Project Proposal and Feasibility Study

CHOP STOP

Team 04

Maddie Collins
Daniel Dick
Kyle Mailhot
Daniel Wharton

Advisor:
Professor Jeremy VanAntwerp

ENGR 339/340 Senior Design Project
Calvin College
December 12th, 2016

Executive Summary

The Capstone Senior project for the Calvin College Engineering program is a two semester course that incorporates engineering design and Christian design norms. The course is split into two parts, ENGR 339 and ENGR 340. The main deliverable for ENGR 339 is a project feasibility study, which is detailed in this report.

The project considered in this report is the Chop Stop, an innovative application of a safety mechanism for a miter saw. Using a mechanical braking system, the Chop Stop is designed to stop a miter saw's blade on contact with skin in five milliseconds. The Chop Stop will employ resistance and voltage to differentiate between human flesh and wood fiber. Upon detection of human flesh, a capacitor will release a power surge which will melt a resistive wire freeing a brake arm, and stopping the miter saw blade. Using engineering design and analysis, Team 04 concludes that the design and manufacture of the Chop Stop is feasible.

Table of Contents

Table of Figures

Table of Tables

1 Introduction

1.1. The Project

The goal of Team 04 is to design an effective and reliable braking system for stopping the blade of a miter saw. This system, called the Chop Stop, is designed to increase the safety of miter saw users by preventing serious cutting injuries. The design incorporates an aluminum braking cartridge and electrical sensing technology to stop a rotating miter saw blade upon contact with skin. The design will maintain the usability and functionality of a traditional miter saw. Ergonomics, cost, and manufacturability will all be considered in the design and construction of the Chop Stop.

1.2. The Team

The team consists of four mechanical engineering students Maddie Collins, Daniel Dick, Kyle Mailhot, and Daniel Wharton. The team has highly diverse and unique skillsets ranging from thermal systems research to 3D modeling.

1.2.1. Maddie Collins

Growing up in both Minnesota and Illinois, Maddie began pursuing engineering through high school programs that led to an internship at a small industrial consultancy company. Through her experience at internships, Maddie has gained a particular interest in 3D modeling and design with respect to mechanical engineering.

1.2.2. Daniel Dick

Originally from Alberta Canada, Daniel has lived most of his life Grand Rapids, MI. Before starting college, Daniel owned and operated a cabinetry business. Through this experience and a recent internship at Van-Andel Research Institute in downtown Grand Rapids, Daniel has increased his knowledge of engineering design and manufacturing. Besides engineering, Daniel enjoys playing tennis and running.

1.2.3. Kyle Mailhot

Kyle grew up in California where his parents first sparked his interest in engineering. While at Calvin, Kyle interned at Lawrence Livermore National Laboratory and The Wine Group LLC. Both of these experiences expanded his knowledge of problem solving and teamwork. Kyle enjoys playing intermural soccer, snowboarding, and working in the shop.

1.2.3. Daniel Wharton

Daniel Wharton hails from the small, farming town of Fremont, MI. Daniel's summer experiences include working as a dining hall cook for Gerber Scout Reservation, interning for Prein&Newhof, and researching fenestration heat transfer under Professor Rich De Jong. His favorite classes are Fluid Mechanics and Heat Transfer, and he enjoys utilizing these classes in his fenestration research, which has continued into the school year.

2 Problem Definition

2.1. Project Need

Wood-working and metal-working tools are inherently dangerous. These tools include rotating cutting heads and blades that can severely injure or even kill a worker. There are various safety systems that attempt to address these issues, but despite heavy investment and numerous innovations, safety is still a concern in the shop. In 2015, OSHA reported over 400,000 emergency room visits directly connected to power tool injuries with an estimated 6,800 injuries caused by miter saws [1]. The design created by Chop Stop will focus on preventing miter saw injuries.

2.2. Reasons for Selection

The miter saw safety system was selected by Team 04 as their Senior Design project for several reasons. First, the project meets a specific and definable need in the market place. Specifically, the design problem provides valuable experience in modeling, manufacturing, customer relations, and ergonomic integration that will serve the team well in future careers and industry.

Secondly, the design was selected because it fits well with the engineering coursework previously taken, such as Statics and Dynamics, Circuits Analysis and Electronics, and Materials and Processes in Manufacturing. The project will also test the team's ability to research and learn in areas that coursework has not covered. For example, the team will need to learn how to use integrated electrical circuitry for the sensing and firing mechanism of the stopping system.

2.3. Miter Saw Introduction

A miter saw is a versatile cutting tool that allows a user to make a variety of cuts at different angles and in different orientations. Miter saws can be belt driven or include a gearing system to transfer power from a motor to a blade. Typical blade speeds range from 3500 rpm to 5000 rpm. The main goal of the Chop Stop will be to stop a rotating miter saw blade fast enough to prevent injury to a user who contacts the blade. A five millisecond stopping time has been selected as the stopping time goal for the Chop Stop Team. The research and calculations supporting the selection of this number have been included in Section 6.3.

2.4. Safety

Safety is a critical concern when addressing the nature of the project and maintaining a safe work environment for the team. With safety in mind, a test bed was constructed so that repeatable experiments could be performed in an enclosed environment. In addition to the physical test bed, some common-sense safety rules have been implemented. For example, the team has agreed to never touch any of the components that can rotate (the blade, shafts, pulleys, belts, etc.) while the motor is plugged in.

Due to large stopping forces and a relatively short stopping time, determining the magnitude and direction of the forces involved were a main focus of calculations and research. The operator of a miter saw will be holding the blade arm when the stop is fired, therefore it is imperative that these forces are fully controlled and dissipated to prevent user injury. To verify the accuracy of the calculations and ensure user safety, several tests will be performed in a test bed prior to implementing any system on the miter saw.

This project requires a large number of electrical components for firing the brake, and like all electrical projects, the risk of electrocution needs to be prevented via various safety precautions. Again, common sense safety must be implemented, such as never working on the circuit while it is still plugged in, testing the circuit to ensure it is discharged when the power is disconnected, and taking precautions to prevent shorts in the wiring. The biggest electrical safety hazard is the large firing capacitor which must carry enough charge to melt the metal resistor that holds the brake. It is especially dangerous because capacitors continue to carry their charge even when the circuit is unplugged. For this reason, the team has agreed to always treat the firing capacitor as if it were fully charged until proven otherwise with the use of a multi-meter. Every member of the team will learn how to safely test the charge of the capacitor using a multi-meter and will perform this test every time they handle the firing capacitor. These precautions will ensure that the team remains safe throughout the project.

Another concern in design implementation is the safety of anyone who encounters the project, regardless if a team member is present. This means that the team will never leave the project while a dangerous situation could occur, and the team will always check that the firing capacitor is discharged before walking away from the firing circuit. The team will unplug the motor before they leave the test bed. Finally, the team will post signs that warn about the safety hazards of the project but still acknowledge that the presence of signs will not exempt the team from the responsibility of keeping other people safe.

2.5. Requirements

2.5.1. Objectives

The objectives for this project are a significant part of defining the problem and evaluating the success of the project. As a team, some key points were discussed which include the safety of the device, the testing process, and the integrity of the design.

Preventative safety is a main objective for this project. In the evaluation of the design's success, the device should not cause more injury than can be remedied by the application of a topical bandage. However, as outlined in Section 2.4 the design objectives are not the only concerns that must be met. With unknowns in the design and the potential consequences of calculation errors, there is a risk of injury during the testing process. The team must implement proper testing procedures and guidelines to insure that the system will not fail in a manner that will cause damage to a person or property.

As summarized in Section 2.6.3, the integrity of the design must be upheld. This means that the design cannot limit the starting functionality of the miter saw and must not damage the miter saw past a simple blade and brake cartridge replacement. The stopping mechanism should not limit or interfere with any ergonomic or safety features of the existing saw. The brake should be easy to reset or replace. Finally, to maintain the safety of the user after blade engagement, the miter saw arm should return to its neutral position at a low speed.

2.5.2. Constraints

More specific requirements were developed as a way to quantitatively measure design success.

- Req 1. Device shall stop a blade rotating at 5000 rpm in 0.005 seconds or less (Section 4.2, 6.3 and 5.2.2)
- Req 2. Device shall not increase the miter saw footprint. For example, the footprint of the saw in Calvin Wood Shop is 24in x 24in x 32in and the design should not increase this (Sections 2.6.3, 2.6.7 and 5.2.2)
- Req 3. Device shall not increase the force required from the user to vertically depress the miter saw arm when making a cut (Sections 2.6.3 and 2.6.7)
- Req 4. Device shall stop the power to the motor simultaneously with brake cartridge firing (Section 5.2.4)
- Req 5. Device shall use voltage and resistance as the flesh sensing mechanism (Section 5.2.4)

Req 6. Device shall include a switch capable of shutting off the safety system (Sections 2.6.1 and 2.6.4)

2.6. Design Norms

2.6.1. Transparency

The potential serious injuries and liability involved in a safety system of this nature make it essential for the design to be transparent. Team 04 will be upfront about the actual capabilities of the product and will still stress proper use within the capabilities of the machine. Just because the miter saw will have a "fool proof" safety mechanism does not mean that improper usage could not cause harm to the user. To fulfill this norm, the design must incorporate as much research and testing as possible. The final report will acknowledge any shortcomings or design decisions that may adversely affect the end user and this information will be clearly communicated to the user.

2.6.2. Stewardship

To meet this norm, the Chop Stop will be carefully and responsibly designed using the God given resources of the earth, to create a tool that accomplishes its design goal, while considering sustainability and recyclability. From a distance, this norm may seem to conflict with the design norm of justice. The design norm of justice requires that certain legal necessities be met for the system to be operated in a typical workplace. Some of these requirements may necessitate the use of materials or redundancy that might reduce the recyclability or preclude the reuse of materials from the design. This conflict between norms may be solved by emphasizing stewardship in areas where legal requirements are not preventative. Specifically, the electronic and mechanical components of the braking cartridge system, have been identified as an area where reuse and recyclability can play a role in stewardship.

2.6.3. Integrity

The design will integrate an ergonomic interface with a reliable and robust safety mechanism seamlessly incorporating the safety system into the current miter saw platform. This design will allow the user to effortlessly operate the saw without loss of feature or control and without fear for his or her safety.

2.6.4. Justice

The chop stop will comply with applicable laws and codes regarding safety systems in the woodshop environment. Recognizing the hazards involved, clear documentation will be provided that educates the operator on proper usage and control of the machine. The cost of the technology will be minimized, and the design kept simple, to fulfill the function, while keeping availability as high as possible for the consumer.

2.6.5. Caring

The Chop Stop itself is being built to fulfill part of this caring norm. It is our hope that systems like these will be implemented on more woodworking and shop equipment so that more people can be saved injury, time, and money.

2.6.6. Trust

To meet the norm of trust, the Chop Stop must unfailingly stop every time it encounters a finger. To do this, the Chop Stop will incorporate liberal safety factors, and redundant system technology.

2.6.7. Delightful Harmony

As an overall design goal the Chop Stop mechanism will be designed to harmoniously integrate with the miter saw and shop environment. Ergonomic features and overall aesthetics will be considered.

2.7. Project Scope

Many directions could be taken in developing a safety solution for a miter saw. To define the scope of the project and to ensure its feasibility in the time constraint of two semesters, the project was limited to the mechanical braking mechanism, corresponding electrical firing and detection system, and arm control of the miter saw.

3 Project Management

3.1. Project Breakdown

To help focus on different facets of the Chop Stop design, the design has been separated into Mechanical and Electrical Components (Figure 1). Within these broad groups, several categories have been identified. These categories include the Firing System, Sensing Circuit, Time Sensor, Brake, Miter Saw, and Test Bed. By creating this organization, more focus is given to each aspect of the project, and the team can work together to create an optimal solution. Although there has been much team interplay on all aspects of the design in general, Kyle Mailhot has been designing and building the test bed, Maddie Collins is developing designs in SOLIDWORKS for both the braking system and test bed, and Daniel Dick and Daniel Wharton have been designing the circuitry for the sensing and firing mechanisms.

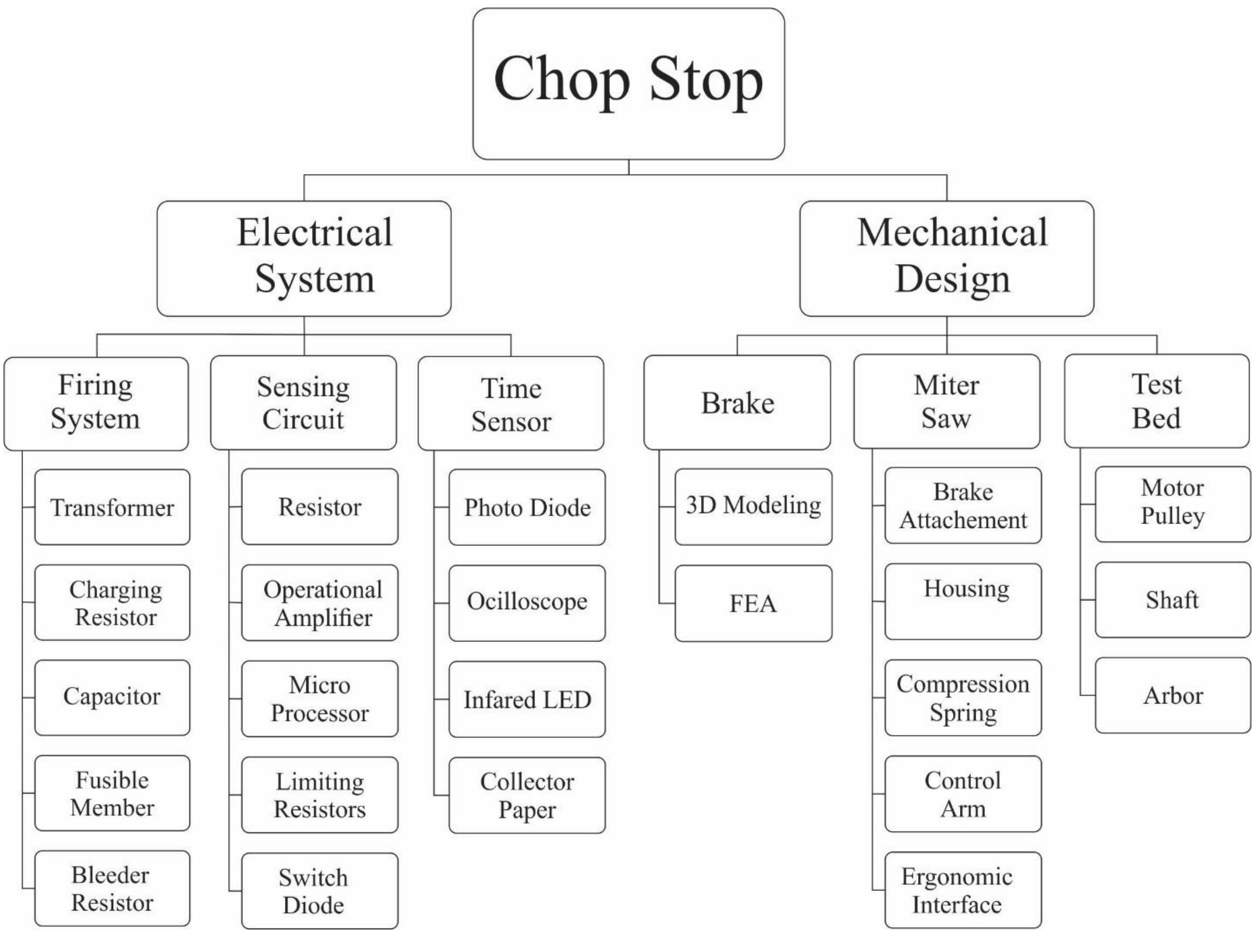


Figure 1. System breakdown

3.2. Mechanical Design Breakdown

3.2.1. Braking Mechanism

The braking mechanism is the primary focus of the Chop Stop. It is the mechanism that will contact the blade, bringing it to a complete stop. It must be designed to exert the maximum stopping force in the fastest and most efficient manner possible. The brake must also be rigid enough to withstand significant impact and jerk forces, and it must be reliable enough to generate consistent stopping times.

3.2.2. Test Bed

By designing and using a test bed, the braking system can be tested in a safe and controlled manner. This design also allows for minimal chance of damage to parts in the event of a catastrophic failure of the brake. The miter saw-motor orientation and design has been incorporated as closely as possible into the test bed to allow for a seamless transfer between the test bed and an actual miter saw.

3.2.3. Miter Saw

Due to the rapid engagement of the braking system on a blade rotating at 5000 rpm, there will be large jerking forces, which will impose undesired stresses on the system. To eliminate the chances of damage to the miter saw, all systems that will be effected by the jerk of the system must be made strong enough to handle the implied forces. At the same time, the brake must help to absorb and direct the forces in a way that will not harm or damage the miter saw

3.3. Electrical System Breakdown

3.3.1 Firing System

Brake release must occur as fast as possible to achieve a five millisecond stopping time for the blade. An electrical circuit with a thermoelectric resister has been chosen as the most suitable solution for quickly firing the braking system.

3.3.2 Sensing Circuit

The sensing circuit is the most fundamental part of the electrical system design. It is essential for detecting and distinguishing human flesh and wood. The response time of this circuit must be kept at a minimum and the circuit will need to filter and amplify a wide range of signals. In addition, the sensing circuit must be robust and accurate including multiple feedback loops and error prevention mechanisms. To increase the level of safety of the miter saw, the sensing circuit will shut down the motor so that the system does not continue to operate during a braking event.

3.3.4. Time Sensor

A time sensor will be built to test the fulfillment of Req. 1, the stopping time of the miter saw. The accuracy of this sensor is fundamental to the success of the project. The sensor will use a photo diode and oscilloscope to measure and record a stopping event. The data collected with the oscilloscope will be used to calculate stopping time and blade rotation.

3.4. Project Status

3.4.1. Total Project Breakdown

The table below lists and describes the tasks and steps necessary for the completion of the project. These tasks are defined in greater detail in later sections of the report.

Table 1. Overall Breakdown of tasks for Chop Stop

Tasks	Description
Define Project	Define problem and create objectives for the project
Conduct Research into Problem	Research what the source of the problem is
Research Solutions for the Problem	Find if there are any current solutions to the problem
Create Gantt Chart	Outline the time breakdown for the parts of the project
Draw Conceptual Models	Create SOLIDWORKS drawings of test bed
Budget of the Project	Determine needed parts and allocate their expenses
Identify Alternative Solutions	Create more than one solution to solve the problem
Conduct PPFS	Determine the feasibility of the proposed project
Build Test Bed	Construction of test bed will allow testing to be conducted
Conduct Testing	Test the braking mechanism to determine effectiveness
Initial Design of Braking system	Implement braking system into a miter saw
Test Implemented Braking System	Conduct additional system using miter saw setup
Build Final Braking System	Adjust design of miter saw base on initial test result
Write Final Report	Report final findings and solution for the problem

3.4.2. ENGR 339 Milestones

There are several key deliverables outlined for the ENGR 339 class (Table 2). These assignments are part of the Chop Stop design process and are key for the fulfillment of the class requirements.

Table 2. Important assignments for ENGR 339

Task	Due Date
Project Proposal	9/14/2016
Project Objectives and Requirements	9/23/2016
PPFS Outline	10/5/2016
Scheduled WBS	10/12/2016
Project Brief for Industrial Consultant	10/17/2016
Presentation 1	10/24/2016
Project Website Posted	10/26/2016
Updated Project Poster	11/4/2016
PPFS First Draft	11/14/2016
Presentation 2	12/7/2016
PPFS Final Draft	12/12/2016

3.4.3. Task Management

As outlined in Section 3.1, the team has broken the project down into a series of achievable tasks. The team has assigned an estimated time-to-completion for each of these tasks. So far the team is on track to finish the tasks in the projected time frame (Table 3).

Table 3. Time summary

	Estimated (hrs.)	Actual (hrs.)
Semester 1	230	320
Semester 2	500	TBD
Total	730	TBD

3.4.4. Team Meetings

The team will meet at least twice a week for a total of no less than two hours outside of class time. Team Meetings will be documented by the team note taker, Daniel Dick. Typical meetings will cover broader issues like system integration and will include a discussion of the problem, analysis, and conclusion. Meetings may occur throughout the week between two or more team members as problems are encountered in each of the design areas. The team will also meet on a weekly basis with the team advisor, Professor VanAntwerp. Meetings may also be scheduled with other advisors or consultants as necessary.

3.4.5. Data Storage and Documentation

Preserving data and facilitating collaboration on team documents is essential. Also, the preservation of team data for the benefit of future senior design teams is desired. Therefore, all team documents and CAD files will be stored in the Team 04 folder on the Calvin server. In addition to this, periodic backups of the team documents will be saved on a Microsoft One Drive account.

4 Research

4.1. Braking Methods Research

To understand the scope and variations possible with a braking system, different types of braking systems were researched on existing safety systems for power tools and miter saws. In particular, brake shoe systems and brake cartridge systems were examined. A cartridge based system utilizes a mechanical element to block rotation by impinging itself mechanically in the path of rotation. A brake shoe system utilizes friction as the primary stopping force. There are advantages to both of these systems. In the case of the brake shoe system, the mechanism is typically less complex and does not result in injury to the rotating mechanism. Brake shoe systems can be used multiple times before the system or components need to be replaced. Conversely, cartridge braking systems are more complicated than classic brake shoe systems, and the use of a cartridge often results in damage to parts of the rotating mechanism. However, stopping time for a typical brake cartridge is considerably less than it is for a comparable brake shoe system [2].

4.2. Braking Time Research

Since the braking system is dependent on user contact, it is difficult to establish any exact measurement of minimum stopping time. The only system on the market that is similar to the Chop Stop is the Saw Stop, which is a safety mechanism that uses a brake cartridge to stop a table saw blade (Figure 2). Since there is similarity between the Chop Stop and the Saw Stop, the stopping time achieved in the Saw Stop mechanism was examined as a starting point for measurements regarding minimal acceptable travel time and stopping distance for the rotating blade. According to Saw Stop, their braking cartridge is capable of stopping a blade rotating at 4500-rpm in 3-5 milliseconds [3]. The combined speed of the user and counteractive response time of the mechanism determine the depth of injury. For example, a user who encounters a blade at 1-ft/sec would achieve an injury 1/16-in deep if the machine response time was five milliseconds (see Calculations Section 6.3).

Figure 2. Saw Stop in action [4].

4.3. System Isolation Research

It is essential to the function of the Chop Stop that the blade or component system be isolated from the surrounding saw body to allow the input signal to be interpreted by a logic controller. Several ways that this can be accomplished include blade isolation, arbor and shaft isolation, or component isolation. Research indicates different advantages for each of these alternative options. In the case of blade isolation, a nonconductive bushing would be fit on the arbor shaft. In conjunction with nonconductive washers, this is then placed between the arbor plates to isolate the blade from the rest of the mechanism. Incorporating a bushing and washers on the shaft would help with shock absorption in the suspension system. However, the main disadvantage of simple blade isolation is the potential deflection of the blade due to material loading, which increases the complexity of the corresponding detection system. The chief alternative to this method of isolation is bearing or component isolation (Figure 3). This method has several advantages over blade isolation in that the bearing system undergoes minimal deflection under load to allow for a more accurate readout with a less complicated system. In addition, bearing-shaft capacitors could be utilized instead of a blade capacitor, which could interfere with blade change out [5].

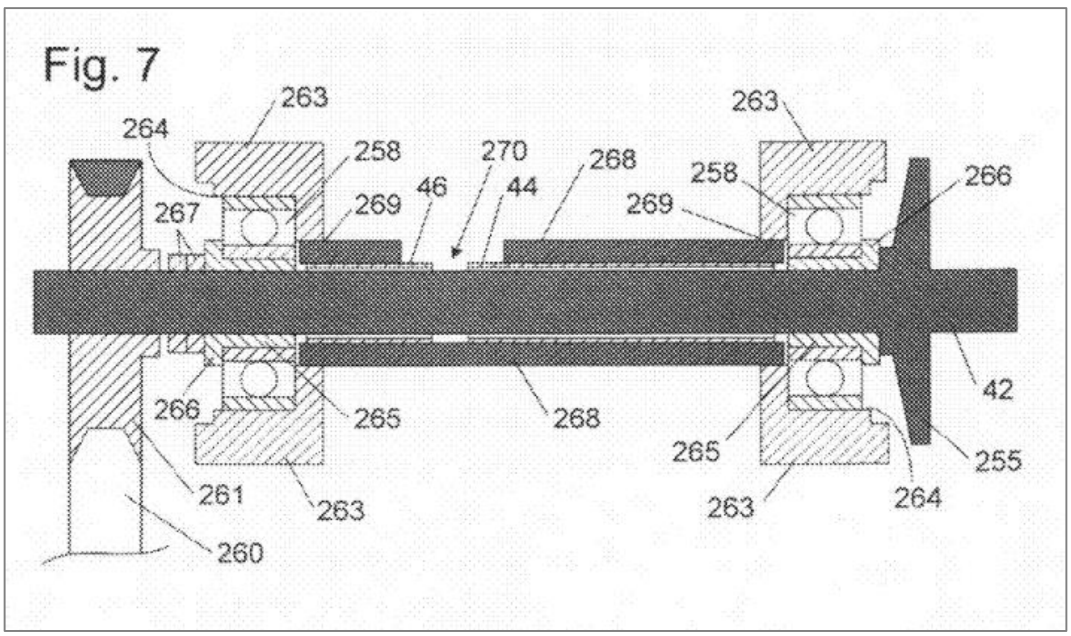


Figure 3. Isolation System in Saw Stop Patent [5].

4.4. Electrical Systems Research

An electrical control system will be necessary to allow the Chop Stop to constantly monitor the status of the blade and quickly fire the brake cartridge. A similar system is already in place on the Saw Stop that utilizes multiple feedback loops to establish a safe system (Figure 4). Alternatives to this design focus on simplification and redundancy. Of all of the mechanisms that have been identified, the sensing circuit will be the hardest for Team 04 to implement. Discussions with Chuk Holwerda and Professor Michmerhuizen have helped the team simplify this circuit as much as possible. A possible designs uses an operation amplifier and resistance feedback loop to clarfiy the input signal and differentiate between small voltage drops. The advantage of a system like this is its simplicity and feasability. However, without more complex circuitry it will be difficult to distinguish between a finger and wet wood. The team will continue to research other alternatives for this circuit and make a decision on scope and implementation in ENGR 340.

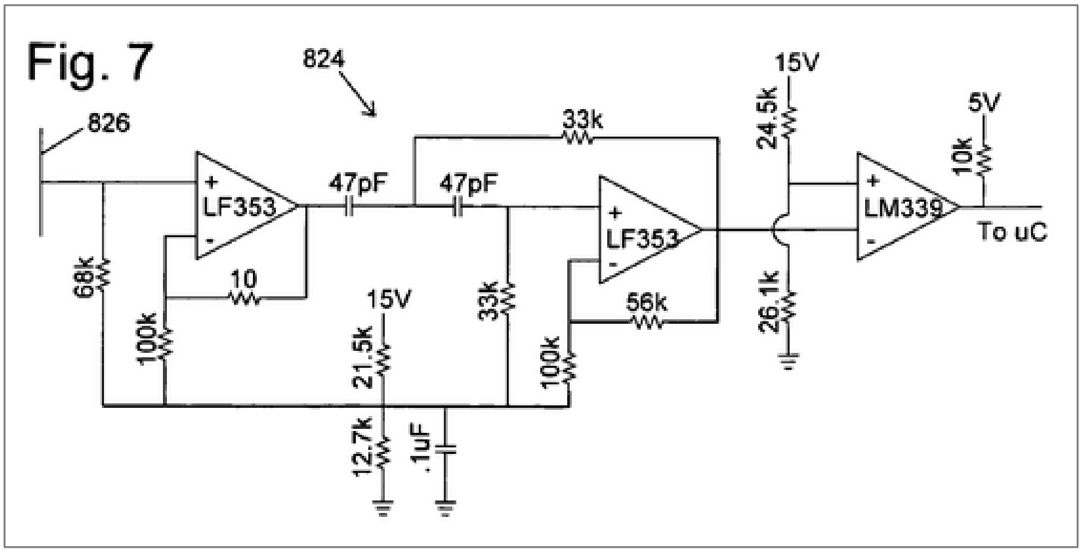


Figure 4. Electrical Sensing System from Saw Stop [6].

4.5. Thermoelectric Research

In the case of the Chop Stop system, implementing a fuse design may be used to quickly release the braking mechanism. A fuse is a sacrificial element in a system that can be used to protect the system from electrical fires caused by current overdraw. The response time of a fuse is based on the type of fuse and the current flowing through the system (Figure 5). The response times also are dependent on the type of the material and the fuse diameter. Some acceptable materials include nichrome, stainless steel, tin, lead, and silver.

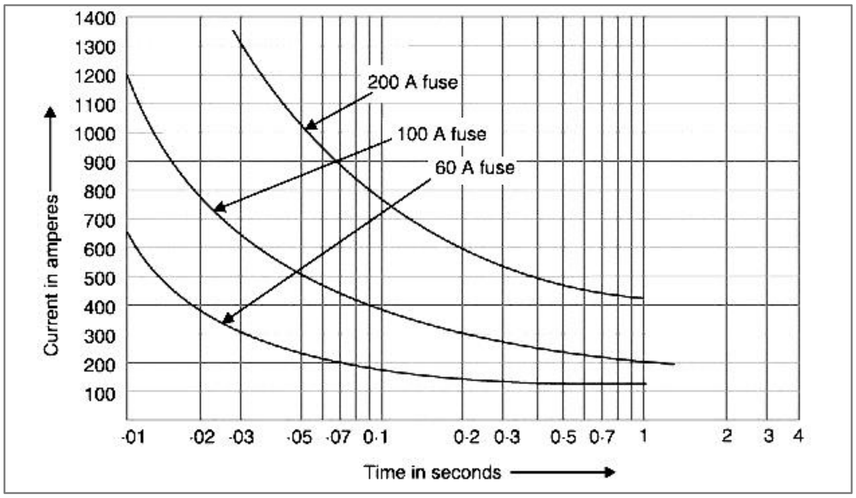


Figure 5. Fuse Response Time [7].

5 Project Design

5.1. Design Alternatives

For each of the components identified in Section 3.2 and 3.3, several specific design alternatives were considered and compared to make justified decisions for the feasibility of the design. Some of the design alternatives that were considered are outlined below.

5.1.1. Test Bed Frame

It was recognized that many potential materials and designs could be applied to develop a test bed for performing safe and consistent testing of the braking system. However, given time constraints and budgeting, the team determined to implement a box design that would perform well as a test bed while minimizing cost and complexity. The design was built around recycled parts and readily available materials from the engineering storage rooms and machine shop. By using these materials, the time and cost saved outweighs the potential benefits that might be gained from using an alternate design that may have been more functional or versatile.

The test bed was sketched and modeled with SOLIDWORKS. Basic dimensions were determined by main component size such as the motor, blade, and pulley system. To first assess the dimensions and layout of the model, a test bed prototype was constructed of one inch by one inch cross sections of wood (Figure 6). It was proposed that the wood frame could be strong enough to use for the final frame of the test bed. The ease of construction and modification were the biggest advantages for the wood frame. However, wood is also a dynamic material. Changes in temperature and constant stress can result in warp and bending of the wood, potentially affecting the consistency and reproducibility of the testing system. Since wood does not hold up well to large impact stresses or torsional buckling, the safety of the team would be jeopardized by any unforeseen failures within the system.

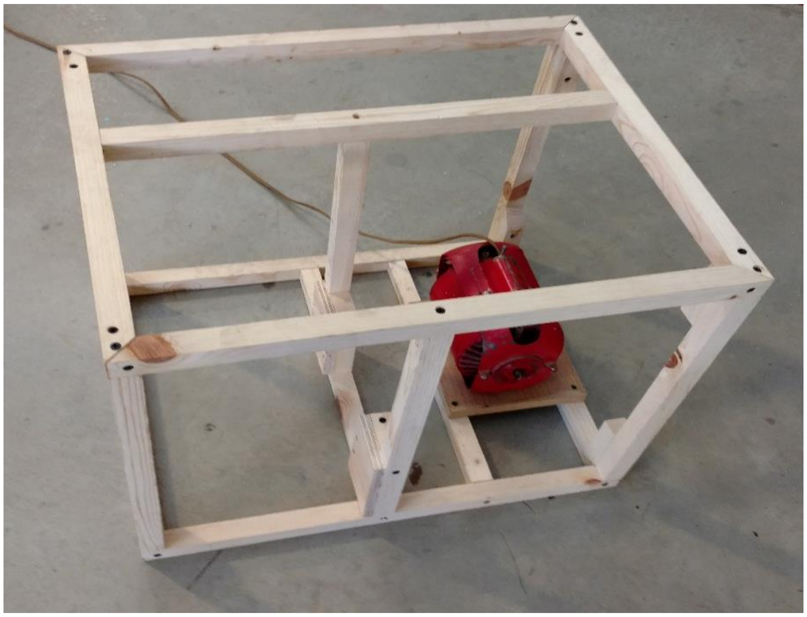


Figure 6. Test Bed Model Wood Prototype

As an alternative to this initial frame design, a steel tube frame was proposed. This design would offer benefits including durability, data reproducibility, and safety. Some negatives to this design choice include the time to create the frame as well as difficulty making any modifications to the design once it is fabricated (Table 4). The steel frame was selected as the final design.

Table 4. Decision Matrix for Test Bed Material

		Reproducible Data	Safety of Team	Availability of Materials	Ease of Construction	Ease of Modification	
	Weightings	9	10	8	5	7	Totals:
Alternatives	Wood	3	5	8	5	7	215
	Metal Tubing	9	9	7	2	4	265

5.1.2. Test Bed Motor

A 1720 rpm motor was originally considered for use as the driving system in the test bed design. It was determined that using a two-shaft pulley system could increase the shaft speed to 5000 rpm which would represent the blade speed of a traditional miter saw varying between 3600 and 5000 rpm. However, after careful search, a 3500 rpm motor was discovered and repurposed. This faster motor allowed the test bed design to be simplified and cut down on the implementation cost allowing the use of a one-shaft belt and pulley system.

5.1.3. Braking System Concept

Two main methods of braking were considered for the miter saw blade. The first alternative included a flywheel that would be attached to an extension of the blade shaft. A brake would then be installed that, when tripped, would contact the flywheel rather than the blade, preventing the need to purchase a replacement blade. Although the saw blade would not be harmed with this system, the flywheel would likely need replacement. Unlike the flywheel, saw blades for a miter saw are readily available in most hardware stores. Depending on its design, the flywheel could be a specialty part resulting in availability and cost issues.

The second braking system considered would work the same way as the flywheel brake, but rather than contacting the flywheel, it would contact the cutting blade. This option would require enlargement of the housing that encloses the top of the cutting blade to allow room for the braking system. As in the flywheel braking system, the blade and brake system would need to be easily accessible for replacement purposes. The drawback of this system is that the blade will be destroyed along with the braking system, rendering the system inoperable until a new brake and blade are installed.

5.1.4. Braking System Attachment Method

Two concepts were considered for the method of attaching the brake system to the miter saw. The first of these options is the replacement of the entirety of the blade housing with a new housing system that incorporates the design of the brake. This choice would provide a visually pleasing finish to the miter saw. However, it would cost more to replace the entirety of the blade cover rather than a focused area. An alternative is to cut away at the existing housing and attach a new section of blade housing that includes the brake system. This system would be cheaper to implement than a complete housing replacement, allowing for cheaper production costs. However, cutting away at the existing framework, would decrease the aesthetics of the miter saw. In choosing which alternative to use, the design norms of Justice and Delightful Harmony were carefully considered (Sections 2.6.4 and 2.6.7).

In addition to the housing design, the location of the braking system is also of importance. The design should position the brake cartridge so that any part of the force not absorbed by the brake will cause the miter saw arm to move upwards. The exact placement of the brake is an alternative that will be considered in ENGR 340. Alternatives will be evaluated with empirical data gathered from tests performed on the test bed.

5.1.5. Sensors

There are primarily two types of sensors that will be needed for evaluation of the Chop Stop. The first type of sensor will record the stop time of the blade.

There are several options available for the blade stopping sensor including photodiodes, photo receptors, tachometers, optical encoders and Hall-effect sensors. However, because tachometers, Hall-effect sensors, and optical encoders are expensive compared to photoreceptors, these options were eliminated. The team focused on photo receptors. Two types of photo receptors were examined: refraction diodes and light sensing diodes. A light sensing diode works similar to an optical encoder using a slotted disk attached to the blade-shaft. An LED light located on one side of the disk shines through the slots to a diode on the other side. When the disk is rotating, the diode picks up the flashes of light created by the moving slots relaying the flash frequency an oscilloscope. A waveform generated by the oscilloscope can be used to determine the stopping time and distance. Light sensing diodes have fast response times, many are in the nanosecond range, making a five-millisecond stopping time easy to detect. This design is a feasible option due to available resources and cost, but it would not account for any slippage of the blade that could occur once the braking mechanism is deployed. Although the disk could be located on the same shaft as the blade, any slip of the blade in the arbor would result in an offset stopping time.

As an alternative to this option, a refraction diode was considered. A refraction diode uses a sensor that can tell the difference between black and white markers along a rotating disk (Figure 7). Similar to the light sensing diode, a refraction diode is capable of a nanosecond response time. Because the refraction paper can be mounted directly to the blade, the sensor will be able to measure the exact stopping time of the blade, making this a better option than a light sensing diode.

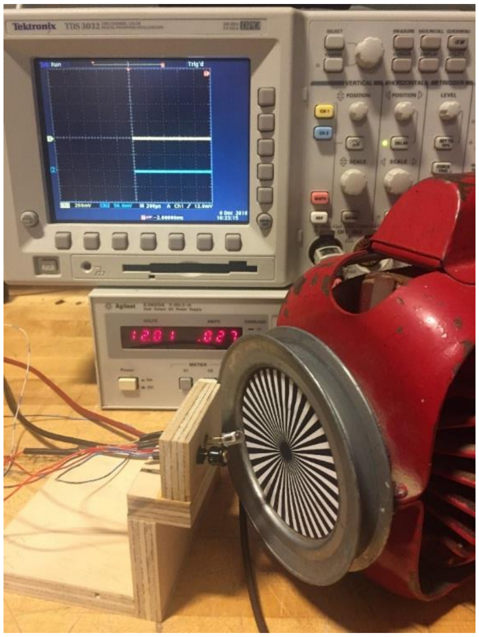


Figure 7. A proof of concept for the refraction diode as it detects the speed of the motor by reflecting off of the white strips and passing this information to the oscilloscope in square waveform.

The second type of sensor needed in the design of the Chop Stop system is the flesh detecting mechanism. This sensor monitors resistance and voltage so it can alert the firing mechanism of human contact with the blade. Once again there were a variety of options for the flesh detecting mechanism. Some of these systems use a change in capacitance, voltage, or resistance, while others use light detection and proximity sensing. The exact setup of this mechanism will be fully explored in the second semester of this project.

5.2. Design Selection and Description

5.2.1. Test Bed Design

The final test bed design was constructed out of 1-inch steel tubing. This was chosen for its strength and durability, and will contribute to team safety throughout the testing process. The 3600 rpm motor was also chosen because of its higher speeds. With this motor, the team used equation 1 to select two pulleys with pitch diameters of 1.75-inches and 2.5-inches to step the blade's shaft speed up to 5000 rpm.

$$d_1\omega_1 = d_2\omega_2 \tag{1}$$

In equation 1, d_1 is the diameter of the driver pulley, ω_1 is the speed of the motor, d_2 is the diameter of the driven pulley, and ω_2 is the shaft speed. Given the required shaft speed, the motor speed, and available pulley sizes, it was easy to select a system to meet the speed requirements. A v-belt with a 30-inch outer circle measurement was chosen to fit the pulley selection.

The shaft of the blade is 0.625-inches and includes two bearings to hold the shaft in place. Finally, the motor sits on a plate that has four slots in place to fasten the motor down and tighten the v-belt once installed. Overall dimensions and test bed layout images are shown in Figure 8 and Figure 9, and detailed drawings of the frame, shaft and arbor plates, and overall assembly are shown in the appendix.

ITEM NO.	PART DESCRIPTION	QTY.
1	FRAME	1
2	BEARINGS	2
3	BELT AND PULLEY SYSTEM	1
4	BLADE	1
5	SHAFT	1
6	MOTOR	1

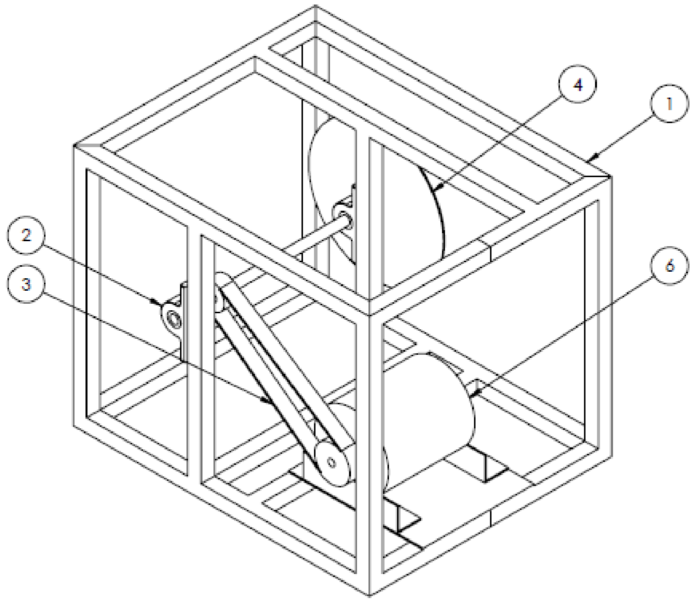


Figure 8. The identification of different parts and their location within the test bed design.

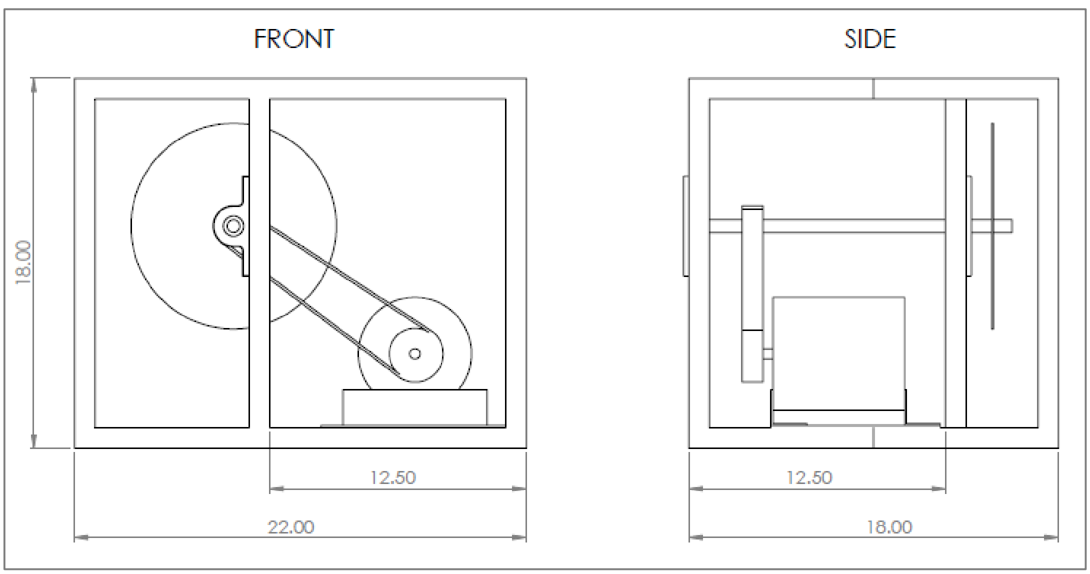


Figure 9. The SOLIDWORKS model of the test bed design including some overall dimensioning.

This finished design of the test bed will allow for repeatable tests of the braking system, measurable results and overall safety during testing (Figure 10). In addition to the frame that has been built, a removable polycarbonate shield will be fabricated to cover the test bed. This cover will provide additional safety to the team while optimizing visibility.

Figure 10. The completed test bed

5.2.2. Braking System Design

The team has chosen a direct braking system. The team found that the blade teeth digging into the aluminum brake plays a crucial role in stopping the blade in the specified time. Also, as outlined in 5.1.3 the flywheel would be damaged after an encounter with the braking cartridge requiring replacement. If the flywheel is damaged during braking it is more logical to replace the blade since they would be less expensive and more readily available. Another consideration was the additional force that would be required to stop the spinning blade if a flywheel was also spinning. Having a flywheel incorporated into the system would double the required stopping force and subsequent reaction forces.

The brake cartridge system (Figure 11) is composed of a circuit board that incorporates the firing system and the sensing circuit. A thermoelectric wire will hold the brake in place, via a pin against a spring force, that will bias the brake toward the saw blade. When the circuit senses human contact it will trigger the release of a charge into the thermoelectric wire melting it and allowing the spring to impinge the brake onto the edge of the blade.

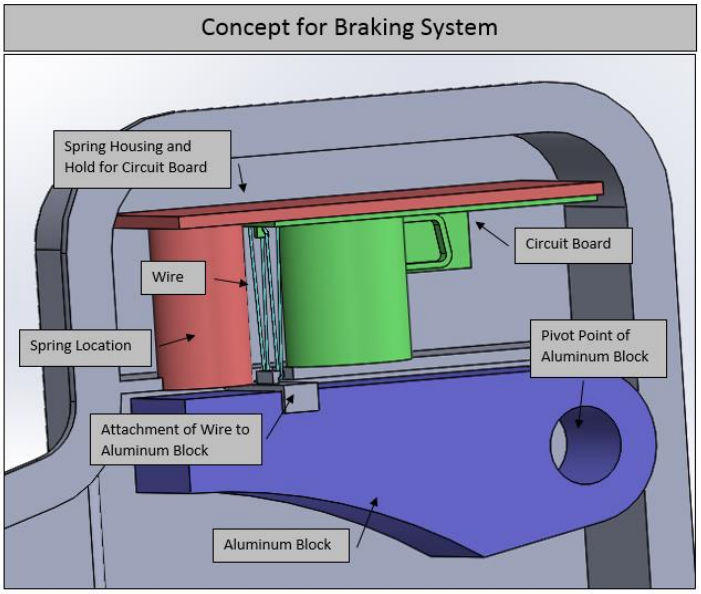


Figure 11. A conceptual idea for the braking system. Labels show key aspects to the design.

In the prototyping phase of this design, several alternatives for the design of the aluminum brake block will be considered and tested though FEA analysis on SOLIDWORKS and on the test bed. Each design will incorporate a different configuration and number of holes to balance the weight of the block and decrease the stopping time (Figure 12). The final configuration of the black will be based on brake deployment results from the test bed ensuring that design Req. 1 and Req. 2 are met. Although aluminum will be used as the initial testing material other materials may be considered to achieve faster stopping times. Other alternatives will be examined in ENGR 340.

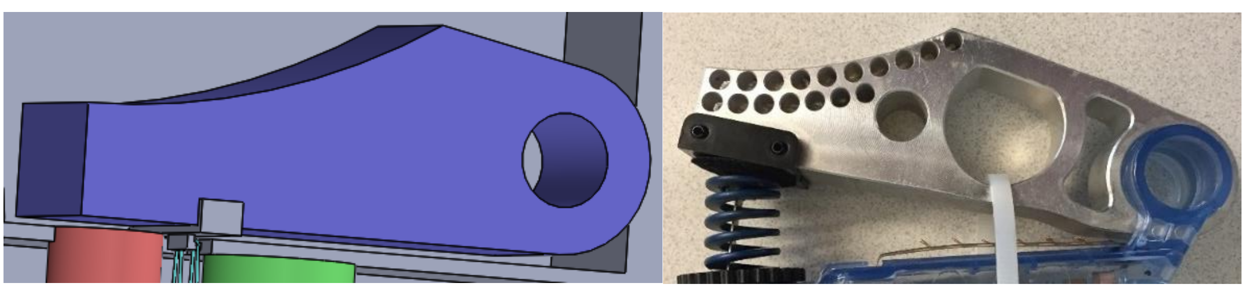


Figure 12. To compare the current representation of the aluminum block and the Saw Stop block.

5.2.3. Stopping Time Measurement Method

One of the main ways to evaluate the success of the project is to measure the time it takes the blade to come to a complete stop in the test bed. The blade will be outfitted with a circular print that alternates between black and white, incremented 360 times. A photo diode sensor and infrared light source will be used in conjunction with an oscilloscope to collect rotational data from the blade in real time. The diode will detect the change between the black color and the white color showing how many degrees pass by the sensor per unit time (Figure 13).

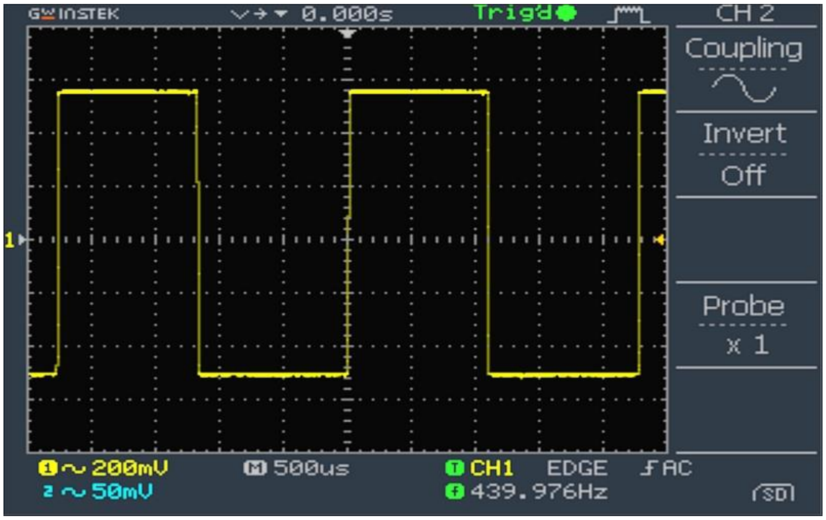


Figure 13. Example square wave Oscilloscope output from refractive paper [8].

Using the trigger feature on an oscilloscope, the stopping time of the blade can be measured. Also, because the refractive paper is divided into 1 degree increments, the number of pulses that occur after the trigger event can be counted to determine the number of degrees that the blade rotates after the brake cartridge is fired.

5.2.4. Detection and Firing Circuits

The detection circuit will use voltage and resistance to differentiate between human flesh and wood as per Req. 5. Although the team has researched the sensing mechanism the exact configuration of this system is yet to be determined (Section 4.4)

The firing circuit shown in Figure 14 will use a transformer to increase the wall voltage to 200V. Resistor R2 will be used to limit the current flow to the capacitor. Switch (S1) is a double pole transistor that will close the capacitor circuit when a detection signal is given. Resistor (R1) is the fusible member that will be melted by the capacitor. Before detection R1 will hold the brake in place against a mechanical spring force. Resistor (R3) is a bleeder resistor that will ensure that the capacitor is fully discharged after firing occurs. Calculations justifying this design are shown in section 6.1.

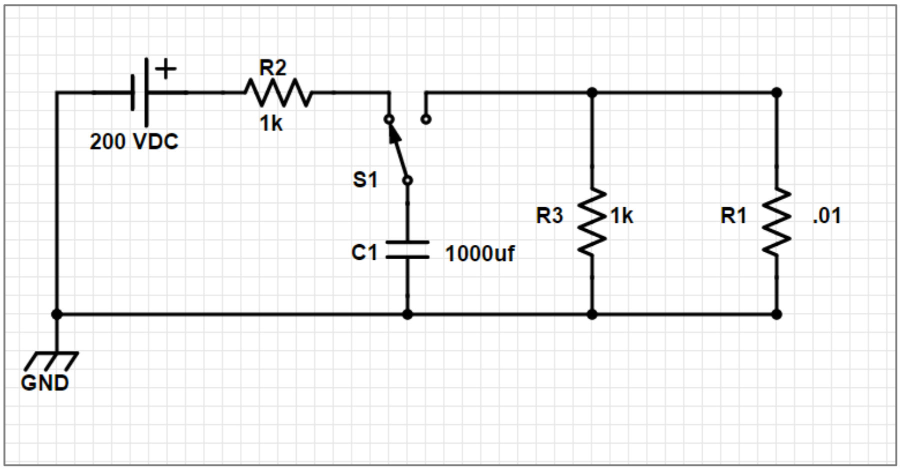


Figure 14. Firing Circuit Design

5.3. Design Budget Proposal

In Table 5, the costs for building the test bed and a prototype were estimated. The budget includes the contingency cost for the purchase of two miter saws.

Table 5. Design costs

Description	Qty	Unit Price	Cost	Status
Zinc V-Belt Pulley for A-Section Belts, 2" OD, 5/8" Bore Size	1	$ 5.11	$ 5.11	purchased
Zinc V-Belt Pulley for A-Section Belts, 2.75"OD, 1/2" Bore Size	1	$ 7.89	$ 7.89	purchased
A-Section V-Belt, Trade Size A28, 30" Outer Circle	1	$ 8.16	$ 8.16	purchased
(2 Pieces) 5/8" Pillow Block Bearing, UCP202-10 Solid Base P202	1	$ 13.28	$ 13.28	purchased
Miter Saw	2	$ 199.99	$ 399.98	TBD
3-D printed saw housing (1kg)	1	$ 29.99	$ 29.99	TBD
resistive wires	5	$ 5.00	$ 17.00	TBD
circuit components (estimate)	1	$ 25.00	$ 18.00	TBD
Total			$ 499.41	

6 Calculations

6.1. Firing System

This section will show the calculations used to make component selections for the firing system. As discussed before, the purpose of the firing system is to melt a resistive wire which will release a spring mechanism that will push an aluminum block into a rotating blade. The first design of the circuit is shown in Figure 15. In this initial circuit, a transformer is used to convert 120 VAC voltage to 200 VDC. This is used to charge a capacitor (C1) which will store the energy necessary to melt the wire.

The first resistor (R1) represents the wire that must be melted to release the spring. The second resistor (R2) is used to regulate the current that flows to the capacitor when it is charging, and to prevent back flow to the power source. The bleeder resistor (R3) ensures that any excess charge stored on the capacitor has some place to dissipate once R1 is severed. Although R3 is in parallel with the melting wire, the resistance of the bleeder is so much larger than the melting wire that a negligibly small amount of current will flow through the bleeder while the melting wire is still intact. R3 will only be relevant once the melting wire is severed.

This first circuit has a problem involving the switch. After the capacitor is charged and the switch is closed, the capacitor is still connected to the power supply. Thus it is necessary to isolate the capacitor so that is only in line with R1 and R3 to prevent the power supply from interfering with the firing circuit. This problem is solved by implementing the circuit shown in Figure 16. This design uses a 2-way switch which isolates the power supply so it doesn't interfere with the firing circuit after the capacitor is charged.

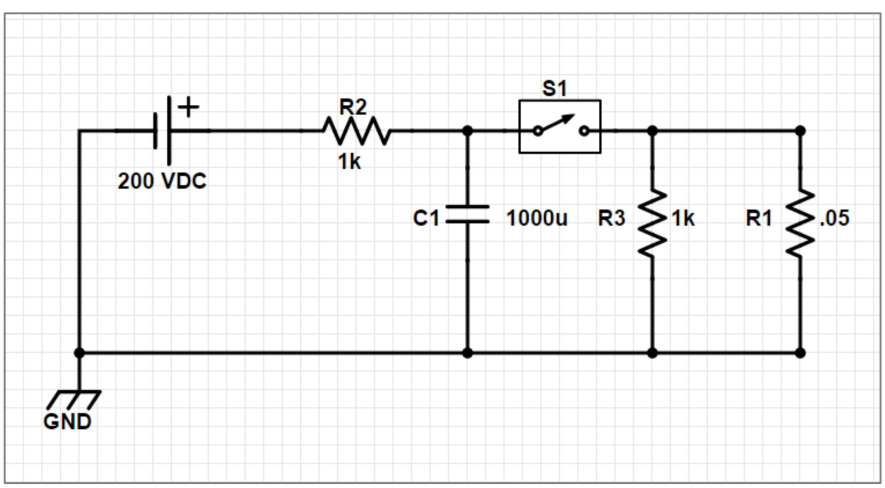


Figure 15. Initial firing circuit

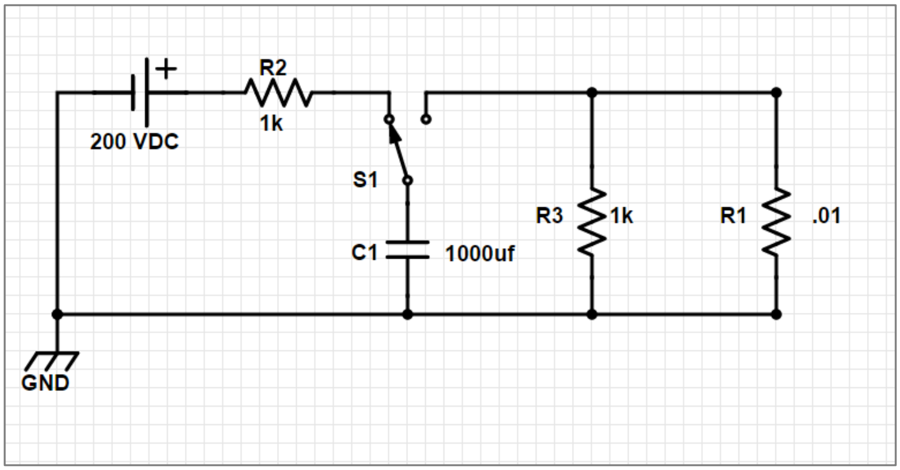


Figure 16. Firing circuit design shown again for comparison

6.2. Melting Calculations

Determining how much energy is required to melt the resistive wire will dictate the voltage of the power supply and the size of the capacitor. Enough energy must be supplied to move the wire from room temperature (T_0) to the melting temperature of the material (T_m) in less than 5 μs. To start this analysis, the specific heat of the material (C_p) combined with the mass (m) can determine the energy required using Equation 2 where (Q) denotes energy required to raise the temperature.

$$Q = mC_p(T_m - T_0), \tag{2}$$

The mass of the wire can be calculated from the geometry of the wire in combination with its density (ρ) where (D) is the wire diameter and (l) is the length of the wire.

$$m = \frac{1}{4}\pi D^2 l\rho, \tag{3}$$

Since a phase change is also involved in melting the wire, the heat of fusion must be accounted for. Combining this with Equation 2 results in Equation 4 where (H_f) is the latent heat of fusion of the melting material.

$$Q = mC_p(T_m - T_0) + H_f m, \tag{4}$$

Equation 4 includes all the energy required to melt the wire, assuming that there are no losses due to resistance in the connective wires, or heat losses to the surroundings. Since the melting must happen fast, it is reasonable to assume that no relevant heat losses occur while the wire is heating. However, the resistance in the connecting wires could be significant. The effect of the resistance on the calculations will be determined next semester using experimental techniques.

The energy (Q) found with Equation 3 can be used to specify the voltage and size of the capacitor. The energy stored in a capacitor can be determined using the following equation where (C) is the capacitance of the capacitor and (V) is the voltage across it.

$$Q = \frac{1}{2}CV^2, \tag{5}$$

It is important to understand that there are tradeoffs for increasing voltage and capacitance. Capacitors have ceilings for how much voltage they can handle. Also, increasing the size of the capacitor slows down the release time. Equation 4 gives the time constant for RC circuits where (τ) is the time constant.

$$\tau = R_1 C, \tag{6}$$

Therefore, increasing the resistance of the melt wire and increasing the capacitance of the capacitor will make the system's reaction time slower. 99% of the capacitors charge will be dissipated after 3 time constants have elapsed. Equation 7 can be used to approximate the time it takes to melt the wire where t_{melt} is the time it takes to melt the wire.

$$t_{melt} = 3\tau \tag{7}$$

The most important trade off, however, is the diameter of the melt wire. Increasing the diameter increases the mass, which increases the energy that must be stored on the capacitor. But increasing the diameter also increases the amount of force the wire can hold, which is an equally critical function. The wire must be optimized so that it melts when the circuit fires and also holds the force of the spring before the system fires. Calculating force (F) based on diameter is shown in Equation 8 where (σ) is the yield strength of the material.

$$F = \sigma \frac{1}{4}\pi D^2, \tag{8}$$

The higher the spring force, the faster the brake arm will contact the blade. Equation 9 shows this basic relation.

$$F = m_{brake} a_{brake} \tag{9}$$

Where m_{brake} and a_{brake} are the mass and acceleration, respectively, of the braking arm which is released into the blade. Equation 10 can be used to determine the time it takes from the brake arm release to contact, start with the blade

$$\Delta x = v_o t_{brake} + \frac{1}{2} a_{brake} t_{brake}^2 \tag{10}$$

where (v_o) is the initial velocity of the brake, (t_{brake}) is the time to move the braking arm from its starting position to the blade, and (Δx) is the distance between the brake arm and the blade. By realizing that initial velocity is zero, and solving for time,

$$t_{brake} = \sqrt{\frac{2\Delta x}{a_{brake}}} \tag{11}$$

which gives the component of stopping time that the brake motion will require. Again, this braking time can be sped up by increasing the spring force, which all ties back to the diameter of the melting wire. However, he diameter of the melting wire is not the only thing that can affect the release time, the mass of the brake arm is also critical. The smaller the mass of the brake arm, the faster the braking time. Optimizing the brake arm to use as little mass as possible will be relevant to meeting the specifications on stopping time.

6.3. Depth of Cut and Stopping Time

Fundamental to the function of the Chop Stop is the achievement of a blade stopping time that will prevent serious injury. When choosing the stopping time requirement, Req. 1, it was recognized that a system that uses blade contact to initiate brake response will still result in some injury. Even with fast stopping times a high hand velocity could still result in serious injury (Figure 17)

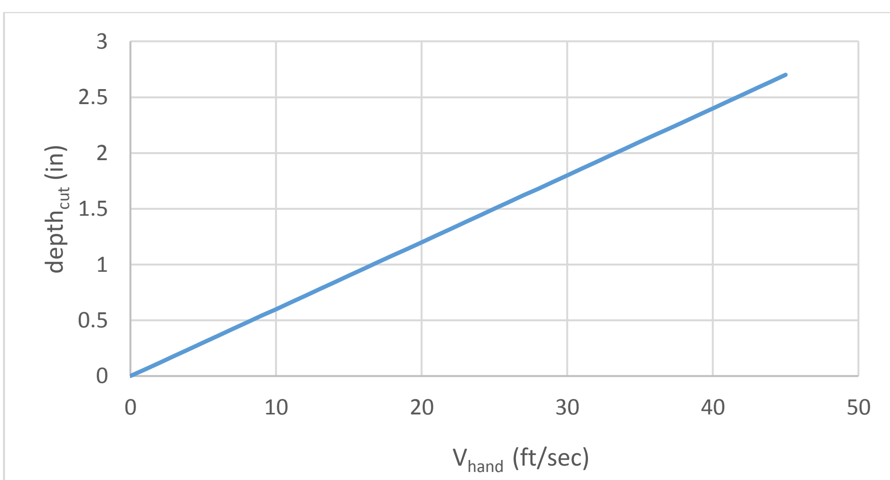


Figure 17. Depth of cut given a five-millisecond stopping time.

The goal is to minimize injury as much as possible. By defining a stopping time, Equation 10 can be used to determine the depth of cut ($depth_{cut}$), where (V_{hand}) is the velocity of the user in feet per second and (T_{stop}) is the stopping time in seconds.

$$depth_{cut} = V_{hand}T_{stop} \tag{10}$$

Saw Stop has done extensive research on the speed required for preventing injuries. Although there are no hard and fast numbers for this, the stopping time of five milliseconds achieved by Saw Stop for their braking system is a good starting point for the stopping time requirement for the Chop Stop [1]. Although faster stopping times would reduce the depth of cut, a miter saw does not require a feed velocity, making it less likely that the user will contact the blade with a significant velocity. The team is confident that a stopping time of five milliseconds is feasible and will produce a significant decrease in serious miter saw injuries.

6.4. Base Case Solution

Making some initial assumptions and applying the requirements from Section 2.4.2 many cases can be developed toward the optimization of the testing system. Directed by the equations the team is currently in the process of choosing some optimal numbers for braking system implementation and testing. Further work and optimization will be completed in ENGR 340.

7. Business Plan

7.1. Business Overview

Although there are currently no automatic stop or safety mechanisms integrated into the design of a miter saw, the braking cartridge system has been broadly patented by the inventors of Saw Stop. Even though the Chop Stop is a unique product in various ways, it is unclear whether marketing the Chop Stop design would breach the patent rights of the Saw Stop. Despite this potential patent problem, a market analysis and business plan shown below has been developed assuming that the marketing of the Chop Stop invention would not entail any litigation from the inventors of Saw Stop.

7.2. Vision and Mission Statement

7.2.1. Company Vision

In tandem with the feasibility research and development for the Chop Stop safety mechanism, Team 04 developed a business plan simulating the startup of a new company called Chop Stop. Chop Stop's vision is to produce a highly reliable blade stopping system that will help to prevent serious injuries caused by miter saws.

7.2.2. Company Values

Chop Stop INC has identified three major principles which will shape company policies and standards. These principles are trust, caring, and integrity. The company will build trust by providing a consistent, reliable product. Caring and integrity will be shown by providing customers with clear and consistent documentation on the effectiveness of the stopping system, and any other relevant safety considerations.

7.3. Industry Background

According to the Bureau of Labor Statistics, woodworking is a multibillion-dollar industry that employs over 230,000 people each year [7]. Since woodworking equipment is inherently dangerous, suppliers have developed and implemented safety systems for their equipment. In spite of heavy investment, there are few holistic systems that are capable of consistently preventing serious injuries.

7.4. SWOT Analysis

A SWOT analysis is a tool based on the company's vision and values that allows the company to quantify its business goals in a light of its Strengths, Weakness, Opportunities, and threats.

7.4.1. Strengths

The primary strength of Chop Stop INC is the necessity of safety for carpenters and hobbyists alike. The preservation of appendages, the pain caused by injury, and the damage to bodily aesthetics are huge personal concerns. For companies, workplace injuries can be costly. From worker's compensation and litigation to negative advertisement and down-time, the cost of workplace injuries is extensive. In fact, OSHA reports that an extreme injury like an amputation will cost a company around $130,000 [6]. This cost doesn't include the pain that a worker undergoes and the negative marketing resulting from a serious injury. Given the extreme liability involved, companies are quick to adopt improved safety systems.

7.4.2. Weaknesses

The biggest weakness of Chop Stop INC is the additional product cost for consumers. Large companies may be quick to adopt Chop Stop, but amateur woodworkers may not want to spend an additional $100 to $200 dollars for a safety system. Although for big companies the investment may seem simple, for the amateur woodworker on a tight budget the additional $100 to $200 for a preventative safety mechanism might not be worthwhile. It is believed that this difficulty can be overcome with careful marketing. Another problem faced by Chop Stop INC is the patent held by the inventors of Saw Stop. With this patent in place it is unlikely that Chop Stop will be able to produce or market any safety systems in the United States. Although Saw Stop has not entered the miter saw market, they have the mechanism and ability to enter the market at any time, posing another risk for Chop Stop INC.

7.4.3. Opportunities

Initial marketing will be focused on higher priced miter saws, but as more stopping systems are produced and Chop Stop refines the technology, the price will decline. Possibly declining enough to allow Chop Stop to add the safety feature to lower price saws, significantly expanding the market base. Although the Chop Stop INC would prefer to begin producing in Michigan, it may be possible to completely avoid the patents of Saw Stop and start production in European or Asian countries. Establishing an initial cliental in some foreign country and then expanding to the United States when the Saw Stop patent has expired.

7.4.4. Threats

The biggest threat to the Chop Stop product is patent litigation. The safety system has been proven effective on the Saw Stop, but it is unclear whether a legal battle might ensue from production. Another threat is the other power tool industries that are constantly developing new safety system to improve their products and compete with the Saw Stop mechanism. One example of this is Bosch's Reaxx table saw. This saw use a mechanism similar to Saw Stop to prevent user injury. Although it is currently unclear whether Saw Stop will sue Bosch for patent infringement the Bosch's safety innovation is a good example of what Chop Stop faces as they enter the competitive market of machine safety. Therefore, it is important that Chop Stop stays on the cutting edge of innovation, continuously improving and modifying their design, and implementing new designs where necessary.

7.5. Target Market

Initially, Chop Stop will be targeting the higher end market for miter saws, especially companies that are at risk from employee injury resulting in litigation. Another main target market will be affluent amateur woodworkers who can afford the best in woodworking equipment and safety systems. Ultimately, however, it is the goal of Chop Stop to develop a preventative safety mechanism that will be widely available on all types of miter saws, allowing those of all incomes and walks of life to more safely use miter saws for their intended purpose.

7.6. Business Plan Conclusion

As a result of the above mentioned research, it was concluded that a business could be developed around the Chop Stop safety system. However, due to Saw Stop's patent and the costs and legal implications of foreign based manufacturing, the designers of Chop Stop have determined not to pursue the development of this business plan for the purpose of manufacturing and selling Chop Stop in the market. However, the business plan has allowed the designers of Chop Stop to quantify their design purpose and implement that on the feature and user interface of the Chop Stop Design. Although more information on this will be forthcoming in the final report, Chop Stop has determined to look at the feasibility of incorporating a safety system on a miter saw to help fulfill the design norm of caring.

8. Conclusion

The evidence presented in the above report has lead the senior design team to conclude that the design of the Chop Stop is feasible. A stopping time of five milliseconds or less is attainable. The stopping mechanism can be built small enough so that it does not increase the dimensional footprint of the miter saw. The device can be built so that it does not increase the force required from the user to vertically depress the miter saw arm when making a cut. The device can be built so that the motor will be powered off as soon as the brake cartridge is fired. The device can utilize voltage and resistance to determine the difference between human flesh and wood. Finally, the miter saw can be built to include a switch capable of overriding the safety features. Therefore, the Chop Stop is a reasonable project to pursue in further prototyping, development, and testing.

9. Acknowledgements

Team 04 Chop stop is grateful to Calvin College, the faculty and staff who have made our education possible, and those who have invested themselves in us and our project. We wish to especially thank our project advisor, Professor VanAntwerp, the metal and wood shop coordinator, Phil Jasperese, the electronics shop technician, Chuck Holwerda, Professor Tubergen, and Professor Michmerhuizen for all of their dedicated and professional assistance with this feasibility study.

10. Bibliography

[1] M, Andrew. "Shop Accident Statistics and Woodworking Safety." Wood Working Guild of America. Accessed October 27, 2016 https://www.wwgoa.com/article/shop-accident-statistics-woodworking-safety.

[2] Gass, Stephen E. "Table Saw with Improved Safety System." Patent Lens. Accessed October 27, 2016. https://www.lens.org/images/patent/US/20090133553/A1/US_2009_0133553_A1.pdf.

[3] Gass, Stephen E. "Table Saw with Improved Safety System." Patent Lens. Accessed October 27, 2016. https://www.lens.org/images/patent/US/20090133553/A1/US_2009_0133553_A1.pdf.

[4] Wood Working Network. "Saw Stop Sues to Block Bosch Reaxx Saw." Accessed November 12, 2016. http://sawstop9.rssing.com/chan-58149733/latest.php.

[5] Gass, Stephen E. "Apparatus and Method for Detecting Dangerous Conditions in Power Tool Equipment." Patent Lens. Accessed November 12, 2016. https://www.lens.org/lens/patent/US_8413559_B2#PhotoSwipe1478986685650.

[6] Gass, Stephen E. "Brake Positioning System." Patent Lens. Accessed November 12, 2016. https://www.lens.org/images/patent/US/7832314/B2/US_7832314_B2.pdf.

[7] Mohan, Jithin. "Electric Fuse." Mepits. Accessed November 12, 2016. https://www.mepits.com/tutorial/472/Electrical/Electric-Fuse.

[8] “Build Your Own DOD. Accessed December 12,2016. http://www.guitars-of-love.com/DOD_OD-250_oscilloscope_screens.html

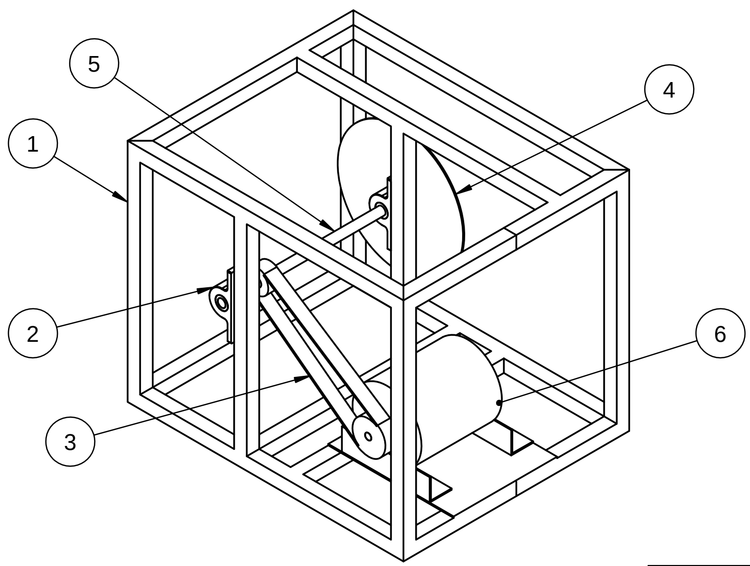
11. Appendix

11.1. Test Bed Assembly Detailed Drawing

11.2. Frame Detailed Drawing

11.3. Shaft Assembly Detailed Drawing

ITEM NO.	PART	DESCRIPTION	QTY.
1	FRAME	1" TUBING, WELDED	1
2	BEARINGS	BEARINGS TO FIT 5/8" SHAFT	2
3	BELT AND PULLEY SYSTEM	MCMASTER PARTS: 6245K62, 6245K65, 6186K126	1
4	BLADE	STANDARD 10" MITER SAW BLADE	1
5	SHAFT	$\varnothing$5/8" SHAFT	1
6	MOTOR	3600 RPM MOTOR	1
7	SHAFT ARBOR PLATE	STEEL TUBE, LATHED (NOT SHOWN)	1
8	SHAFT WASHER	STEEL TUBE, LATHED (NOT SHOWN)	1
9	SHAFT SCREW	5/16"-18 X 1" (NOT SHOWN)	1



PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

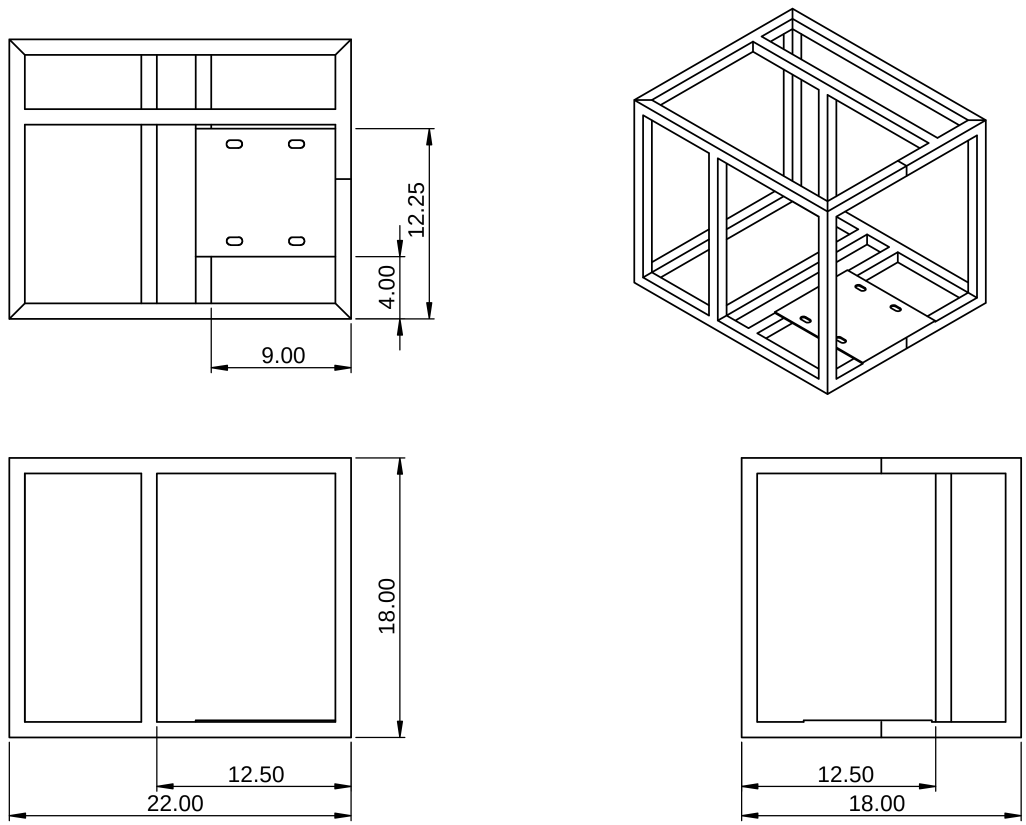
COMMENTS:

TITLE:

TEST BED ASSEMBLY

SIZE **B** | DWG. NO. | REV

SCALE: 1:7 | WEIGHT: | SHEET 1 OF 1



NOTES:
1. FRAME IS 1" STEEL TUBING
2. MOTOR PLATE IS 12 GA. STEEL
3. MOTOR PLATE SLOTS ARE DEPENDENT ON LOCATION OF MOTOR ATTACHMENT HOLES AND ARE IN PLACE TO ALLOW THE INSTALLMENT OF THE BELT

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL STEEL
FINISH NONE
DO NOT SCALE DRAWING

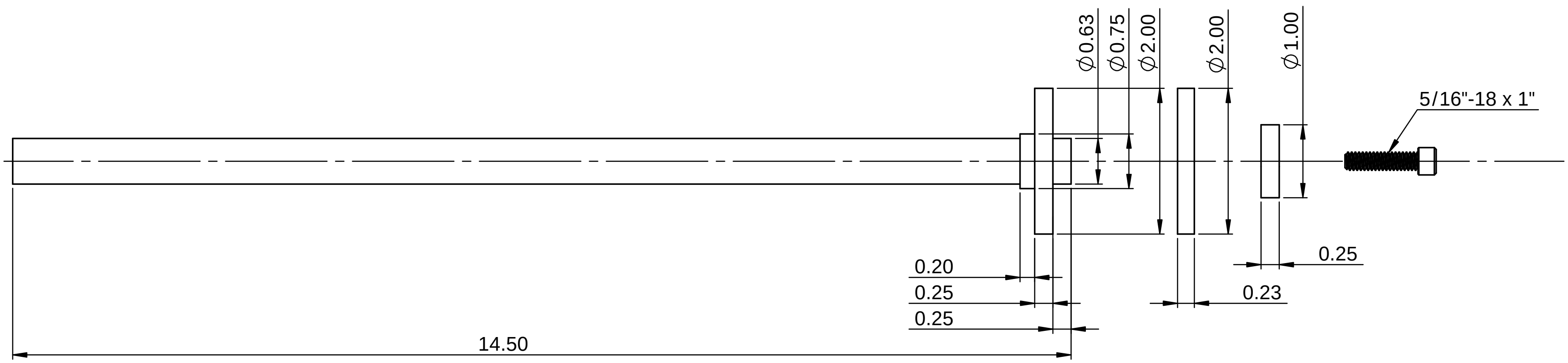
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE: FRAME

SIZE	DWG. NO.	REV
B		

SCALE: 1:8 WEIGHT: SHEET 1 OF 1



NOTES:
1. EXPOLODED VIEW OF SHAFT ASSEMBLY. BLADE FITS BETWEEN MAIN SHAFT AND ARBOR PLATE AND IS PRESSED IN BY WASHER AND SCREW.
2. MATERIAL IS STEEL TUBING
3. HOW MAIN SHAFT WAS MADE: FIRST ARBOR PLATE WAS LATHED AND THEN WELDED TO SHAFT

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
SHAFT ASSEMBLY

SIZE	DWG. NO.	REV
B		

SCALE: 2:3 WEIGHT: SHEET 1 OF 1