ECE 445

SENIOR DESIGN LABORATORY

FINAL REPORT

Deep Tunnel Mobilization: Final Report for ECE 445

Team #26

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Abstract

In this work, we develop a method to control an electric winch so that it can pull a movable deep tunnel across its track. Pulling the structure across its track with a standalone commercial winch risks damaging the winch or structure. This project is our attempt to mitigate this risk and the time it takes to operate the winch to move this structure.

Contents

1 Introduction

1.1 Preface

For the project as pitched in Dr. Witmer's ABE 469 capstone course see appendix B.

Most vegetables are done growing late in the season at The Student Sustainable Farm (SSF), except some cold hardy crops [1]. A Deep Tunnels, equipped with UV resistant polyethylene plastic, can be used to extend growing periods by protecting crops from direct sunlight. If deep tunnels are moved, a tunnel can be used as an incubator for more crops.

There are three Deep Tunnels at the SSF, each on a track twice the length of the 96ft long tunnel. By hand, it takes 10-12 volunteers to push a deep tunnel. Our goal was to devise a solution that would reduce the number of people and the time they would spend on moving the tunnels, while also taking into account how to preserve the tunnel and mobilization mechanism's structural integrity.

In agreement with the Agricultural and Biological Engineering senior design course, we decided that using a single electric winch for moving the tunnels was the best fitting approach. By mounting an electric winch to a vehicle, a single winch can be relocated and re-anchored by the vehicle to pull at any of the 6 tunnel ends. This process would require 1 person. A winch would perhaps pull the tunnel if attached to the spine of the frame that holds the tunnel ridged.

Figure 1: Satellite View

1.2 Problem and Solution Overview

Commercial winches pull at around 10 feet per minute on lighter loads and are suggested to be turned off for long cool down periods after even short intervals of being turned on. If adhering to the winch manual's recommended cool down periods, moving a single tunnel would take more than 3 hours. With the off the shelf remote, operating the winch is done by manually holding down a a switch; when the user lets go of the remote, the winch turns off. We modified the winch by fitting to it instead, a latching switch and a micro-controlled relay. With a latching switch, the user can flip the switch, leave it, and the winch will continue to stay on. The micro-controller's clock automates the winch to turn off for some time before turned back on, for cool down.

Many winches will also pull hard enough to break the wire ropes that they come with. A current sensor informs our system to turn the winch off when the mechanical load is above a threshold.

In the case of the deep tunnel, if the winch pulls too far, the tunnel could rip past and damage the end of its track. Any load needs to stop being pulled once it has reached the winch, otherwise the hook on the line will get lodged and forced into the rollers on the face of the winch drum. We use an ultrasonic sensor to account for the location of the mechanical load. We turn off the winch when the load is near the sensor.

1.3 Visual Aid

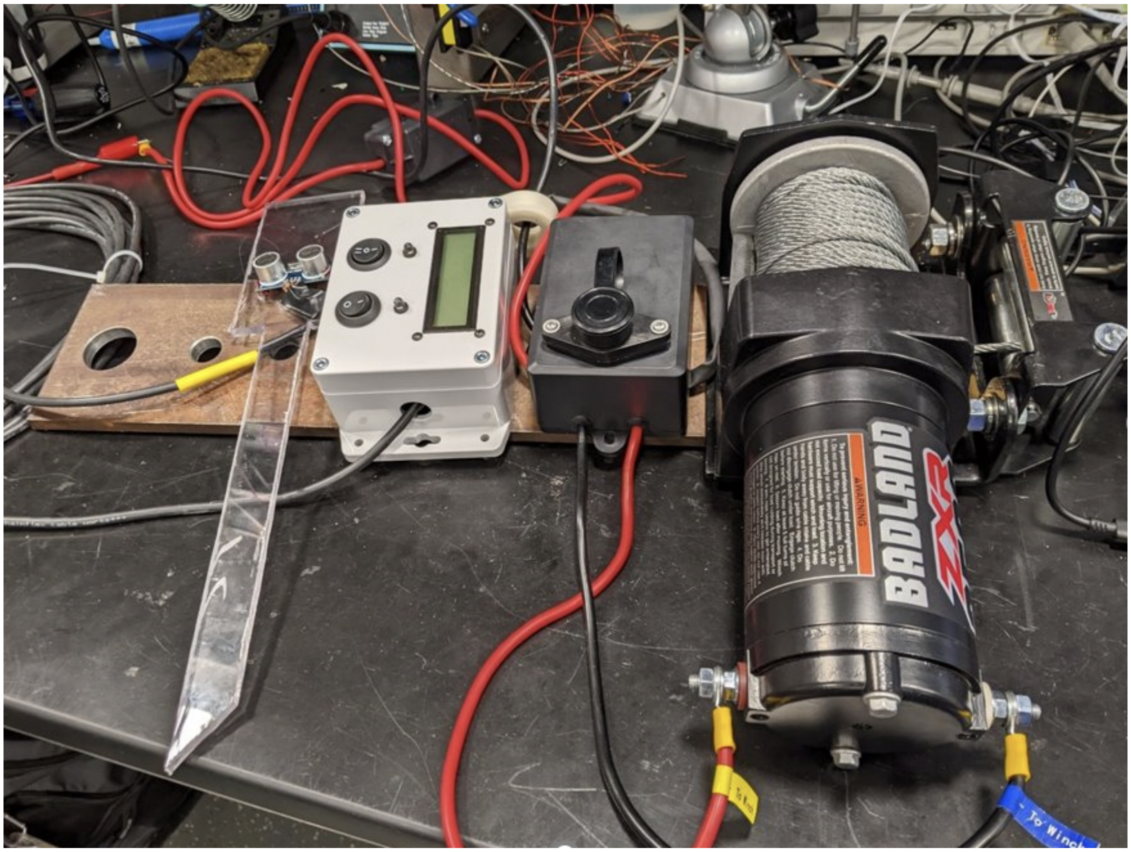

Figure 2: Visual Aid

1.4 High-level requirements list

- Winch can be turned off and on by micro-controller.
- Current is measured and displayed.
- The winch maintains all capabilities it had out of the box and our design is transportable and manageable.

1.5 Subsystem Overview

1.5.1 Block Diagram and Descriptions

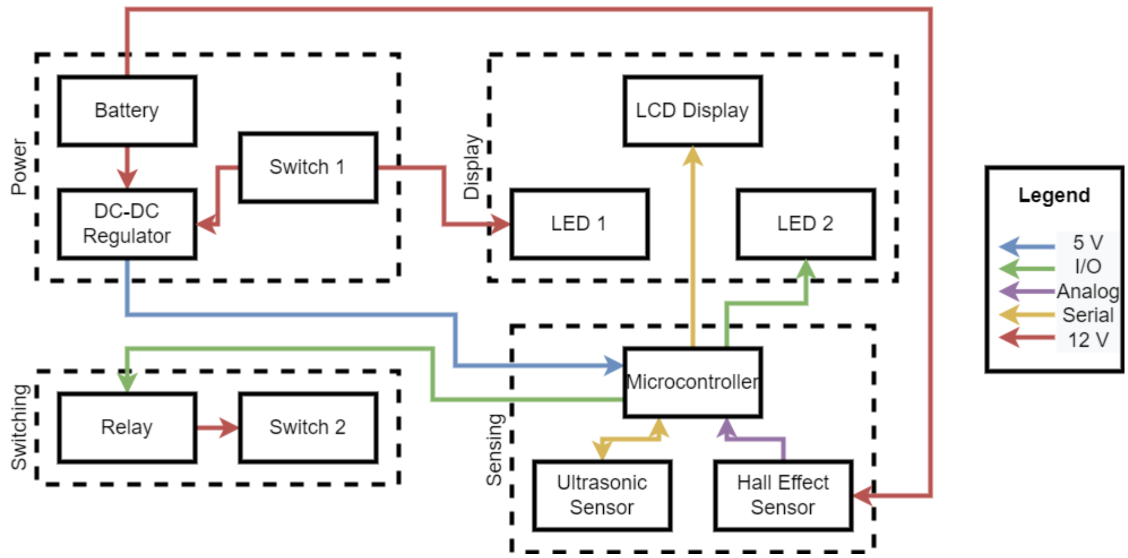

Figure 3: Block Diagram

1.5.2 Power

The power subsystem is comprised of a 12 volt car battery or other 12 volt supply and the DC-DC regulator that is used to supply the micro-controller part of the circuit at 5V.

1.5.3 Display

Two LEDs and an LCD. The LCD and right LED are controlled by the micro-controller. The LED on the left is connected to the power supply and goes on when switch 1 is flipped connecting the power supply to our controller.

1.5.4 Switching

This subsection encompass the components that are used to make the digital-out pin voltage from the micro-controller actually control the winch, a relay circuit and switch. The digital out-pin connects to the relay. When the pin goes low the relay effectively cuts a wire on the a latching switch and the connection the switch was making to activate the motor is broken.

1.5.5 Microcontroller

An ultrasonic sensor and current sensor give voltage values to the ATmega168 micro-controller. It can be programmed via an on board ISP. It is currently programmed to control the relay, controlling the winch based on the sensor values and the micro-controller's clock.

2 Design

2.1 Power

The winch needs to be powered at 12 Volts and needs to be mounted to a vehicle (tractor at SSF) so that it is anchored for pulling the high tunnel. Conveniently, mounting to a vehicle means the winch will be in proximity to a 12 Volt vehicle battery which can store enough charge (0.6kwh) to operate the winch long enough to pull a tunnel. We wanted our design to ensure that would power both the winch at 12 volts and pcb at 5 volts from a 12 volt supply.

2.1.1 Battery

The battery provides the power for the whole system. This includes the winch and the various components on the printed circuit board like the sensors and the microcontroller. Since the most common voltage rail for both car batteries and winches is 12V, this system was designed to run off of a 12V truck battery. The limitations of the battery would be the amount of continuous current that the battery can provide and the amount of energy stored in the battery.

The main connection to the winch system is through battery terminal connectors to make the connection more secure although jumper cables can be used for testing.

2.1.2 DC-DC regulator

The DC-DC regulator converts the 12V line from the battery to 5V to power the sensors and control systems on the printed circuit board. The battery input voltage might vary in certain conditions such as the alternator is charging the battery or the battery is trying to start the engine. In both of those cases, the regulator needs to be capable of supplying power to the microcontroller. This means that the input voltage to the regulator can have a wide range and still needs to provide a stable output voltage. Since switching regulators have more flexibility in the input voltage ranges and are generally highly efficient [2], the switching regulator topology was chosen over the linear regulator. At the time of this project, the LM2575D2T-5R4G was chosen for its lower cost and availability. Although this component can be used to supply up to 1A of current, the other specifications also depend on the external components that are paired with this integrated circuit.

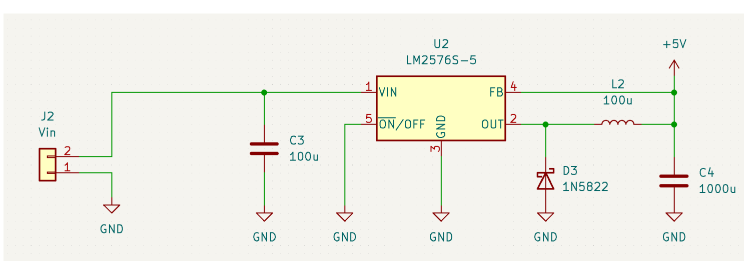

Figure 4: DC to DC Converter

For the switching regulator as shown in figure 4, the external components such as the input capacitor, diode, inductor, and output capacitor need to be chosen for the specific circuit application.

- The role of the input capacitor is to prevent large voltage transients from the battery which filters the input voltage for its DC component.
- The diode acts as a one-way switch where current is only allowed to pass through in one direction. This is necessary since the integrated circuit works by quickly connecting and disconnecting the input and output pins. The ratio of time where the input is connected to the output of the integrated circuit is called its duty cycle. The period of this circuit is the inverse of the switching frequency. During the ”on” portion of this switching period, the diode blocks the current path directly to ground, so the current flows through the inductor. During ”off” portion of the switching period where the input is disconnected from the output of the integrated circuit, the inductor provides the current to the load. The diode is necessary to complete the loop. Thus, the diode was chosen to have a maximum peak current that is greater than the maximum load current and a reverse voltage rating that is larger that the maximum input voltage.
- The inductor is the energy storage unit in the power conversion since the energy from the input is transferred to inductor and then the energy is transferred to the load. The inductor needs to have a maximum current rating greater than the maximum load current. The maximum peak current can be calculated as

  $$I_{p(max)} = I_{Load(max)} + \frac{V_{in} * V_{out} * t_{on}}{2L} \quad (1)$$

  where $I_{p(max)}$ is the maximum peak current, $I_{Load(max)}$ is the maximum load current, V_{in} is the input voltage, V_{out} is the output voltage, L is the inductance of the inductor, and t_{on} is given by

  $$t_{on} = \frac{V_{out}}{V_{in} * f_{osc}} \quad (2)$$

  where f_{osc} is the frequency of oscillation.
- The role of the output capacitor is to reduce the output voltage ripple. Since the inductor does not act like a perfect current source, the current rises and fall in every period which means that the output voltage will also change at the same switching frequency. The capacitor rating needs to be large enough to filter these unwanted voltage fluctuations and have a voltage rating higher than the output voltage of the converter.

2.1.3 Switch 1

Switch 1 is two position panel mounted switch. It is used to disconnect and connect power supplied from the battery to the rest of the circuitry. Since the printed circuit draws current for the components like the front panel LED, LCD screen, and microcontroller even when not in use, the front panel switch can help save on battery life. This feature also ensures that the relay remains open so that Switch 2 will not be able engage the winch.

2.2 Display

The purpose of the display is to provide the user with the relevant information about the operation of the winch. Namely, the current drawn, the distance from the ultrasonic sensor, the time, and the state of operation. The main limitations for the front panel display was the size of the case that houses the print circuit board. The layout includes the LCD panel at the top of the enclosure and the two LEDs are below it.

2.2.1 LEDs

When switch 1 is closed, the LED on the right turns on indicating that there is power to the system. When the switch is open, the LED is turned off. The LED on the left is normally turned off, and turns on when there is a fault in the system. A fault occurs if the tunnel is at the end of the track and the ultrasonic sensor reads a sufficiently low distance or if the hall effect sensor input is sufficiently high.

2.2.2 LCD

The LCD (Adafruit 398) displays relevant information to the operation of the winch. The distance between the ultrasonic sensor and the tunnel in cm is displayed in the top left of the screen. In the bottom left is the current being measured by the Hall effect sensor. If the winch can currently be turned on the panel will display ”ON” in the top right. If it cannot, ”OFF” will be displayed in the top right. In the bottom right, is a representation of the amount of time elapsed since the system was powered on.

2.3 Sensors

The ultrasonic and hall effect sensors make sure that the winch operates safely. If a fault occurs, the relay will cut power to the winch and the display will update accordingly.

2.3.1 Ultrasonic

The ultrasonic sensor is mounted to an acrylic stake which will be placed 20 cm from the end of the tunnel. When the tunnel reaches the end of the track, the ultrasonic sensor will signal to the relay to cut power to the winch.

2.3.2 Hall effect

The hall effect sensor is used to monitor the current off the cable that connects to the 12 volt car battery supply. If the load of the winch gets caught on something, the winch will draw more current[3]. The voltage from the V_{out} pin will increase with an increase in current draw from heavier loads. The analog input on the ATmega is converted to a digital value through the 10-bit ADC and the program has a threshold value that will disconnect the winch when it has been reached.

During the design process, the Tamura L37S300S05M CURRENT SENSOR was chosen since it is rated to read up to 300A. This value was based on the winch that the agricultural and biological engineering team choose at the beginning of the project.

2.3.3 ISP/Microcontroller

The microcontroller provides the control for the system. The main requirements for the microcontroller in this project were the operating voltage, the number of available pins for digital and analog input and output, and the availability.

2.4 Switching

From reverse engineering the solenoid box that was purchased with the winch, there were 3 modes (OFF, clockwise, counterclockwise) for the winch remote. This was done by making contacts in the solenoid box that came with the winch. The out-of-the-box remote enables the user to make these contacts by holding down the intended direction on the remote's switch. When the user releases their hand from the switch, it is released and no contact is made, so the winch turns off. Instead, this design uses a microcontroller to dictate the state (OFF, ON) of the winch. The front panel switches are latching switches so that the winch could be left pulling the high tunnel without having to physically holding the switch down. The micro-controlled relay will disengage the winch as necessary to stop at the end of the field and the motor from overheating.

2.4.1 Relay

The TLP3544(F) solid-state relay was chosen because it has a high even current rating to switch the control terminals of the solenoid box. Since the microcontroller is unable to provide enough current to drive the solid-state relay, a bipolar junction transistor was implemented to increase the current gain from the microcontroller. The 2N3904 transistor in conjunction with a $4.7k\Omega$ resistor was chosen to have the proper current for the solid-state relay control. A fly back diode is used to protect the transistor and micro-controller as shown in figure 5.

When the digital value for the micro-controllers relay pin switches, there will be a sudden change in current. Without the diode's forward bias the voltage across the inductor in the relay would go high and damage the rest of the circuit[4]. This is also described by the time dependent equation for the inductor which states that

$$V_{inductor} = L * \frac{di}{dt} \tag{3}$$

where $V_{inductor}$ is the instantaneous voltage across the inductor, L is the inductance of the inductor, and $\frac{di}{dt}$ is the instantaneous rate of current change.

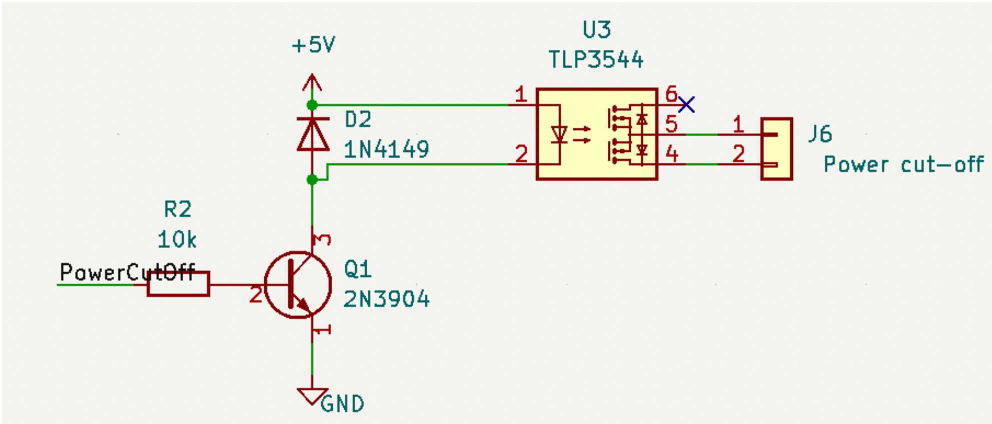

Figure 5: Relay circuit for Winch Control

In figure 5, the label "PowerCutOFF" on the left of the schematic is a digital output pin on the ATmega. The wire connecting the middle pin contact on switch 2 of the solenoid box runs through connector J6 on the right of relay schematic. When the digital output, "PowerCutOff", goes low the relay disconnects the wire running through J6 disconnects and the winch turns off.

2.4.2 Switch 2

Switch 2 is a three-position panel-mounted switch mounted to the front of the poly case. The middle plate on the switch is wired to the relay on the printed circuit board, and then from the relay on the printed circuit board to the middle contact in the solenoid box. The other two plates on the switch are wired directly to the same contacts in the solenoid box to which the off-the-shelf remote is wired. If the relay is closed, then this switch connects the contacts in the solenoid box to engage the winch.

3 Verification

3.1 Power

One aspect of verifying power is verifying that there is a power supply adequate for powering the motor. In the lab we had access to a power supply that could supply enough current (10A) at 12V to power the winch without load. The other aspect of verifying that the power circuit functions as desired is if the 12 volt supply can be converted to 5 volts for the rest of the system.

3.2 LCD

We first tested the LCD screen on a breadboard. We connected the LCD to the micro-controller and printed "Hello World!". We then tested it of the PCB and printed "Hello World!" again. Once we made sure the the LCD screen worked, we printed the other information on the display.

3.3 Ultrasonic

We first tested the ultrasonic sensor on a breadboard by connecting it to the microcontroller. The Arduino IDE measures the length of the pulse from the echo pin. To get the distance in cm, we multiplied the value by the speed of light and divided it by 2 since the wave travels both ways. The equation we used was

$$distance = \frac{duration * 0.034}{2} \tag{4}$$

This value was displayed on the LCD screen. By placing the sensor at different distances from an obstacle, we were able to make sure the output was correct. It worked the same way on the PCB since it is wired the same.

3.4 Hall effect

The Arduino IDE takes the analog read voltages (Vsensor) and translates them to sensor value with a range from 0 to 1023 so that,

$$Vsensor = sensorValue * \frac{5}{1023} \tag{5}$$

For sensorValue to increment by 1, voltage would have to increase 5 over 1023 volts, or 4.9 mV. With the 300A sensor we had initially got, we were only able to create enough current from the winch to change the hall effect's voltage out, Vsensor, .2 mV. We observed this on a DMM after we found that sensor value would read a fixed value on our LCD which explained why the value read was fixed. To solve this we would of needed to implement an additional circuit for processing the signal to be read by the micro-controller. We considered this, but worried that we would sacrifice having a pcb for it in time for demo. We found that finding the right current sensor would solve this problem in time and it did. We got the Bayite BYT-VAM-033 100A sensor. 100 Amps still exceeds what to it should take to pull the tunnel and the variation in voltage is enough for us to read changes in current on the micro-controller.

3.5 Switching

Verification that the switching was working right required two things to be in order. First that the micro-controller can control the relay. Second that the relay and switched is connected appropriately to the off the shelf components.

3.5.1 Relay

Once our micro-controller was programmable, we tested the relay on a breadboard to switch off and on an LED. After verifying relay on circuit on the breadboard we waited on getting a hold of a winch to hook up the relay and switch 2 to. After switch 2 was successfully connected to the solenoid box, the middle wire was cut and attached to the relay part of the circuit on the pcb ad a program was written to keep the relay closed until 10 seconds elapsed when it would be open and the winch would stop. It did, and that verified that relay had worked and it continued to work, the diode is protecting the controller as it should and the transistors gain is enough to have the controller open and close the relay and shut on and off the winch without any issues.

3.5.2 Switch 2

We decided on connecting this switch to the contacts inside of the solenoid because we couldn't find a plug with pin arrangements that matched the ones that are on the winch. Although there would be some solder residue inside the solenoid box, the winch could still be returned. This shift in design allows for the off the shelf remote to work without unplugging and re-plugging our remote which turned out to be preferable.
Verification for this was simple. Supply 12 volts to the winches "battery" terminals, hit the switch and the winch turned.

4 Costs and Schedule

4.1 Labor and Parts

From the UIUC ECE average starting salary data for Electrical Engineering students, the average salary from the graduates of the academic year of 2019 to 2020 was $76,129 [5]. For our team, we each expect to contribute 10 hours per week for the rest of the semester to develop and test our prototype. In our cost calculation, we assume that the salary corresponds to a regular 40 hour work week while working 50 weeks out of the year.

During this project, we also received help from the machine shop. They have an hourly rate of $38.17 [6]. We estimate that the machine shop has spent 20 hours on our project between meetings and making parts.

Student Cost calculation:

$\$76,129$ / 50 weeks / 40 hours per week = $\$38.06$ per hour

$\$38.06 * 2.5 * 10$ hours per week $*$ 7 weeks = $\$6660.50$ per student.

$\$6660.50 * 3$ students = $\$19981.50$

Machine Shop calculation:

20 hours $*$ $38.17 per hour = $\$763.40$

The total project cost is the sum of the costs from the student labor, machine shop labor and the components in appendix C.

student + machine shop + components = $\$19981.50$ + $\$763.40$ + $\$376.06$

Total cost = $\$21120.96$

4.2 Schedule

Table 1: Schedule

Week	Youssef	Nisha	Jonathan
2/28	Finish Design Document and Design review	Finish Design Document and Design review	Finish Design Document and Design review
	Finalize Winch to circuit interface	Finish Microcontroller PCB	Power system PCB
	Assist with programming	Start developing the Microcontroller code	PCB validation and simulation
3/7	Finalize Machine shop revision	Ordering parts for PCBs	Assist with the machine shop final revisions

Week	Youssef	Nisha	Jonathan
	Order parts for the winch construction	Continue developing microcontroller code	Assist with microcontroller programming
3/14	Spring break	Spring break	Spring break
3/21	Get winch from ABE team	Soldering for Microcontroller	Soldering for Power System
	Characterization of the winch system and testing the winch under different loads	Characterization of microcontroller with testing with front panel and input switches	Characterization of power board
	Second round components	Second round Microcontroller PCB	Second round Power System PCB
3/28	Finish winch modular testing	Finish adjustments to Microcontroller	Finish adjustments to power board
	Full system build and integration testing	Full system build and integration testing	Full system build and integration testing
4/4	Full system testing with ABE team	Full system testing with ABE team	Full system testing with ABE team
4/11	Last week adjustments and testing	Last week adjustments and testing	Last week adjustments and testing
4/18	Mock demo	Mock demo	Mock demo
	Work on Final Paper and Presentation	Work on Final Paper and Presentation	Work on Final Paper and Presentation
4/25	Demonstration	Demonstration	Demonstration
5/2	Presentation and Final Paper	Presentation and Final Paper	Presentation and Final Paper
End of Table			

5 Conclusions

This project was started with the aim of improving the process of accomplishing a specific task, moving the deep tunnels at the SSF. Though, technically this project is not exceptionally complex, there were challenges in taking on a concrete but unsolved task and coming up for a design to tackle it. The contribution we thought would both be most useful as a senior design and in moving the tunnels are the modified features we added to the wire pulling motors found at department stores. It is possible that such an adaptation to these winches would be useful in moving the deep tunnels. But, maybe another method for moving the tunnels will show to be preferable. Even so, figuring out what doesn't work can be valuable as well. We are excited to have taken the opportunity to experiment and see if we could contribute to the mission of improving the mobilization of the tunnels at the SSF.

5.1 Accomplishments

We were successful in re-wiring the winch to be turned on and off by the micro-controlled relay on the latching switch. The micro-controller is being informed by two sensors to operate the winch so that it will not break under high tension or burn itself out. Also if the winch pulls its load to a destination, in front of an ultrasonic sensor, it will stop. A metal plate with holes for mounting to vehicle hitches was made by the machine shop. All the components (polycase, pcb, sensors, winch, solenoid box) fit onto this plate and everything can be powered from a 12 V car battery.

5.2 Uncertainties

The winch manual suggests the winch is let to cool off for 14 minutes following just 45 seconds of use. We are uncertain about the necessity of such a long cool down period for the duration of use cycle. Especially if it is not operating at capacity, it is likely the winch will be fine running longer than only 45 seconds every 15 minutes. Testing could be done, measuring the temperature of the motor over time while running the winch. With the data a duration of use cycle that would move the tunnels safely faster could be deduced.

One notable short coming was not having made the opportunity to test the system on the high tunnel. Perhaps if we were able to get our system built sooner, and had made plans to move the tunnels earlier, we would be able to have tried. Still, there is opportunity to see the mobilization of the tunnel evolve.

5.3 Ethical Considerations

Considering this project is aimed to help make sustainable agriculture easier, the implementation should maintain this sustainable ethos. Unfortunately, the mining the rare earth metals needed to build and power an electric winch and gas required to bring the anchor point (tractor) to the tunnel is less sustainable than making a rope and pulley system could be at moving the tunnels. One of the goals listed in section 7.8 of the IEEE code of ethics is, "to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies."(IEEE 7.8) The technology we are developing enables farmers to utilize the most out of their season without needing to rally or hire a large group of people to move their deep tunnels. It is important to emphasize that this convenience advances our ability as individuals to produce agriculture independently so that we are no longer dependent on unethical, unsustainable food chains to feed us. People are becoming aware of the societal and environmental benefits of such a shift into local, owner run farms. As the code suggests, it is important to make sure that people are aware that with agricultural and technological advancements, organizing to live locally is possible. But also again there is the important point that we are insistent on taking, and we may take the earth metals, neglecting the crust of the earth we are reliant on in order for perhaps unnecessary conveniences.

5.4 Future Work

Calculating a way to estimate an appropriate cool down cycle that adjusts to the load the winch is pulling would be an interesting challenge. Or, simply adding potentiometers so the winch user can make adjustments to the duration of use cycle manually could be helpful.

Neither of these would be of any value for the SSF if the mechanical portion of the winching is not compelling. Improvements likely need to be made. Having 100ft of wire on a drum rather than the 50ft would be one. Another important one is connecting to the tunnel so that the forces applied on the winch and the tunnel are not large in the direction perpendicular to the soil. The possible distance between the tractor hitch and the end of the tunnel nearest the hitch is constrained so as to make this desired direction of force to be applied harder to achieve. You wouldn't be able to just park the winch far away from the tunnel so that the line is more parallel to the ground when you pull. This issue is, in regards to moving the tunnels with the winch, critical.

References

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[6] S. of Chemical Sciences. “Machine shop rates.” (2020), [Online]. Available: https://answers.uillinois.edu/scs/page.php?id=106353 (visited on 05/01/2022).

Appendix A Microcontroller Code

```
#include <LiquidCrystal.h>

//ultrasonic sensor
const int echoPin = PIN_PB7, trigPin = PIN_PD5;
long duration; // variable for the duration of sound wave travel
int distance; // variable for the distance measurement

//lcd panel
const int rs = PIN_PC4, en = PIN_PD1;
const int d4 = PIN_PC0, d5 = PIN_PC1, d6 = PIN_PC2, d7 = PIN_PC3;
const in rw = PIN_PD0;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

//Other pins
const int LED1 = PIN_PD6, current = PIN_PC5, relay = PIN_PB0;

void setup() {
  //LCD
  pinMode(rw, OUTPUT);
  digitalWrite(rw, LOW);
  pinMode(trigPin, OUTPUT); // Sets the trigPin as an OUTPUT
  pinMode(echoPin, INPUT); // Sets the echoPin as an INPUT
  // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);

  //other pins
  pinMode(current, INPUT);
  pinMode(relay, OUTPUT);
  digitalWrite(relay, HIGH);
  pinMode(LED1, OUTPUT);
  digitalWrite(LED1, LOW);
}

void loop() {
  //Ultrasonic sensor
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  // Calculating the distance in cm
  distance = duration * 0.034 / 2;
```

```
//Print distance
lcd.setCursor(0, 0);
//reset lcd row 1
for (int i = 0; i < 16; ++i)
{
  lcd.write(' ');
}
lcd.setCursor(0, 0);
lcd.print(distance); //prints distance in cm
lcd.print(" cm");
delay(10);

//reset lcd row 2
lcd.setCursor(0, 1);
for (int i = 0; i < 16; ++i)
{
  lcd.write(' ');
}

//current sensor
lcd.setCursor(0, 1);
float current1 = 8*(analogRead(current)-528)/31;
lcd.print(int(current1));

//Relay
lcd.setCursor(8,0);
//if off, stay off until system reset
if(off ==1)
{
  digitalWrite(relay, LOW);
  lcd.print("OFF");
  delay(20);
  off = 1;
  digitalWrite(LED1, HIGH);
}
else if(analogRead(current) > 700)
{
  digitalWrite(relay, LOW);
  lcd.print("OFF");
  delay(20);
  off = 1;
  digitalWrite(LED1, HIGH);
}
else if(distance <20)
```

```
{
  digitalWrite(relay, LOW);
  lcd.print("OFF");
  delay(20);
  off = 1;
  digitalWrite(LED1, HIGH);
}
else if((millis()% 90000) >45000)
{
  digitalWrite(relay, LOW);
  lcd.print("OFF");
  delay(20);
}
else
{
  digitalWrite(relay, HIGH);
  lcd.print("ON");
  delay(20);
}

//Clock
lcd.setCursor(8, 1);
if(millis()<60000)
{
  lcd.print("00:");
  if(millis()<10000)
  {
    lcd.print("0");
  }
  lcd.print(millis()/1000);
}
else if(millis()<3600000)
{
  if(millis()<600000)
  {
    lcd.print("0");
  }
  lcd.print(millis()/60000);
  lcd.print(":");
  if((millis()%60000)/1000 < 10)
  {
    lcd.print("0");
  }
  lcd.print((millis()%60000)/1000);
}
```

```
  else  if(millis()<86400000)
  {
    if(millis()<36000000)
    {
      lcd.print("0");
    }
    lcd.print(millis()/3600000);
    lcd.print(":");
    if(millis()<600000)
    {
      lcd.print("0");
    }
    lcd.print(millis()/60000);
  }
  else
  {
    lcd.print(">1day");
  }

}
```

Appendix B Project Description from ABE's Canvas website.

Method:	
Project Description:	The Sustainable Student Farm has 3 moveable hight tunnels (unheated greenhouses). We move them 1-2 times a year depending on the crop rotations we are working with. Currently we need 10-14 people to help push these tunnels. If the Tunnels were situated differently we might be able to pull them with 2 tractors but as they are positioned there are sheds on one end of the tunnel area and on the other side a field that may or may not have active crops in it at the time of our tunnel move. We are asking that you design some kind of system that would allow us to automate at least one of our tunnels. We often move 2 tunnels in a day and move 1 seperately, it can be a challenge to get 10-14 people together out to the farm at the same time let alone twice in a a 1-2 week period. If you can design somthing that would allow us to move at least one of these tunnels with only a couple of people that would be a huge help. If it is a system that could potentially move multiple tunnels, all the better. Assume we have no active electricity near the tunnels, so power will need to be brought in somehow. The the tunnel cannot be pulled from a single location, the structure has very little strength laterally so each side of the tunnel needs to be pulled from a seperate point so that the pulling vector is parallel to the tracks. The tunnels each have 2 positions so they get moved from east to west and then from west to east so the system will have to be able to move the tunnels in two directions.
Comments:	Project will be completed collaboratively with ECE Capstone team members

Appendix C Parts Table

Table 2: Components Table

Item And Part Number	Quantity	Unit Cost	Total Cost
2500 Lb. ATV/Utility Winch With Wire Rope And Wireless Remote Control	1	$94.99	$94.99
bayite DC 5-120V 100A Mini Digital Current Voltage Amp Meter Ammeter Gauge with Hall Effect Sensor Transformer	2	$18.98	$37.96
280 PCS Insulated Wire Electrical Connectors Assortment - Fork, Ring, Spade, Quick Disconnect - Crimp Marine Automotive Cable Terminals	1	$10.99	$10.99
ATMEGA168PV-10PU-ND IC MCU 8BIT 16KB FLASH 28DIP	4	$4.34	$17.28
2389-CF880.05.04-ND CABLE 4COND 20AWG BLACK 1=1FT	30	$0.57	$17.10
377-2210-ND CABLE GLAND 4.1-7.9MM PG9 NYLON	8	$0.90	$7.20
338-2336-ND CAP ALUM 100UF 20% 100V RADIAL	3	$2.14	$6.42
1189-1545-1-ND CAP ALUM 1000UF 20% 16V RADIAL	3	$0.47	$1.41
445-SPM7054VC-101M-DCT-ND INDUCTORS FOR POWER CIRCUITS, FO	3	$1.82	$5.46
497-11370-1-ND DIODE SCHOTTKY 40V 3A DO201AD	3	$0.43	$1.29
LM2575D2T-5R4GOSCT-ND IC REG BUCK 5V 1A D2PAK-5	3	$2.84	$8.52
1276-1015-1-ND CAP CER 10000PF 50V X7R 0805	6	$0.10	$0.60
MBR0520TPMSCT-ND DIODE SCHOTTKY 20V 500MA SOD123	3	$0.35	$1.05
1N4149-ND DIODE GEN PURP 100V 500MA DO35	3	$0.13	$0.39

Item And Part Number	Quantity	Unit Cost	Total Cost
516-HL3P-NR45-J00DDCT-ND LED HL3P RED 627NM T1	2	$0.60	$1.20
TLP3544(F)-ND SSR RELAY SPST-NO 3.5A 0-40V	3	$4.28	$12.84
132-L37S300S05M-ND CURRENT SENSOR (300A; +5V)	2	$18.76	$37.52
ED3050-5-ND CONN IC DIP SOCKET 28POS TIN	2	$0.37	$0.74
2057-BHR-06-VUA-ND CONN HEADER VERT 6POS 2.54MM	2	$0.26	$0.54
WM4111-ND CONN HEADER VERT 2POS 2.54MM	6	$0.29	$1.74
WM4202-ND CONN HEADER VERT 4POS 2.54MM	2	$0.33	$0.66
WM11186-ND CONN HEADER VERT 16POS 2.54MM	2	$2.35	$4.70
587-2045-1-ND FIXED IND 10UH 150MA 360MOHM SMD	3	$0.14	$0.42
2N3904TARCT-ND TRANS NPN 40V 200MA TO92-3	3	$0.38	$1.14
RNCP0805FTD10K0CT-ND RES 10K OHM 1% 1/4W 0805	8	$0.10	$0.80
RNCP0805FTD1K00CT-ND RES 1K OHM 1% 1/4W 0805	10	$0.10	$1.00
1568-1616-ND TRIMMER 10K OHM 0.5W PC PIN TOP	3	$0.95	$2.85
WM4202-ND CONN HEADER VERT 4POS 2.54MM	6	$0.33	$1.98
WM2022-ND CONN HOUSING 4POS 2.5MM	3	$0.44	$1.32
1528-2711-ND ULTRASONIC SENSOR SONAR DISTANCE	2	$3.95	$7.90
1528-1505-ND LCD MODULE 32 DIG 16 X 2 R/G/B	2	$12.95	$25.90

Item And Part Number	Quantity	Unit Cost	Total Cost
ED3050-5-ND CONN IC DIP SOCKET 28POS TIN	1	$0.37	$0.37
WM21005TR-ND CONN 22-30AWG CRIMP TIN	20	$0.60	$12.00
1528-4944-ND 2.54MM 0.1 PITCH 16-PIN JUMPER C	1	$1.75	$1.75
A106489-ND CONN RCPT HOUSING 2POS CRIMP	3	$0.49	$1.47
2299-RA1-2F-DC-2-B-5-ND ROUND ROCKER DP ON-OFF-ONPRINT	1	$3.57	$3.57
EG1889-ND SWITCH ROCKER SPST 10A 125V	1	$3.12	$3.12
WP-23F Polycarbonate NEMA Enclosure	1	$15.65	$15.65
SCREWS-MBR-100 PCB Mounting Boss Screws	1	$4.22	$4.22
Printed Circuit Board, PCBWay	4	$5.00	$20.00
End of Table			

Note: Some small components such as resistors, LEDs, and screws are not included in the parts table.

Appendix D Schematics

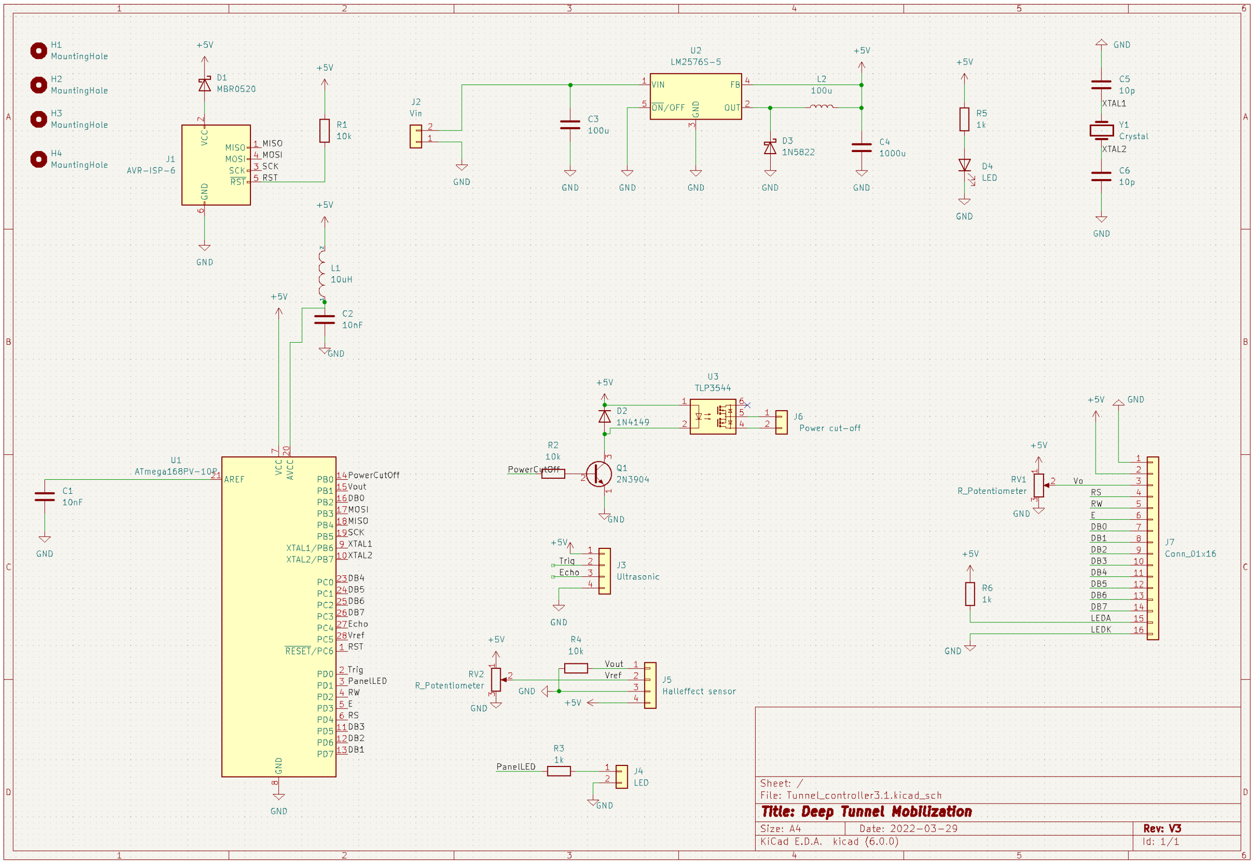

Figure 6: Overall Schematic