.4 Scanning System Design

The scanning system’s primary purpose is to rotate the LiDAR. It also rotates the magnet that is used to trigger the Hall Effect Sensor used by the control unit during the calibration process. The most important requirement of the scanning system is to ensure the LiDAR can spin fast enough to meet the “one measurement every two seconds” requirement. This essentially translates to a 30RPM Requirement.

The scanning mechanism and the sensing system work in tandem to track the position of the Motor, and thus the LiDAR. This information is critical for mapping distance measurements to directions and haptic motors.

The LiDAR requires 5 wires to operate. Therefore, a slip ring is required for this design. The use of a slip ring necessitates that the LiDAR must be driven by a gear instead of the motor directly.

Initially, the scanning mechanism consisted of a brushless motor and a 1:1 gear ratio. This design prioritized speed over control. The hypothetical benefit of this system is that more LiDAR readings could be collected faster, which would provide a better experience for the users. Practically, the control unit was not fast or powerful enough to perform LiDAR Readings at the pace required for this. It additionally placed a heavy burden on the control unit and sensing systems to track the motor.

The final version of the scanning mechanism uses a stepper motor and a 2:1 gear ratio to turn the LiDAR. The stepper motor is preferable because, after calibration, the control unit will have a perfect understanding of the motor’s position at any given time. This heavily reduces computational and developmental burdens. The drawback to this system is that the motor naturally operates at 15RPM. We were able to use a gear ratio to mitigate this, and preserve our 30RPM requirements.

## 2.5 Power System Design

The power system had a dynamic development process. Failures during the verification process, alongside untimely component ordering problems, caused the team to abandon the original power system described in the proposal.

Our team proved resourceful. With two days until the demonstration, we found a commercially available and accessible power system that still passed every verification test that we designed for its predecessor. This section will first describe the final version of the power system as it appeared in the demo. Afterwords, we will detail the process of designing the failed power system.

### 2.5.1 Final Power System

The final product utilizes a multi-stage power system. The primary power supply is a standard USB Portable Cell Phone Charger. The rated output voltage from the portable charger is 5 V. The rated output current is 2.1 A.

The primary battery directly powers the Control Unit. Alongside acting as the control unit, the Arduino Mega functions as the voltage regulators for the power system. The development board contains linear regulators to create stable 5 V and 3.3 V power buses. These two buses are used to power all components of the Scanning, Sensing and Haptic systems. The maximum current draw from the Arduino is 800 mA. This effectively limits the maximum current draw from the power system to 800 mA. The Arduino development board has built-in Undervoltage Lockout and Short Circuit protection. Under either of these conditions, the Arduino will shut down, which cuts power to all other subsystems by extension.

This model was chosen because our PCB design failed the final verification test. However, this design has a lot of merit. Custom designs introduce points of failure. Utilizing stable commercial components grants consistency to a design, which is valuable for key systems. The new power system was able to pass the required verification tests. Prioritizing time and consistency allowed the product to be completed and for the demo to be successful.

### 2.5.2 PCB Power System

The power system’s design process can be described as a lesson in overengineering. The power system was designed as a part of the standard project PCB. The initial concept was to use a 7.4 V LiPo battery as the primary power supply. The on-board power system would include branches for a 5 V and a 3.3 V power bus. This would be accomplished with two buck converters. Buck converters were used because, at the time, we did not think linear regulators could perform the necessary conversion without overheating. Undervoltage and short circuit protections were initially provided by e-Fuse components. Figure X shows the schematic included in the design document.

A diagram of a circuit

Description automatically generated

Figure 2: Power System V1

The e-Fuse components were removed to reduce cost and complexity. The LM22678 Buck Converters can use an output inductor to limit the maximum output current. A voltage divider between the Vin and EN pins could act as undervoltage protection. Because the safety features covered by the e-Fuse were redundant, they were removed. A professional product would still prefer to include these components for redundancy. Figure X shows the second model of the power system. This model adds capacitance to stabilize the ripple voltage.

A computer screen shot of a diagram

Description automatically generated

Figure 3 Power System V2

The power system was designed to use LM22678-ADJ converters. ADJ denotes that the output voltage is adjustable using the compensation loop shown in the previous figures. Mistakenly, LM22678-5.0V components were ordered instead. These components have a fixed 5 V output voltage. Upon realizing this, the correct components were ordered, but they never arrived. At this stage, we realized that the design is needlessly overcomplicated. The flaw with using linear regulators was that 7.4 V to 3.3 V at 1 A would hypothetically heat the regulator to 302 degrees Celsius. However, a linear regulator could be used to branch the 5 V buck converter output to the 3.3 V line. This would lower the cost of the system, increase component safety, and reduce design complexity.

A computer screen shot of a circuit board

Description automatically generated

Figure 4: Power System V3

Power System V3, shown in Figure X, was never completed because the package containing the buck converters was returned to sender by the USPO. We proceed with power system V2. Power System V2 smoked upon connecting the 7.4 V LiPo Battery for the first time. We believe this is due to in-rush currents. However, we have no way of testing this hypothesis. If further development decided to return to a custom power supply, this would require investigation.

# 3. Design Verification

Insert text.

## 3.1 [Component or Block]

Insert text.

### 3.1.1 [Subcomponent or subblock]

Insert text.

# 4. Costs

Make sure that any tables of costs are numbered, given titles, and cited directly in the text.

## 4.1 Parts

Following is a starter table for parts costs. Add cell contents as well as rows and, if necessary, columns. Update the table number according to your sequence. Note that columns 1 and 2 are set up for centered text (words) and columns 3-5 (numbers) are set up for right-alignment so that decimal points align.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table X Parts Costs** | | | | |
| **Part** | **Manufacturer** | **Retail Cost ($)** | **Bulk Purchase Cost ($)** | **Actual Cost ($)** |
|  |  |  |  |  |
|  |  |  |  |  |
| **Total** |  |  |  |  |

## 4.2 Labor

# 5. Conclusion

The conclusion may contain the following sections or others of your choosing.

## 5.1 Accomplishments

## 5.2 Uncertainties

## 5.3 Ethical considerations

## 5.4 Future work

# References

[1] *Motorola Semiconductor Data Manual,* Motorola Semiconductor Products, Inc., Phoenix, AZ, 2007.

[2] *Double Data Rate (DDR) SDRAM,* datasheet, Micron Technology, Inc., 2000. Available at: <http://download.micron.com/pdf/datasheets/dram/ddr/512MBDDRx4x8x16.pdf>

[3] Linx Technologies LT Series, web page. Available at: <http://www.linxtechnologies.com/products/rf-modules/lt-series-transceiver-modules/>. Accessed January 2012.

[4] J. A. Prufrock, *Lasers and Their Applications in Surface Science and Technology,* 2nd ed. New York, NY: McGraw-Hill, 2009.

[5] W. P. Mondragon, “Principles of coherent light sources: Coherent lasers and pulsed lasers,” in *Lasers and Their Applications in Surface Science and Technology,* 2nd ed., J. A. Prufrock, Ed. New York, NY: McGraw-Hill, 2009, pp. 117-132.

[6] G. Liu, “TDM and TWDM de Bruijn nets and shufflenets for optical communications,” *IEEE Transactions on Computers*, vol. 59, no. 1, pp. 695-701, June 2011.

[7] S. Al Kuran, “The prospects for GaAs MESFET technology in dc–ac voltage conversion,” in *Proceedings of the Fourteenth Annual Portable Design Conference*, 2010, pp. 137-142.

[8] K. E. Elliott and C. M. Greene, “A local adaptive protocol,” Argonne National Laboratory, Argonne, IL, Tech. Rep. 916-1010-BB, 2006.

[9] J. Groeppelhaus, “Java 5.7 tutorial: Design of a full adder,” class notes for ECE 290, Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, 2011.

# Appendix A Requirement and Verification Table

An appendix is a good place for the Requirement and Verification Table from your design review. Below is a starter table. Including these details here will help to avoid lengthy and tedious narrative descriptions in the main text, which may not be of immediate interest to your imagined audience of company managers and professionals. Any requirement that is not verified should be explained either in the main text or the appendix. Note that both the pagination and the numbering of figures, tables, and equations continues from main text to appendices.

|  |  |  |
| --- | --- | --- |
| **Table X System Requirements and Verifications** | |  |
| Requirement | Verification | Verification status  (Y or N) |
| 1. Requirement    1. Subrequirement    2. Subrequirement    3. Subrequirement | 1. Verification    1. Subverification    2. Subverification    3. Subverification |  |
| 1. Requirement    1. Subrequirement    2. Subrequirement    3. Subrequirement | 1. Verification    1. Subverification    2. Subverification    3. Subverification |  |
|  |  |  |
|  |  |  |