

Accessible Manufacturing Equipment

ECE480 Fall Semester 2008

Design Team 1

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Sponsored by:



Executive Summary

We have built an accessible automated machine that can accurately cut material (our main focus is material typically used in award ribbons and gift wrapping) to a user specified length. The machine has a simple interface for use by the impaired and provides audio/visual feedback of system settings. The machine has been constructed using a collection of simple electric motors, custom built mechanical components, and integrated circuits. The final product requires minimal supervision from the user, is properly safeguarded, and is sufficiently mobile. The machine is simple to use, and it has repeatable output of accurate ribbon lengths. The total cost of this project has remained well within budget limitations. A far reaching goal of this project is to help create more employment opportunities for disabled persons, if only to demonstrate a universally accessible design.

Acknowledgements

Special thanks to Lettuce Duit for providing our design team with a meaningful project. We also appreciate that Lettuce Duit covered travel costs for two of their employees, Marty and Dave, to come to East Lansing on two separate occasions, once to give us feedback on our early design, and again this coming Design Day to demonstrate our final design.

Special thanks to Marty and Dave, for providing useful feedback about our project and for coming out to East Lansing on Design day to demonstrate our design.

Special thanks to Stephen Blosser, the Assistive Design Specialist at MSU. He has been with us every step of the way. Stephen provided an incredible wealth of support, technical and otherwise, to our group, and we have learned a great deal from him.

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Chapter 1- Introduction and Background

INTRODUCTION

Problem to be Addressed

Our sponsor, Michigan business Lettuce Duit, has many manually operated machines in their factory that are used for general purpose cutting of materials. Currently, workers are cutting ribbon material to length manually by hand using only scissors and rulers. Lettuce Duit would like to see an automated machine made that can efficiently handle this task. It is also required that the machine to be built be operable by individuals with disabilities (mainly seeing, hearing, and learning disabilities). Also, in terms of production volume, the machine should be able to at least match the production speed of the individuals who are currently doing the task by hand.

Sponsor Specifications:

- Machine will be manually fed material by the user initially, and the machine can then take over automatically with minimal aid from the user
- Machine can accurately cut material from a minimum length (three or four) to seventeen inches, with 1/10 inch resolution
- Machine accessible to disabled persons
- Machine has simple user interface, with audio/visual feedback for the impaired
- Material to be cut will have width no greater than two inches
- Machine will be electrically and mechanically safeguarded
- Machine must be reasonably portable

BACKGROUND

Research Conducted for Design Solutions

Given the nature of the ribbon cutting task, we needed to find components that could successfully replicate motion in a controlled manner. We began by researching electric motors, particularly stepper motors and servo motors. These types of motors were considered because of their smaller size and precision control capabilities, while still being powerful enough to handle the expected demands of our final product. Finding that stepper motors are commonly used inside of printers to control the inkjets, we decided to focus on them and their implementation.

For the audio/visual feedback of the machine, we researched many varieties of devices. For the display, we needed to locate a device that could display simple numeric information and be easy to read for the impaired. A collection of 7-segment display modules was decided upon because we had no need for more complicated display technologies, such as the dot matrix.

Only a small amount of research was conducted for the audio feedback components because our sponsor contact, Stephen Blosser, donated to us an audio chip. Stephen is familiar with the functionality of the chip and is confident it will fulfill the needs of the project. We later acquired the software necessary to program the chip and implement it after becoming adequately comfortable with its functionality.

To bring together and control these various components, we found that the Microchip 18F4520 microcontroller, provided to us by the ECE480 course curriculum, would be more than adequate due to the relatively low amount of processing power and task handling required by the project.

Regarding the mechanical components of our design, we researched many premade and custom built options for linear motion stages, clamps and actuators. Some linear motion devices were even found to have stepper motors already built into them. Though many of the devices we came across would functionally fill the needs of the design, product cost and turn-around time prevented these options from being feasible for the scope of this project. However, our sponsor Stephen Blosser offered to build and machine these components himself free of charge. This solution was the best fit to our project because we can work closely with Stephen in a timely manner to obtain exactly the functionality we require.

Previous Pertinent Work

In 2004, an MSU design team created a talking dryer for the company Whirlpool. This dryer provided voiced audio feedback, allowing the visually impaired to successfully change the machines settings and use the device to its fullest extent. We are taking a similar approach in making an automated machine operable by those with hearing and seeing disabilities.

Also at MSU, a design team reconfigured the circuitry of a beep baseball system in spring of 2008. From a technical standpoint, their project provided audio feedback to visually impaired users as well. From a functional standpoint, their project allowed disabled persons to participate in previously inaccessible activities.

Chapter 2 - Exploring the Solution Space and Selecting an Approach

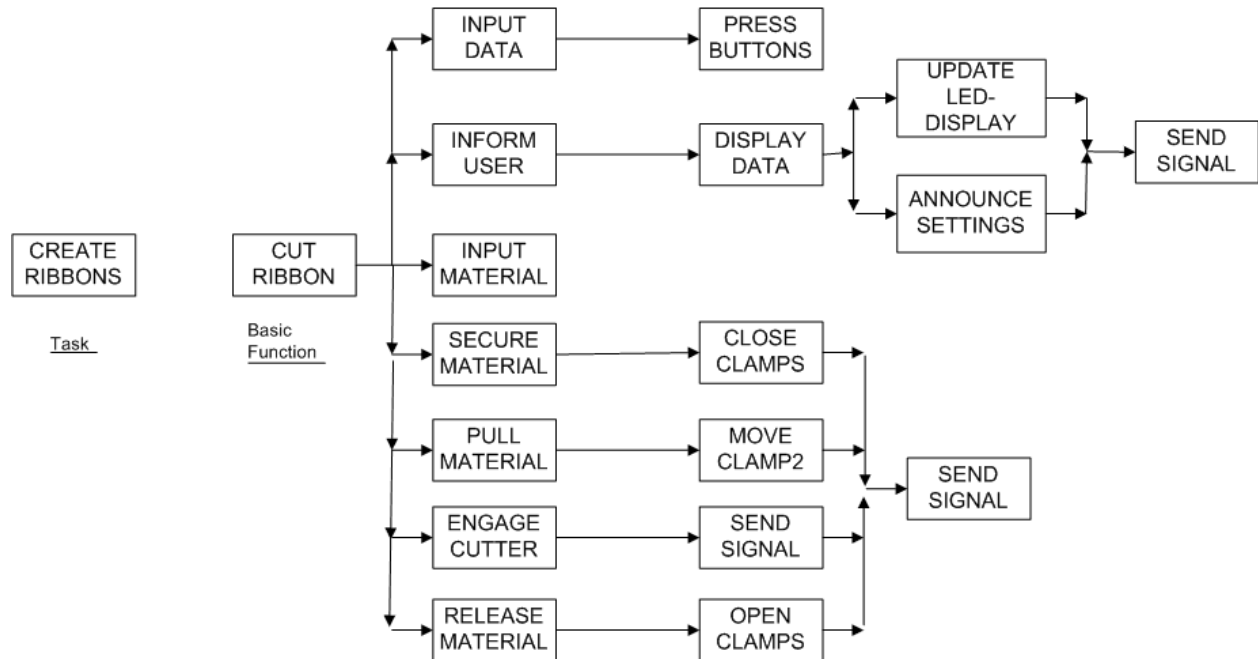
MSU Design Team 1 Proposed Solution

The task our machine is to replicate involves many simple repeated motions. We are proposing the use of an arrangement of stepper motor driven belt drives, actuators, a rotary cutting device, and mechanical clamps to handle the motion requirements of the machine. The expected operation of the final machine is as follows: Two clamps will hold the material, one to pull the material to length and the other to secure the material for cutting. Initially, both clamps will be open and adjacent to each other. The user must place the material in the open jaws of the clamps, and then run the machine. First, the movable clamp will close on the end of the material and pull the material from the feeder. Once the material has been pulled to length, the stationary clamp will close to secure the length of material. Then the machine will send the rotary cutter (located adjacent to the stationary clamp) across the material, cutting the material. The movable clamp will then open, releasing the material to be collected. The movable clamp will then return to its initial position, grab the exposed end of material now being held by the stationary clamp, and repeat the process. The coordination of these devices will be handled by a central microcontroller. For the audio/visual feedback requirement of the machine, we will implement a large LED display to show the current material cutting length, and a digital audio device with a speaker to read aloud the current material cutting length. The microcontroller will control these devices in addition to the mechanical components. A simple keypad will allow the user to change the cutting length, power up/down the machine, and to read aloud the currently selected cutting length.

Summarized Operating Sequence:

- System is powered on
- User feeds material into opening, and places material into open clamps
- User initiates automation
- Movable clamp secures end of material and pulls it to length
- Stationary clamp closes
- Rotary cutter engages and cuts the material
- Movable clamp opens, releasing the material to be collected
- Movable clamp returns to its initial position
- Process repeats

We developed the following FAST diagram was developed early in the semester to help us with our design.



Technical Summary of Expected Final Design

- The position of the two linear motion stages will be controlled by stepper motor driven belt drives. The linear stages will lay parallel equivalent planes, and the axes of motion of the two drives will be perpendicular.
- The linear motion stages will be constructed with a configuration of timing belts, pulleys, and stepper motors.
- The angular position of each stepper motor will be controlled via the microcontroller, which will send the appropriate signals to a stepper control IC (one for each stepper motor, requiring two control bits apiece), which will drive the motor.
- The 120 AC power required for the rotary cutter will be controlled by a relay via the microcontroller, requiring one control bit.
- Any time the cutting length is adjusted via the pushbutton pad, the movable clamp will return to its initial position before enacting the new length
- The display is a collection of three large seven segment displays, which will always show the currently selected cutting length.
- Multiple sound samples will be recorded on our audio chip, which contains its own memory. Each sound sample can then be addressed by the microcontroller to be played.

- The Microchip PIC microcontroller provided for ECE480 will be used as the central processor for this machine.
- The software used to program the PIC will be Microchip's own MPLab IDE.

Evaluation Plan

We will consider our design successful during the testing stages if the machine accomplishes a few key tasks: precisely moving the clamp to the proper length, keeping the material under control during operation (i.e., not dropping the ribbon), accurately displaying user input information through the audio and video feedback, properly accepting user input, and maintaining a sufficient production speed. Two disable persons, Marty and Dave, will be demonstrating our design on Design Day, and they will be the final test for our design's success.

The following chart, Figure , arranges graphically our design possibilities discussed in the previous section of this document. The chart shows design possibilities, their function, and their importance to the core functionality of the final product. In the chart, a '5' represents a 'High' value (i.e., 5 in cost is very expensive) and a '1' represents 'Low.' This was used several weeks ago to make design decisions.

Design Idea Analysis	Screw Clamps	Bicycle Calipers	Audio Feedback	Premade Linear Motion Stages	Simple LED Display	Automated Feeder
Cost	3	1	2	5	1	3
Difficulty	3	4	4	2	3	4
Relevance	4	4	5	5	5	1
Effectiveness	1	3	5	5	5	2

Chapter 3 - Technical Description of Work Performed

Hardware Design Efforts

The hardware design of our project was driven primarily by our sponsor contact, Stephen Blosser. Upon our first meeting with Stephen, he already had a rather specific idea of the mechanical characteristics and layout of the machine. Pictured in Figure 1 is an early sketch of the expected design described earlier in this document.

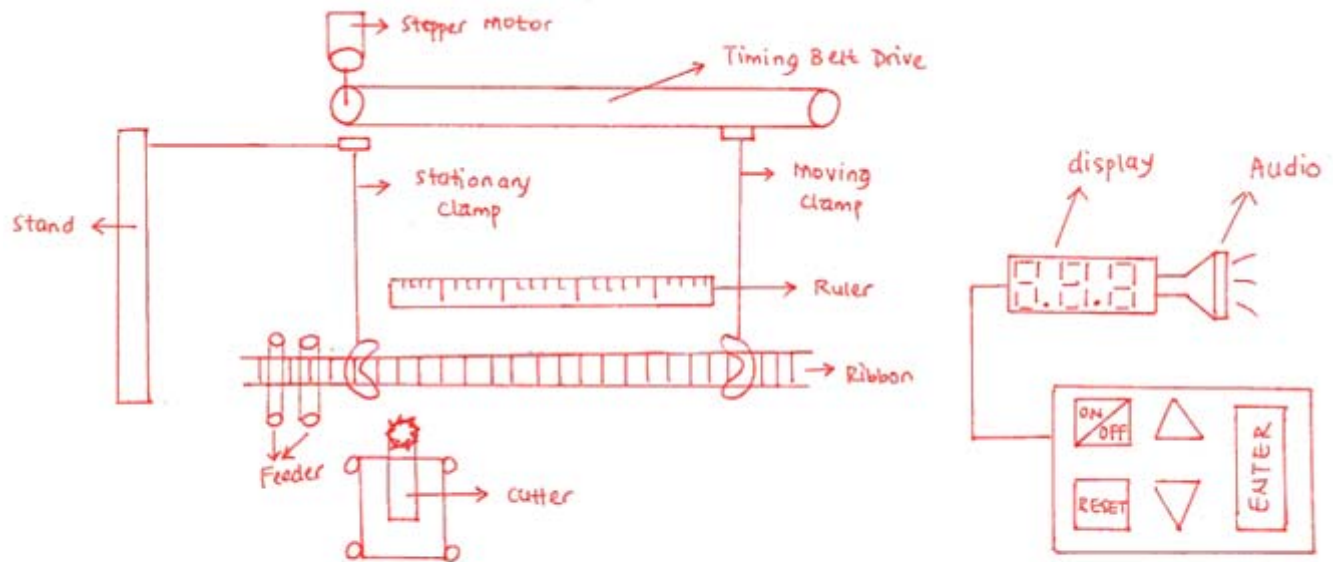


FIGURE 1

At a meeting with Stephen earlier in the semester, we discussed our options for clamps to hold the material during operation. Stephen proposed using a pair of bicycle clamps, which could be driven by some sort of small linear actuators. A week later, while our team was still conducting research for useful electrical components, Stephen contacted us with a solution for clamps. He offered to custom build a pair of clamps, and emailed us his sketch of the idea. The following image, Figure 2 is the sketch he sent us.

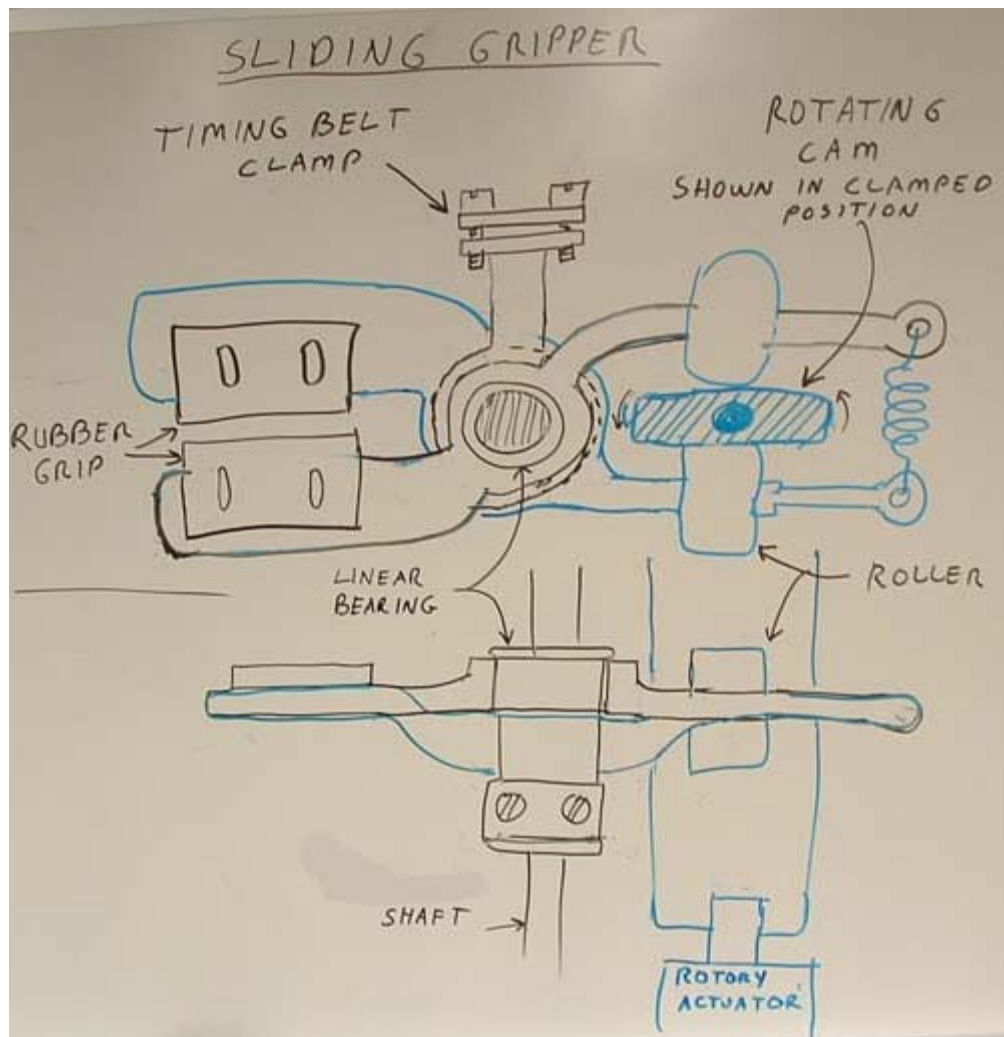


FIGURE 2

Stephen's proposed custom clamp made sense for our design, and we chose to follow that path. Having made that decision, we then needed to make a decision for rotary actuators to drive the rotating cams. We found a pair of left handed and right handed DC gear motors online and decided to order them for the design. Once the motors arrived, we had all the mechanical components for the design. Stephen took measurements of the stepper motors, DC gear motors, and cutter, then went to work in his own workshop to create the frame of the machine. The final mechanical structure of the machine is displayed in the following photo, Figure 3.

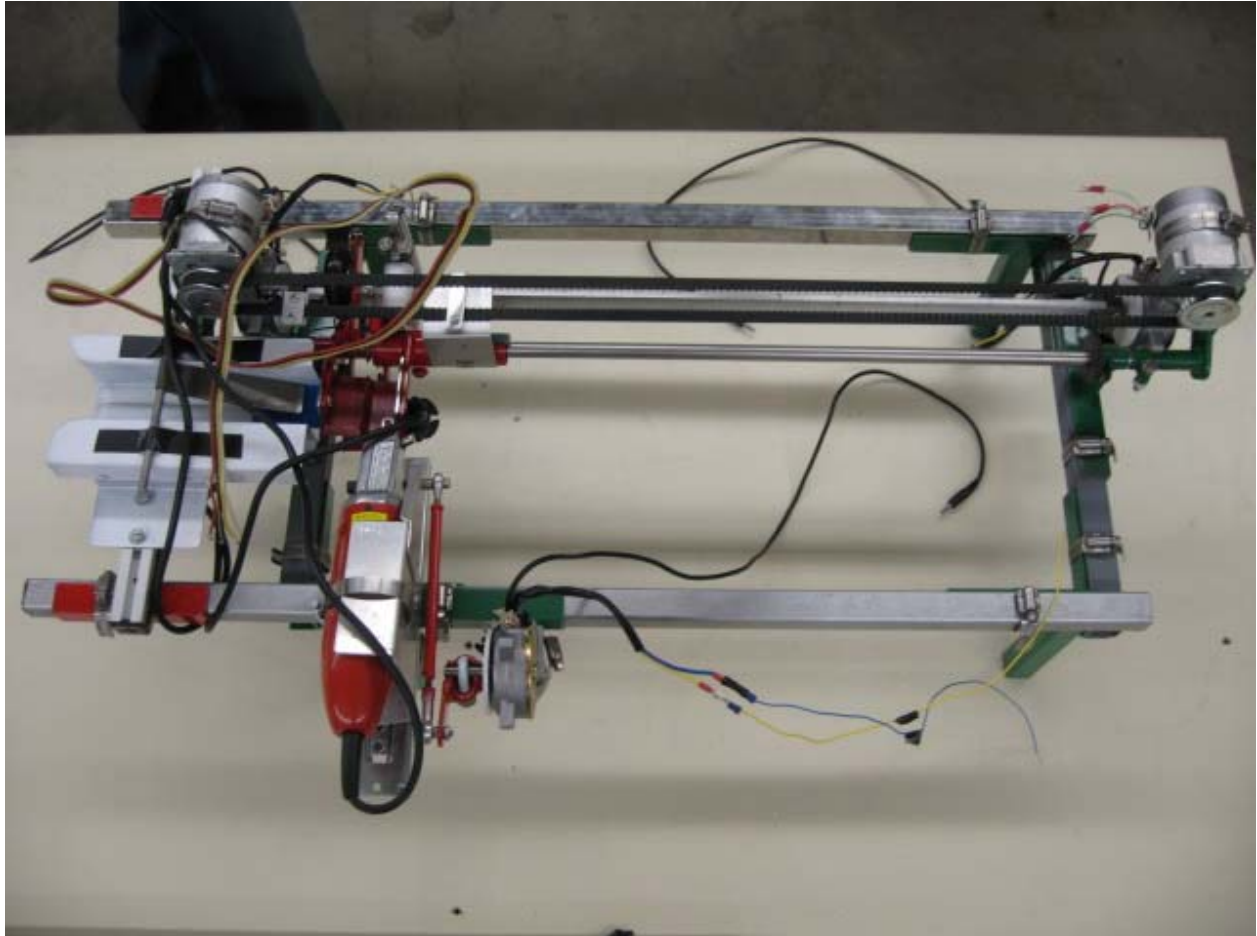


FIGURE 3

For the DC gear motors, we required some sort of restriction on their motion or position sensing. Stephen placed disks of PVC pipe at the base of the rotor of each DC motor. On these disks, he machined grooves along the edge of each disk. On the cam disks, grooves were created 90 degrees apart. On the cutter disk, only a single small groove was made. The purpose of these grooves is related to our position sensing solution. Stephen proposed using microswitches with rollers to sense the rotor position by using the grooves in the disks. The rollers of the microswitches would roll along the circumference of the disk, and could sense different positions due to the grooves. The following photo, Figure 4 , demonstrates this setup on our final design. The microswitch can be seen resting at the edge of the 'open' position on the PVC disk. Again, this is for the rotating cams that open and close the clamps.

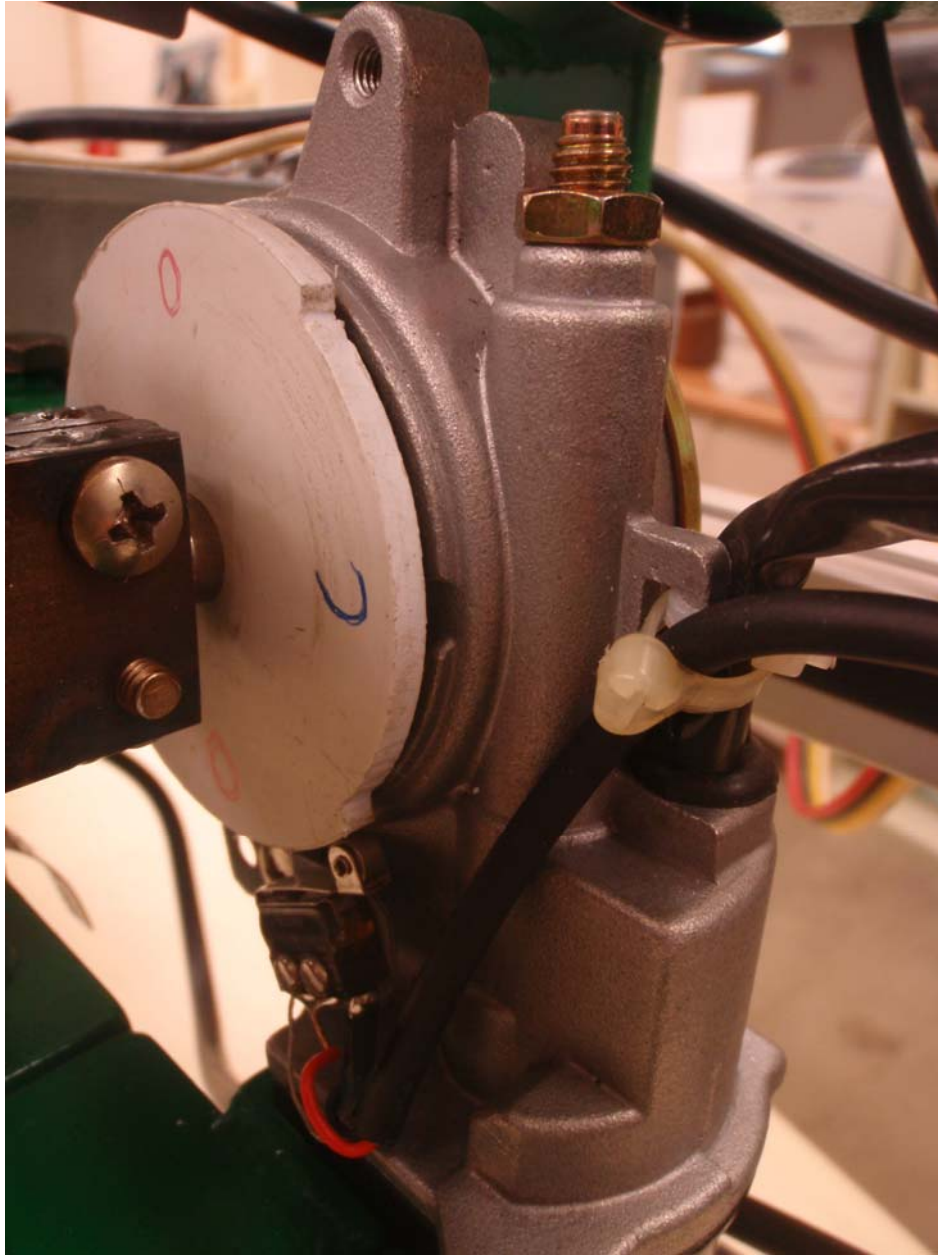


FIGURE 4

Over the next couple of weeks, we put together our individual circuit components. Each section of circuitry was implemented individually, one at a time. After each circuit was demonstrated to function properly on its own, all circuits were then implemented in tandem. Our final circuit design has four major components: the stepper motor circuit, the seven segment display circuit, the audio circuit, and a second PIC to control the gear motor positioning. The main PIC controls the display circuitry, stepper motor circuit, and audio circuit directly. The main PIC is connected to the secondary PIC by only two bits, and the state of those bits tells the secondary PIC what position the gear motors need to be in. Figure 5 shows our functioning protoboard with the main PIC, and audio and display circuitry. For the display, the main PIC controls three separate seven segment

display drives which, in turn, drive each of the three seven segment displays. Just above the main board in the photo is the stepper motor driver circuit, which is controlled by the main PIC. Near the upper right portion of the main board there are three pushbuttons. The lower two buttons change the desired cutting length, while the upper button reads aloud the currently selected length. The toggle switch visible at the bottom of the photo either allows the user to change the desired cutting length, or initiates the cutting process.

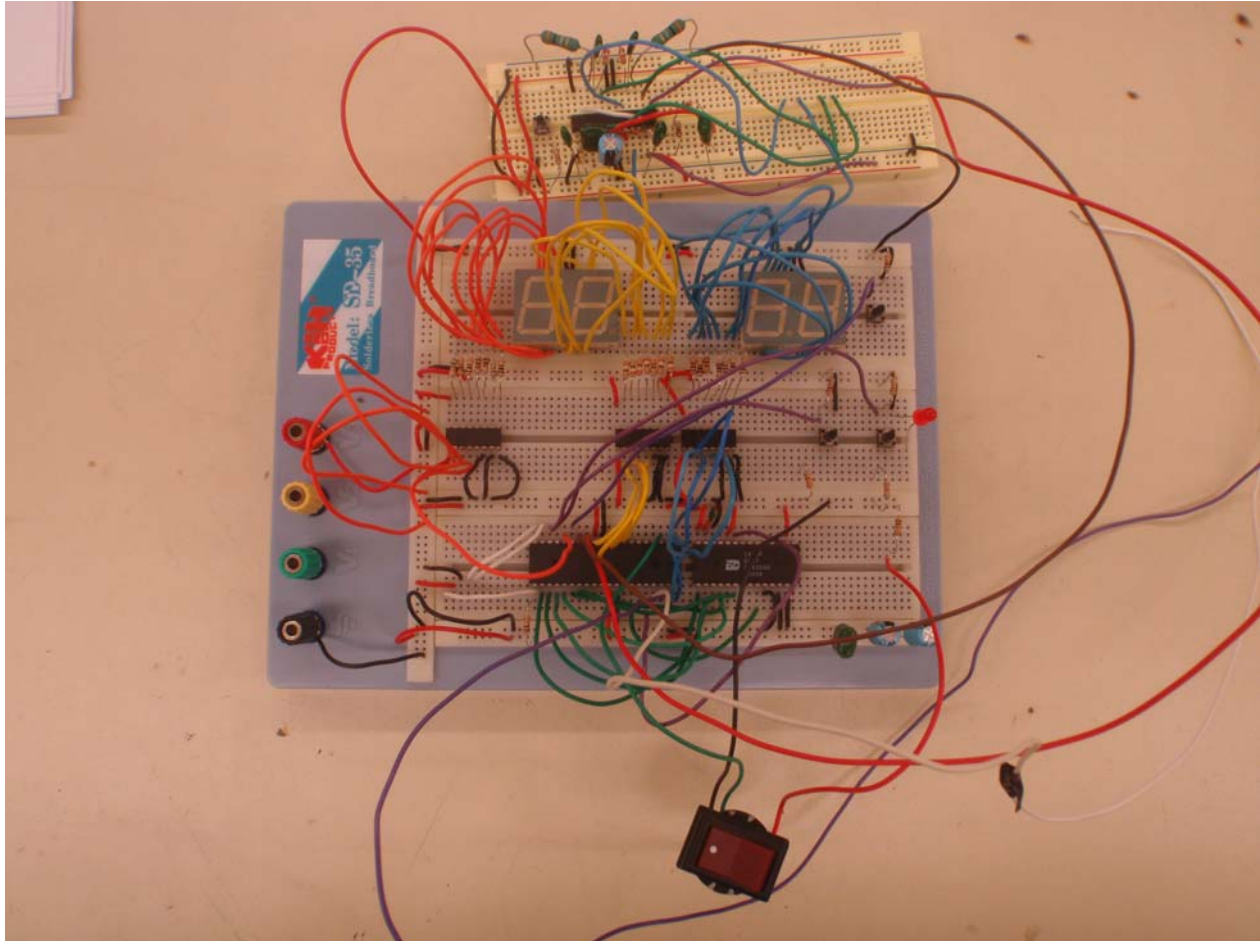


FIGURE 5

Figure 6 shows our functioning secondary PIC. Notice the three relays paired with three MOSFETs. These are controlled through the secondary PIC, which uses the MOSFETs to energize the relay coils and thus power the gear motors.

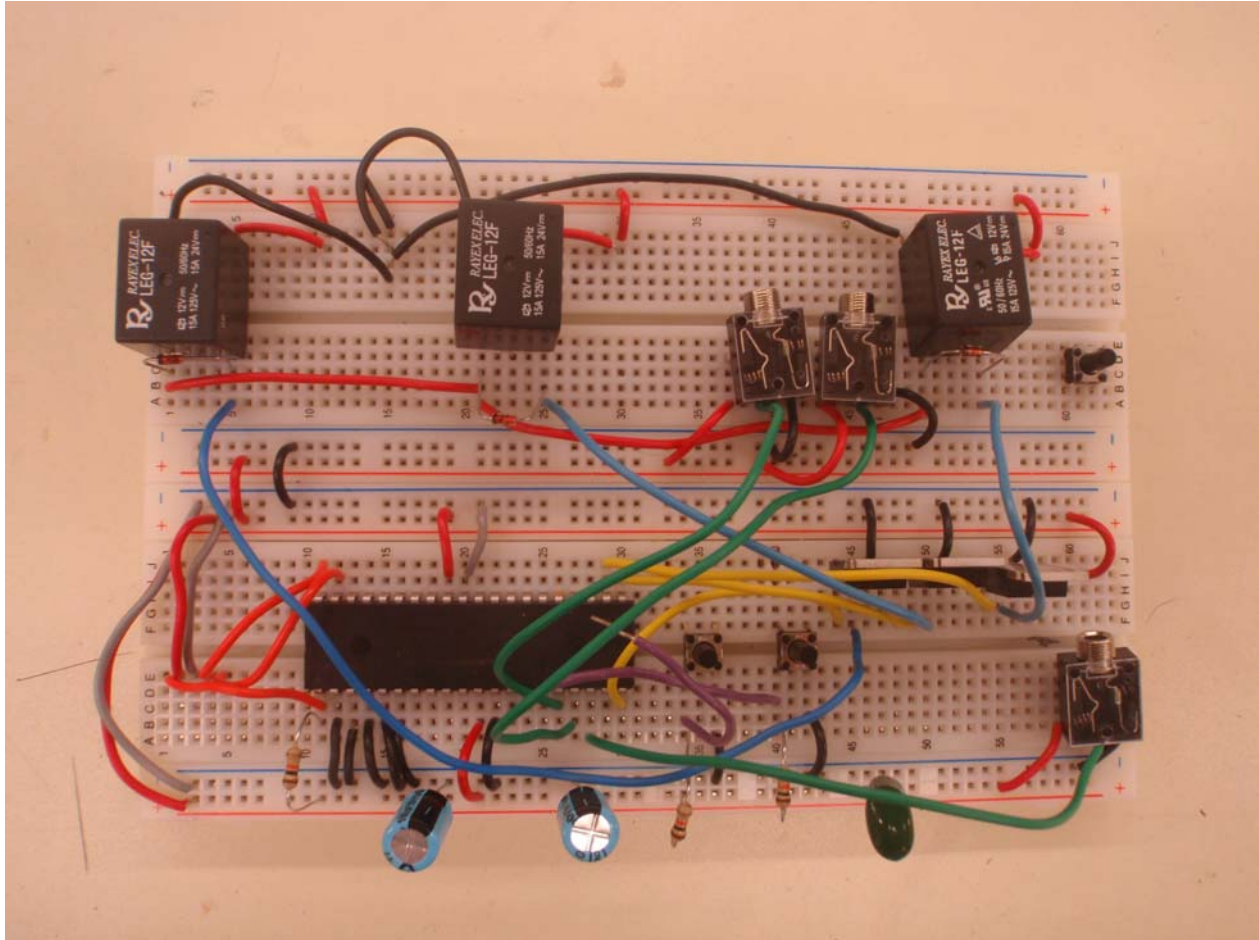


FIGURE 6

There are also three stereo headphone jacks wired to the pick. Each gear motor's microswitch leads are wired to a stereo headphone cable, which allows for easy connection to the protoboard for position sensing (the pushbuttons on the board were only used for early testing of the prototype, and are not part of the final design).

Software and Interface Design

Our main focus while designing the interface of our machine was simplicity. As per our sponsor specifications, we kept the interface simple for users with disabilities. The whole system only requires four buttons to completely control.

The emphasis on user simplicity drove how code for this project was written. We wanted to burden the user with as little fuss as possible, which meant leaving our PICs to control as much as they could. Two separate source files were written from scratch; one for the main PIC and the other for the secondary (gear motor control) PIC. These source files can be viewed in Appendix 3 of this document. The second PIC is

programmed essentially as a sequential state machine, controlling the states of the clamps and the cutter ('states' meaning 'open' or 'closed' for the clamp motors, and 'home' for the cutter). The main PIC is responsible for the timing and progression of the states in the secondary PIC.

Chapter 4 - Proof of Functional Design

Once the final design had been coded and wired together, the entire system was ready to run as a whole. Incredibly enough, the whole system worked on the first complete run. There was a small code problem that involved an input length of anything larger than '9' for the whole inches. The problem acted in the following manner: if the input desired length was '14' inches, the machine would cut only to '4' inches. The machine was only cutting to whatever value was on the ones place of the whole inches value. This glitch was quickly found in the code for the main PIC and fixed in less than five minutes after discovery. A sensitivity issue was also discovered with the cutter servo motor. The notch in the PVC disk was not wide enough, and when the cutter came to rest at its home position, the microswitch roller rested such that an abrupt movement of the machine would trigger an undesired cutting motion (one rotation of the cutter servo). This issue was easily solved by widening the notch in the PVC disk; the sensitivity issue no longer exists. Our next task was to calibrate the machine for accurate cutting length. We collected some rolls of ribbon material and used the machine to cut them to different lengths. Some quick tweaks to a scaling factor in the main PIC code produced satisfactory results. Having addressed these early troubleshooting issues, we had have a working prototype. Stephen Blosser came into the lab to observe the operation of the machine and was pleased with its accuracy and functionality. As of this writing, we are waiting for our printed circuit boards to be finished so that we may get our electronic components into a more organized and stable configuration than the protoboards.

Chapter 5 - Summary and Conclusions

In summary, our design team was tasked with creating an automated piece of production equipment that was accessible to persons with disabilities. Our machine is simple to use with only four buttons to operate, and our audio and visual feedback allow use by persons with vision or hearing impairments. The machine meets our sponsor's specifications, and we remained within our allotted project budget. Our team successfully used servo motors, stepper motors, programmable integrated circuits, and various other electrical components to complete this design, which were some of the learning goals associated with this project. We hope that our finished design will prove useful to Lettuce Duit and its employees.

Final Cost

Our project was constructed mainly of components we obtained free of charge, be it through the ECE shop or materials Stephen Blosser donated to us. A breakdown of the design cost for components we purchased can be viewed in the following table:

Description	Cost
Stepper Motor Drivers (2)	\$18.42
BCD to 7-segment Latch/Driver/Decoder (3)	\$1.50
150 RPM 12VDC Right Gear Motor (2)	\$29.98
150 RPM 12VDC Left Gear Motor (1)	\$14.99
LED Display Driver (3)	\$5.91
Miscellaneous	\$32.83
TOTAL	\$103.63

Schedule

Our project remained on schedule throughout most of the semester. At the end of the semester, we had intended to test the entire functioning system before the Thanksgiving holiday. This was accomplished on the Saturday and Sunday following Thanksgiving, a delay of only three days, which shrank our window for creating and soldering our printed circuit boards. Again, as of this writing, we have not yet received our PCB boards.

APPENDIX 1 - TECHNICAL ROLES



Jeli Joegiono - My technical role for the project is to wire and program the audio chip ISD 1420P. This single chip is able to record and playback the audio, and the chip itself has a memory up to 20 seconds of recording and provides high quality. The minimum record and playback subsystem can be configured with a speaker, or a microphone. Recording are stored into on-chip memory cells that provides zero - power message storage that will eliminates the battery backup circuits. As I stated before, it provides a better and high quality, solid state voice reproduction because the voice and audio signals are stored directly into the memory. The chip ISD 1420P is able to handle multiple messages and has on - chip oscillator. It has 100,000 typical record cycles and has sampling frequencies of 6.4 and 8.0 KHz. This chip is has 28 pins configuration and has its own internal clock. The ISD 1420P is wired to the microcontroller model PIC18F4520 that has 40 pins. This type of microcontroller has five different ports, so we can choose which port to use. For the audio, I used PORTA to wire it with the address input from the audio chip. Once the wiring is done, we will connect it to the microchip to run the program/code.



Kyle Coveart - My technical role was the power systems, printed circuit board design, and final packaging design. For the power systems it was my responsibility to determine our projects power needs. After we as a team had decided upon what DC motors and the stepper motors we would use I was then able to figure where we would get the +5 volt logic, the +12 volt for the motors, and the -12 volt for the audio power amp. I determined that using a computer power supply would give us the needed voltages, as well as the high current ratings on the 12 volt rails. This was as opposed to using a single 12 volt source and trying to step it down and regulating it ourselves.

The printed circuit boards were done using CadSofts Eagle PCB program. The version that was available to us had a limit on the size of board that could be created. With this, I was able to break up our circuit in to two separate boards. One board would contain the two microcontrollers as well as the audio IC. The second board would house the stepper motor driver chips, and the DC motor relays. The two would then be interfaced with each other via ribbon cable. Going with two printed circuit boards allow us to separate the microcontrollers and their 5 volt logic from the 12 volt high current of the motors. During initial testing we ran the microcontrollers and motor relays off the same protoboard, which caused the microcontrollers to behave erratically due to the sharing of a common ground.

Lastly I was also responsible for the final packaging of the controller box. The ECE 480 shop has a number of housing boxes available for us to use and I was able to find one that would house all the necessary components as well as provide space for our 7 segment display and user input interface. All of the printed circuit boards would be

located inside the and connected to the motors via XLR and 4 pin microphone connectors. I chose these connectors primarily due to their robustness as well as their ability to handle high current loads. However, these connectors also provide a quick and easy way of connecting and disconnecting the device, making it much easier to move the machine from one place to another.



Vinod Natla - By engaging in extensive research of our project and understanding key concepts behind different types of motors, microcontrollers, drivers for 7 segment display, audio and stepper motors and more key tools were understood in applications towards the design process. I was able to gain a better grasp on the industry practices and trends used in electrical engineering today. I learned how they worked with various suppliers to achieve their own design goals. My assigned technical role as stated in the team proposal included programming the controller to display the length on a multi digit seven segment display. In order to accomplish this we used 7 segment drivers to carry the information from the PIC to display. As mentioned the specifications the minimum length that we could cut the ribbon is 4 inches and maximum we could go is 17inches. The PIC was programmed such that the machine can accurately cut material to a length of four to seventeen inches, with 1/10 inch resolution. The user can input the length using a switch/ push button, to increase and decrease the cutting length. This length is displayed on a large 7 segment LED displays to show the current material cutting length, and a digital audio device with a speaker is used to read the current material length set by the user. The microcontroller will control these devices in addition to the mechanical components. I also helped in some part of programming in main PIC controller to operate the stepper motors and dc motors to operate the clamps. A lot of mechanical work was done to build and join all the individual parts like clamps, circular disks, feeder, cutter and motors with the help of our sponsor. His experience of working among people with disabilities helped us to understand in designing process of machine that could be used for normal people and also for people with disabilities.



Ryan Everaert - My main responsibility for my technical contribution to this project was construction of the stepper motor circuit and programming of both PICs. Though the functionality of the stepper circuit is simple and easy to understand, a handful of external components and wiring was required for the L6208 chip to operate properly. Once the rest of the group finished their respective individual circuits and wiring, it was my responsibility to get everything to function at the same time. I programmed both of our 18f4520 PICs using MPLab IDE software, available on the ECE lab computers. The first PIC, which I will refer to as our 'main' PIC, controlled the audio, display, and stepper circuits directly. This required extensive manipulation of the available ports on the main PIC. Port D is configured entirely as an output port, and it

handles the output signals to the seven segment display drivers. Port A is also configured entirely as an output port, and its lowest seven bits directly assigned address values to the ISD1420 audio chip. The remaining available bits of ports B and C were used for other I/O functions, including stepper motor control and one way communication to the second PIC. The second PIC was responsible for controlling and monitoring the states of our three servo motors, essentially acting as a state machine. The main PIC controls the timing and progression of the states on the second PIC. I gained an intimate knowledge of all circuitry involved in this project, as it was necessary for properly interfacing all the separate technologies through our PICs.

APPENDIX 2 - REFERENCES

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APPENDIX 3 - DETAILED TECHNICAL DOCUMENTS