ECE 445 Senior Design
Project Proposal

Electronic Page Turner

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1 Introduction

1.1 Problem

When reading a book, manual page-turning is a key requirement. This can be an inconvenience for those wishing to multitask while reading. A prime example of this occurs when a musician has to stop playing their instrument in order to turn the sheet music when practicing or performing music. Another example is when cooking and using a cookbook, one may not have free or clean hands to turn the pages. Furthermore, a group to consider is those with disabilities who are unable to physically turn a book's pages [1]. There are a number of examples supporting the usefulness of electronic page turners, but not many exist. Those that do are generally expensive and are typically designed for electronic reading on tablets. Another issue with existing page turners for physical books is that they are made for a limited number of pages and can only turn the pages in one direction. They also require lengthy setup to attach each page to the device. This is an issue for those wanting to use a book with more pages than the device can handle.

1.2 Solution

To solve this problem, our team aims to create a hands-free electronic page turner that functions with a foot pedal. The device will use a dual switch foot pedal such that a page can be turned in both directions. When the foot pedal is pressed, the control system communicates to the motors to begin turning a page. A paper safe adhesive, attached to a motor, will be used to lift up a single page at a time. Next, the page will be turned over by a rod sweeping underneath. This system and motion will be reused for turning a page both forwards and backwards. Additionally, the device will be powered using batteries so that the device can be made as portable as possible. Our solution is unique because the device does not require extensive setup and can turn through all the pages in a physical book, both forwards and backwards.

1.3 Visual Aid

We provide a pictorial representation of our solution in Figure 1. The primary components such as the motors will be attached to a book stand.

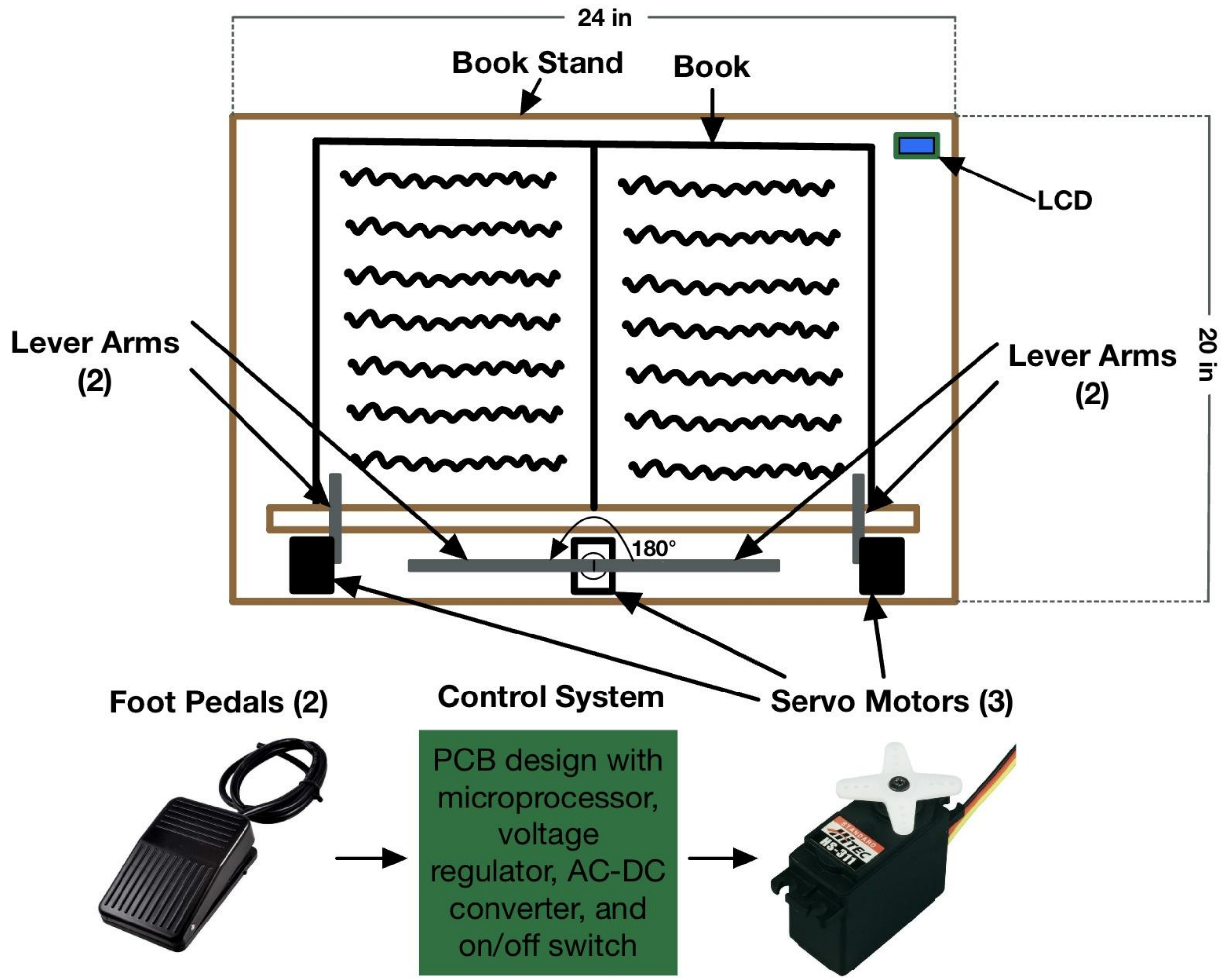

Figure 1: Visual Aid

1.4 High-Level Requirements

For our solution to be considered successful, it must achieve the following three goals. If the team is able to accomplish all three high level requirements, we aim to produce prototypes that can turn a page by using additional sensors.

- ➢ The device must be able to turn one page within 5 seconds ± 2 seconds. This motion should be repeatable for turning a page backwards.
- ➢ The device must be able to turn at least 10 consecutive pages with 95% ± 5% accuracy and take at most 1 minute ± 10 seconds when the foot pedal is pressed consecutively.
- ➢ The device must be able to store the total number of pages turned, in a singular sitting, with 95% ± 5% accuracy and display this information to the reader.

2 Design

2.1 Block Diagram

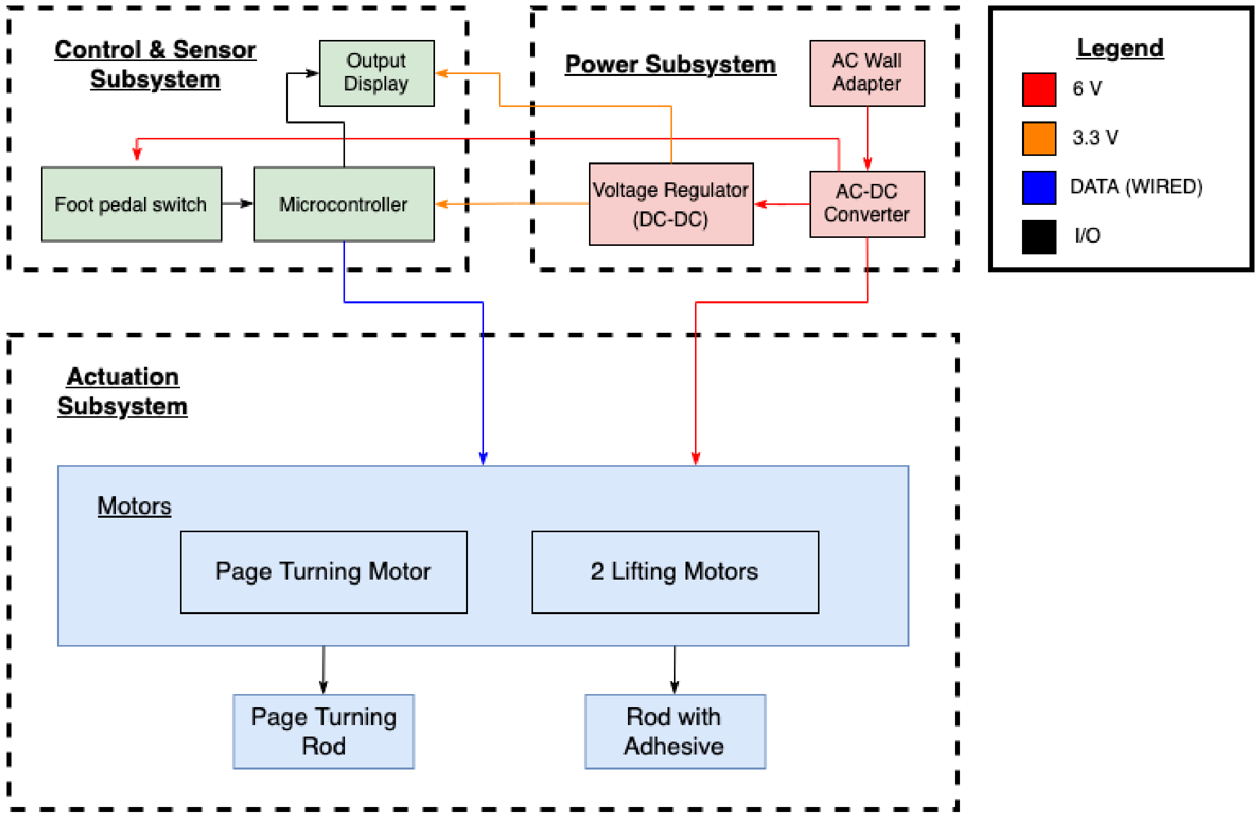

Figure 2: Block Diagram

2.2 Subsystem Overview

Our design is divided into three subsystems: Power, Control & Sensor, and Actuation subsystems.

2.2.1 Power Subsystem

The power subsystem handles sending power to the rest of the components in the other two subsystems. The power subsystem includes an AC wall adapter, an AC-DC converter that should supply 6 V, a DC to DC voltage regulator, and an On/Off switch. The voltage regulator reduces the voltage needed to power the foot pedal and microcontroller.

2.2.2 Control & Sensor Subsystem

The control and sensor subsystem contains the microcontroller and sensors needed to move the motors. This primarily includes the Arduino Nano 33 BLE Sense and dual switch foot pedal. When the foot pedal is pressed a signal is sent to the microcontroller which determines whether a page is turned forward or backwards. The microcontroller then sends a signal to turn on the correct servo motors. Any additional sensors such as a microphone and camera will be included here as well.

2.2.3 Actuation Subsystem

The actuation subsystem handles the mechanical work of turning the page and includes three servo motors. Two servo motors will be used for lifting a single page, the left and right page respectively. Attached to each lifting motor will be a short rod with paper safe adhesive attached to the end. The shorter rods will be located at the bottom corners of each page. The remaining servo motor will be used for turning the page forward or backwards. This page turning motor will be located near the center of the book stand. Attached to the page turning motor will be a long swiping rod that rests below the bottom of the book. In its entirety, when the foot pedal is pressed, and the microcontroller processes and sends the signal, the lifting motor will lift the current page using the attached adhesive. The page turning motor will then turn on and sweep beneath the current page, turning it over to the next page.

2.3 Subsystem Requirements

The requirements for each of our subsystems.

2.2.1 Power Subsystem

The power subsystem handles sending power to the rest of the components in the other two subsystems.

Requirements	Verification
• Must have a 6V wall adapter that plugs into a wall outlet. • Must have an AC-DC converter. • Must have a voltage regulator to supply 3.3V.	• Use a multimeter to check that the wall adapter's barrel jack is supplying a steady 6V. • Use an oscilloscope to measure the output of the AC-DC converter to make sure it is consistently 6V.

• Motors must be supplied 6V and 100mA each.	• Use an oscilloscope to measure the output of the voltage regulator to make sure it is consistently 3.3V. • Power the motors using a 6V power supply and use an oscilloscope to plot the current and voltage across the motors power wire.

2.2.2 Control & Sensor Subsystem

The control and sensor subsystem contains the microcontroller and sensors needed to move the motors. The foot pedal sensor must be able to send a signal when pressed to the microcontroller. The microcontroller must then communicate with the motors to begin turning pages.

Requirements	Verification
• When the foot pedal sensor is pressed, it must send a signal to the microcontroller. The microcontroller must then send a signal to the motors that causes them to rotate.	• Program the foot pedal and a motor using an Arduino Nano 33 BLE Sense development kit. • Test the situation where the foot pedal is not pressed. Ensure that the motor does not rotate. • Test the situation where the foot pedal is pressed. Ensure that the motor rotates 45° and 180°. • Time the process to rotate the motors 45° and 180° respectfully. Make sure on average the entire process is done within 3 seconds ± 2 seconds.

2.2.3 Actuation Subsystem

The actuation subsystem handles the mechanical work of turning the page and includes three servo motors. The motors must successfully lift a page and then turn that page over. This motion must be repeatable for forwards and backwards page turning.

Requirement	Verification
• The rods attached to the lifting motors must successfully lift a page 1 in. vertically, using adhesive. • The motors must be able to turn a page forwards and backwards. • The servo motors must create negligible backwards EMF. • The force of the motors should not be enough to cause tearing or damage to the books pages.	• Run 10 trials to see how much adhesive is needed to lift the page 1 in. vertically. • Using a singular lifting motor, run 10 trials to test how much force is required from the motors to lift one page. Tune the parameters in software accordingly. • Using the sweeping motor, run 10 trials to test how much force is required from the motors to lift a one page. Tune the parameters in software accordingly. Ideally, the slowest speed that still turns a page will be chosen to avoid any safety issues. • Power the motor using a 6V power supply and use an oscilloscope to plot the voltage across the motors power wire. If the voltage across the wire is on average 100mV ± 50mV we can consider the backwards EMF from the motor negligible. • Adjusting the rod distance from the page to fluctuate force applied, run 10 trials that successfully cause no damage to the book.

2.4 Tolerance Analysis

A key part of our project to be successful are the motors to lift up a single page and the center motor to flip the page. We must take into account the thickness of a book and how far along into the book we are for the lifting motors to successfully hold a page vertically. For testing we will be using a music sheet book with the following dimensions: 9 x 0.24 x 12 inches. The lifting motors must be able to reach low enough so that they can grab the very last page of the book, which would be at a height of 0.0025 inches. We determined that the page must be lifted up 1 inch to provide the sweeping rod attached to the center motor enough space to flip the page. This means a singular page must be displaced 45° with respect to the book, if using a 1 in. rod to lift the page as shown in Equation 1.

$$\Theta_{page, max} = tan^{-1}(\frac{1}{1}) = 45° = 0.785\, rad$$

Equation 1: Angular displacement for a 1 in. rod attached to lifting motor

$$\Theta_{page, min} = tan^{-1}(\frac{1}{3}) = 18.4° = 0.321\, rad$$

Equation 2: Angular displacement for a 3 in. rod attached to lifting motor

$$\Theta_{sweep} = 180° = 3.14\, rad$$

Equation 3: Angular displacement for sweeping rod attached to center motor

Additionally, two of our high level requirements involve time. More specifically the time it takes to flip a single page and the time to flip 10 pages consecutively. According to the datasheet for the motors, the maximum torque each one of these can provide is 5.5 kg/cm = 0.053937 Nm as shown in Equation 4. Ideally, each motor will receive 600 mW of power, as shown in Equation 5. By finding the maximum angular velocity, Equation 6, the time it takes for each motor to complete its angular displacement can be calculated as shown in Equation 7. In its entirety, this process will ideally take 423.62 ms (2 X 70.603 + 282.41 ms). While these calculations are under ideal conditions, in reality we can probably expect this entire process to take about 1 second to complete. We also have to consider going too fast may cause physical damage to the book's pages, which we plan to avoid. Furthermore, the time delay for signals from the foot pedal and microcontroller will require additional time. Therefore our given estimate in the high level requirements is a reasonable baseline.

$$\tau_{motor} = 5.5\, kg/cm = 0.053937\, Nm$$

Equation 4: Maximum torque provided in motor datasheet

$$P_{motor} = I_{motor} V_{motor}$$

$$P_{motor} = 0.1\ [A] \times 6\ [V] = 0.6\ W$$

Equation 5: Maximum power provided to each motor

$$P = \tau\omega \rightarrow \omega = P \div \tau$$

$$\omega = 0.6\ [W] \div 0.053937\ [Nm] = 11.124\ rad/s$$

Equation 6: Maximum angular velocity for each motor

$$t_{\Theta_{page,\, max}} = \frac{1\ s}{11.124\ rad} \times 0.785\ rad = 70.603\ ms$$

$$t_{\Theta_{page,\, min}} = \frac{1\ s}{11.124\ rad} \times 0.321\ rad = 28.924\ ms$$

$$t_{\Theta_{sweep}} = \frac{1\ s}{11.124\ rad} \times 3.14\ rad = 282.41\ ms$$

Equation 7: Time required for each motor to reach their angular displacement

3 Ethics & Safety

3.1 Ethics

The IEEE code of ethics lists a few policies that should be kept in mind while working on this project. Policy 1.5 states “to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to properly credit the contributions of others''. [2] This policy applies to this project because there are currently page turners available on the market. We will properly credit any work done on page turners and build upon those ideas. Additionally, criticism and new ideas will be welcomed so that our project development process is rewarding.

3.2 Safety

Although our project is a hands-free device, there is a possibility of injury if any bodily parts interfere with the device while it is in motion. The rods attached to the motors will perform a sweeping motion to turn the pages. While not enough force to cause very serious injury, placing your hand in the way while the rod is in motion may hurt. We need to keep in mind the material of the rods and the speed of the motors so that if contact does occur it will not cause any serious damage. Also, if someone has their hands in the way and causes the motor to stall, this will cause the motor to heat up. Although unlikely, this could potentially cause a burn to the individual. Because of this, we will need to be mindful of when the system is in use so that all hands are out of the way and the motors can move freely.

Another potential danger could be from the power subsystem. Although our device does not require high voltage to operate, we will be using a wall power adapter which will require us to step down from 120 volts to 6 volts. This will cause high heat dissipation which can cause harm to the user. To minimize the heat dissipation, we plan to use a switching regulator. The use of high voltage also presents the issue of electric shock. Electric shock occurs when current flows through your body. The higher the voltage being used, the more current there is and the worse the shock could be. An electric shock can occur if you touch the live and neutral wire of the power supply as you become a part of the circuit and allow current to flow through you. It is important to be mindful of this connection and to not touch the leads of these wires when plugged into the power supply. It is also important to make sure none of your equipment is faulty as this can also cause electric shock. Faulty equipment includes but is not limited to damaged wires, damaged plugs, broken connections, wet plugs, and plugs with missing prongs[3]. Before using any equipment our team will take the mandatory high voltage safety training and plan to keep this training in mind as we work on our project to avoid the danger of electric shock. We will also implement the one-hand rule as this will prevent current from flowing into your body and out the other connection point. We will also check to make sure all equipment is undamaged before use.

References

[1] “Assistive Technologies for Reading,”ASCD, Dec-2005. [Online]. Available: https://www.ascd.org/el/articles/assistive-technologies-for-reading.
[Accessed:06-Feb-2023]
[2] “IEEE code of ethics,” IEEE, Jun-2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html.
[Accessed:06-Feb-2023].