Team 1 Design Phase 1

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I. Introduction

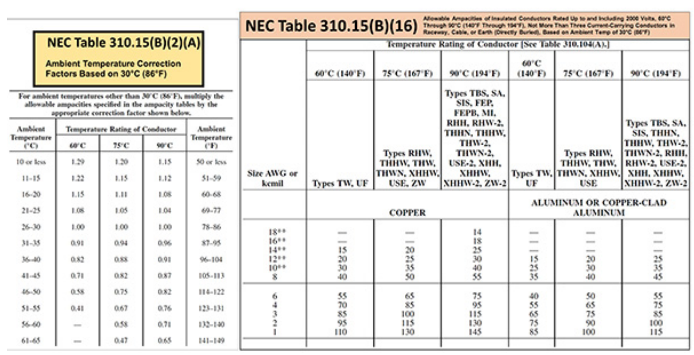
In Design Phase 1, the team began to formulate a high-level design of the autonomous crawl space inspection robot. This included an atomic block diagram of the overall system along with a schedule of tasks. Preliminary ideas for each subsystem's detailed design were also generated during this phase along with justifications describing why the decisions were made. The Design Phase 1 process also allows team members to begin to break their design into atomic subsystems and to formulate possible relationships between each of the subsystems. In the block diagram, the information being sent between each block is specified along with a unit to provide a clear picture of what information is being sent. After describing the conceptual design, the methods used to analyse each subsystem are explained to confirm that the team has a way to prove that the system can be confirmed on paper before assembly while also removing the risks associated with the design.

A. The Identified Problem

The current inspection of crawl spaces requires the use of human time and effort, which is an inefficient use of time and labor. Additionally, the current inspection process of crawl spaces by human operators could result in a lack of recorded measurements which would be useful in the analysis of the crawl space environment. The objective of this capstone project is to create an autonomous crawl space inspection robot which is capable of navigating, traversing, and capturing images, humidity levels, temperature levels, and moisture levels of a crawl space environment. The robot also will need to adhere to an understanding of the specifications and constraints placed on the design by engineering background requirements, broader impacts, ethical considerations, and engineering standards. The design set forth by the capstone team for an autonomous crawl space inspection robot is adherent to all constraints, however, some specifications such as the transmission of live video feed for manual control have not yet been resolved. In order to allow for the possibility of including this specification in the future, the project team has chosen to incorporate all hardware needed for the foundation of manual control by radio or WIFI transmission.

In addition to increasing the time management of individuals and the accuracy of recorded measurements, the device designed will allow for the inspection of crawl spaces that would otherwise be challenging to examine due to size constraints of human inspectors. A maximum height specification of sixteen inches has been created which will allow the robot to fit into crawl spaces which have a height equivalent to two or fewer eight-inch concrete blocks. Additionally, the robot will need to have a power system which is capable of supplying the different voltages required for DC Motors. Micro-controllers normally require around 5V so a bus for this value will be included a well. The power system of the device will also need to be capable of supplying enough power for the time required for the robot to navigate throughout the crawl space environment. The project team has not yet determined an exact range of time needed for the total inspection process, however, after comparing the proposed design to other available commercial products, the team believes that a total operation time of one to three hours will be needed.

II. Ethical, Professional, and Standard Considerations



NEC Table 310.15(B)(2)(A)
Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor 60°C	75°C	90°C	Ambient Temperature (°F)
10 or less	1.29	1.20	1.15	50 or less
11-15	1.22	1.15	1.12	51-59
16-20	1.15	1.11	1.08	60-68
21-25	1.08	1.05	1.04	69-77
26-30	1.00	1.00	1.00	78-86
31-35	0.91	0.94	0.96	87-95
36-40	0.82	0.88	0.91	96-104
41-45	0.71	0.82	0.87	105-113
46-50	0.58	0.75	0.82	114-122
51-55	0.41	0.67	0.76	123-131
56-60	—	0.58	0.71	132-140
61-65	—	0.47	0.65	141-149

NEC Table 310.15(B)(16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temp of 30°C (86°F)

	Temperature Rating of Conductor [See Table 310.104(A).]					
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)
Size AWG or kcmil	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM		
18**	—	—	14	—	—	—
16**	—	—	18	—	—	—
14**	15	20	25	—	—	—
12**	20	25	30	15	20	25
10**	30	35	40	25	30	35
8	40	50	55	35	40	45
6	55	65	75	40	50	55
4	70	85	95	55	65	75
3	85	100	115	65	75	85
2	95	115	130	75	90	100
1	110	130	145	85	100	115

Fig. 1. NEC Wire Gauge Chart

As outlined in Article 310.10.C of the NEC standard, also called NFPA 70, the cables and conductors used in the design will need to be moisture impervious or metal-sheathed due to the crawl space environment possibly being wet and containing high moisture levels [2]. Due to the presence of flammable material within the crawl space environment, the robot must include proper wire insulation and fuses which will help to regulate the temperature of the machine and mitigate fire safety hazards. The NEC also outlines a process for choosing wire gauges based on current loading and ambient temperature [1]. The associated chart is found in figure 1.

Destruction of a person's home serves as the primary ethical consideration for this project; thus this consideration has affected many design decisions. Firstly, the extending arm and wood moisture probe must not damage any overhanging items within the crawlspace. A spring and initial resistance measurement have been put in place to meet this. Next, the size, speed, and weight of the robot have been considered. A large, rampaging robot is a much more serious risk than a small controlled one. Limiting the robot's size and regulating the speed at which it operates ensures that important structures under the home are not damaged because the robot is incapable of generating the force required to do so.

Another major concern with sending a robot through a client's house will be privacy. Network privacy will be protected by using a separate, local router when further communication needs to be implemented for the manual control video stream. This video stream will also only be activated during times of manual control and will not include audio to avoid the recording of private data. Although this addition will likely not be a part of the first prototype, these considerations will be kept in mind throughout the hardware design to set the basis for future development.

III. System Design

The robot has been broken into 4 subsystems which are designed to be as modular and self-contained as possible. These subsystems are power, navigation, sensing, and movement. Power will be responsible for supplying power to all the other modules at the required voltages. Navigation handles positioning sensing and autonomy. This is distinct from the sensing subsystem as the navigation system uses sensors only for positioning and the sensing subsystem is concerned with environmental sensing such as humidity, temperature, and moisture. Finally, the movement subsystem is responsible for controlling all the motors and mechanical aspects of controlling a robot.

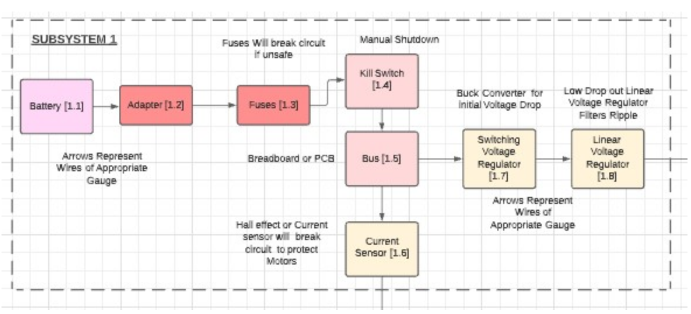


Fig. 2. Power Subsystem

A. Subsystem 1: Power

Rechargeable power tool batteries will be used as the voltage source for the power subsystem. The batteries are modular by design and are readily available for ease of use. The voltage source will be divided using an electrical bus bar. The bus bar will have fuses built in to protect subsystems from pulling dangerous amounts of current from the battery. A bus bar built for marine applications will be most appropriate for the crawlspace environment, and there are many inexpensive options available. The micro-controllers required for other subsystems creates a need for an efficient and safe way to decrease battery voltage. The most efficient method readily available is a buck converter. The buck converter has efficiencies approaching 100%, but they come with drawbacks. The most concerning drawback is high-frequency noise from switching transistors. High-frequency noise has the potential to cascade through the bus and create disruption in all subsystems. The first solution to this problem will be capacitors in parallel with all subsystems. The capacitors may eliminate the need for further high-frequency filters. The other concern is a startup transient that is observed in simulations. The startup transient is an under-damped response that requires time to reach a steady-state response of voltage. There is a potential that the initial overshoot in voltage may damage sensitive components. The proposed solution is a Low Drop Out Linear voltage regulator in series with the buck converter before the micro-controllers. Figure 3 shows a simulation of the proposed setup.

The voltage for the motors will be controlled with a motor controller module that accepts commands from a micro-controller and has under voltage protection to prevent large instantaneous current from damaging the components.

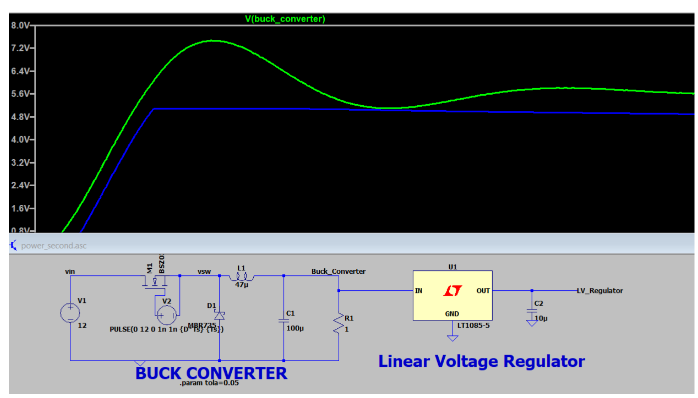


Fig. 3. Proposed Micro-Controller Power Supply

B. Subsystem 2: Environment Sensors

The sensing system will be responsible for recording environmental data and saving it in a table along with a location stamp. The design will emphasize modularity so that broken

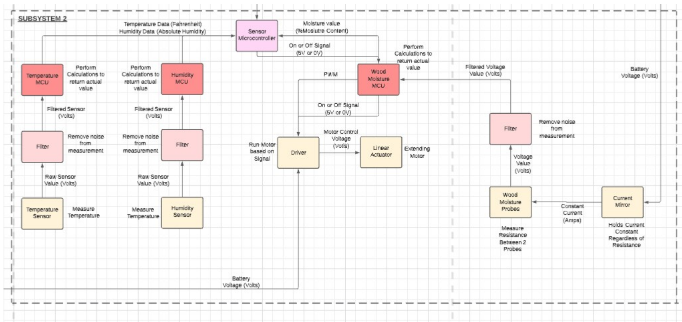


Fig. 4. Environmental Sensing Subsystem

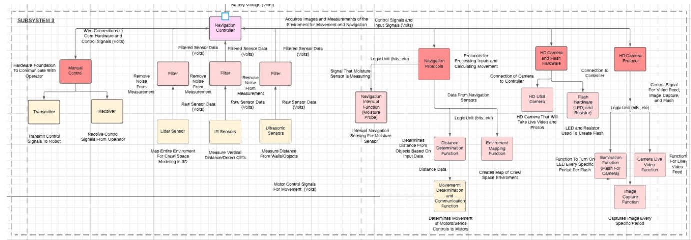


Fig. 5. Navigation Subsystem

sensors can be replaced and new sensing options can be added. Each sensor will be paired with its own small micro-controller which will communicate back to the MCU by first sending a tag with the values label and then sending the data. The main MCU will then sort this into a table with the tag determining which column it falls into. The locations are included to allow the operator to match data points to the robot's location at the time of recording.

For the first iteration of the robot, three sensors will be included. Commercial sensors will be used for humidity and temperature along with filters to remove extraneous data. However, the wood moisture sensor will need to be designed specifically for this application. This will be done using a current mirror which can provide a constant current through the probe. This means that when the probe is connected through the wood a voltage will be read across it and simple math can be done to convert this to a resistance. The resistance of the wood is proportional to the moisture content so the conversion can then be completed. Filtering will be included with this circuit as well. To prevent the moisture probe from damaging anything and ensure it applies the correct pressure, a spring will be included on each prong of the probe. These springs will work as mechanical feedback to stop the arm from pushing too deep. Another damage prevention measure will include checking the resistance between the probes as they are raised. If there is found to be near-zero resistance at any point, it can be concluded that the probes are contacting something metal such as ductwork or conduit. When this is detected the arm will stop raising, lower back down, and a new spot will be found for the measurement. This protection system will be updated in future iterations but this will be the system used in the first revision.

C. Subsystem 3: Navigation

The navigation subsystem will be responsible for the following: acquiring data from the LIDAR, IR, and Ultrasonic sensors, processing the acquired data in order to determine the movement protocol for the robot as well as developing a 3D model of the environment, capturing images of the crawl space environment with an HD camera, and incorporate transmission hardware for a foundation for manual control of the robot. The navigation subsystem will be controlled by a micro-controller, most likely a raspberry pi, and will operate as the main processor of the autonomous crawl space inspection robot. The five main branches of the navigation subsystem are manual control hardware, navigation sensing, navigation protocol, HD camera hardware, and HD camera protocol.

The manual control branch of the navigation subsystem will consist of a transmitter and receiver, which will lay the foundation for communication between the device and an operator in the case that human intervention is required for the robot to return to its origin. The navigation sensor branch will consist of three sensor modules, LIDAR, IR, and Ultrasonic, which will be used to measure the position of the robot, as well as the distance of objects from the robot. A light detection and ranging (LIDAR) sensor is a device that fires a narrow, infrared, pulse of light, commonly referred to as a laser, from a transmitter terminal. The LIDAR sensor then utilizes a clock in order to track the time taken for the pulse to refract from an obstacle back to a receiver [3]. This LIDAR sensor module will be used to determine the static position of the surrounding obstacles, thus allowing the capstone team to develop a two-dimensional model of the crawl space environment [3].

A LIDAR sensor is commonly mistaken with a non-laser, infrared (IR) sensor, which utilizes infrared light in order to detect when an emitted beam is broken, revealing that an obstruction is present and outputting an appropriate logic signal [3]. The IR sensor module will be used to determine the vertical position of the crawl space robot in the case that dips and holes are encountered during the inspection of the crawl space environment. While the first design iteration of the device might not utilize the IR sensors for vertical measurements, the team members believe that the inclusion of these sensors are an important feature to include for future iterations of the design.

Sound sensors, commonly referred to as ultrasonic sensors, utilize a clock, a transmitter, and a receiver in order to determine distance from an object. Ultrasonic sensors are able to determine the distance from an object by tracking the time taken for a transmitted sound wave to be received after reflecting off an object [3]. The ultrasonic sensor module will be composed of ultrasonic sensors on each side of the robot which will help to determine the distance of objects from the robot. This module will be used together with the LIDAR sensor module to confirm the robot's distance from surrounding object and determine if any objects are in the path of the robot as it navigates throughout the crawl space environment.

The navigation protocol branch of the navigation subsystem will be responsible for utilizing data acquired from the LIDAR, IR, and Ultrasonic sensors in order to determine the location of the robot and develop a virtual model of the crawl space environment in real-time, while simultaneously determining the movement for the robot. The first main function of the navigation protocol branch will be the function to call inputs from the navigation sensors and then use that data to determine the current distance of all objects from the device. After determining the distance of objects from the device, another function will be used to develop a two-dimensional model and establish the current position of the robot in respect to the surrounding objects.

Another function will then be used to determine the best direction of movement for the device based on its current position and relationship to unexplored areas of the crawl space environment. Finally, the command signals for the motors will be sent to the movement subsystem through the utilization of the robot operating system (ROS) application. By utilizing the mid-ware application ROS, the team members can establish motors, sensors, other components and protocols as nodes of a system, which will allow for the processing and transmission of information to be executed simultaneously, known as multi-threading [4]. The previously described protocols will be repeated as quickly as possible to allow for the least amount of delay between the determination of movement and motor execution.

The HD camera branch of the navigation subsystem will consist of the high definition (HD) camera which will be used to capture images as well as possibly stream a live video feed. This HD camera hardware branch will also include a simple LED and resistor circuit which will be used to provide proper lighting for image capture and the possible live video feed. The HD camera will be connected to the proposed micro-controller via USB connection. The LED and resistor circuit will consist of a LED and a resistor to limit the current provided to the LED, which will prevent damage to the illuminated component. The LED and resistor will be connected directly to the micro-controller to allow for control of the illumination for image capture and possible live video feed.

The HD camera protocol branch of the navigation subsystem will consist of three basic functions which will be used to control the hardware responsible for flash illumination, live video feed, and image capture. The illumination function will be used to turn the LED on and off when needed for capturing images, thus creating a flash effect typically seen in photography. Additionally, if live video feed is incorporated for the human operator to manually control the robot, this LED can be left on to provide sight when controlling the robot. The live video function will be used to constantly provide access to the live video feed from the camera, which will lay the foundation for live video feed transmission for future manual control protocols. Typically, when using a camera and micro-controller to capture images, live video feed is first established with image capture occurring once a condition is met [5]. The image capture function will be executed as the robot navigates throughout the crawl space environment. The condition for image capture will be specific intervals of time, thus allowing for images to frequently be taken as the robot navigates its surroundings.

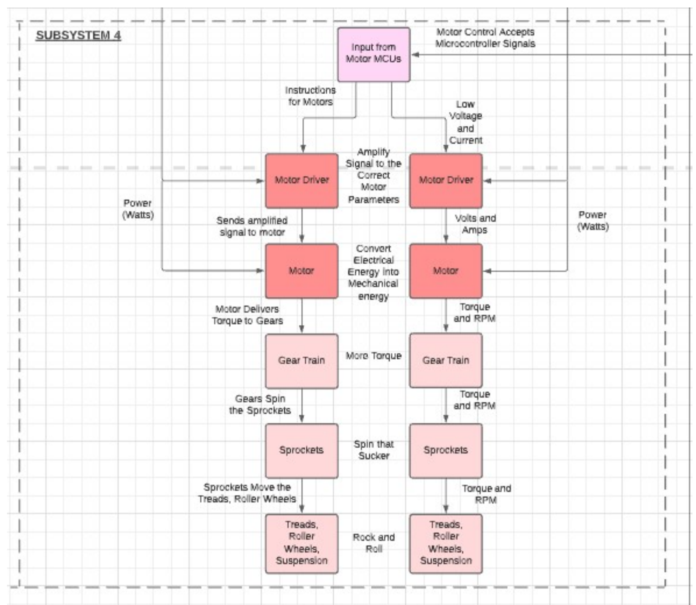


Fig. 6. Navigation Subsystem

D. Subsystem 4: Movement

The movement subsystem is responsible for the motors and mechanical aspects of the movement. This subsystem can be divided into two main sections: electrical and mechanical.

The electrical section of the movement subsystem receives its input from the navigation subsystem. Those signals are then amplified through motor drivers and delivered to the motors where the electrical energy is converted into mechanical energy. The motor drivers and motors will require power input from the power subsystem. The voltage delivered to the motors will determine the speed at which the robot moves.

The mechanical section of the movement subsystem consists of a gear train, sprockets, continuous treads, and roller wheels both mounted and suspended. A gear train will be necessary for the appropriate torque to be supplied to the sprocket and continuous tread system. Mounted roller wheels and a suspension system of additional roller wheels will be put in place to allow for a smoother ride. The robot will be able to overcome many types of terrain and obstacles using this technique.

IV. Analytic Methods of Subsystem Verification

A. Subsystem 1: Power

The power system will need to have each atomic subsystem tested to ensure they are within specifications. Components such resistors and capacitors are relatively straight-forward to test, but the buck converter and linear voltage regulator are the components that require rigorous testing. The first test will use a DC power bank and oscilloscope to ensure that the buck converter is outputting a safe voltage for the micro-controllers to use. Depending on the specific models selected, the target voltage from the buck converter will be 5 V. The transient response of the buck converter will be around 1.2 ms if simulations hold accurate. Depending on the model of buck converter selected it may not be an issue, but an oscilloscope will be used to verify it. The bus bar can be measured with a DC power supply and a multimeter to ensure correct operation. The motor control module will also be connected to a DC power supply and measured to ensure it is within specifications. The exact numbers to look for during analytic testing will depend on the requirements of other subsystems.

B. Subsystem 2: Environment Sensors

The easiest systems to verify will be the off the shelf sensors for humidity and temperature as these can be mostly verified using the datasheets. Specifically, power ratings will be found and calculations will be performed to ensure that the parts will be receiving and returning the correct voltages. Communication protocols will also be checked to make sure the sensors and controller are communicating correctly. The filters for each of these will be designed according to their individual sensor and will be verified using an LTspice simulation. Similarly, the moisture sensing circuitry such as the circuit mirror will also be verified using a circuit simulation. A preliminary version of the circuit has been built already and can be found in figure 7 although the part numbers and values are not yet finalized. For the mechanical parts like the arm and spring feedback, force and kinematics analysis will be done to verify that the arm can lift everything it needs to and that no damage will be done to the crawlspace. This will be verified by looking at the graphs in the linear actuator datasheet to find the force to input voltage ratio. Force and kinematic analysis will then be applied with the spring factored in as well to achieve a full picture of the mechanical operation of the arm.

C. Subsystem 3: Navigation

In order to verify that the Lidar, IR, and Ultrasonic sensors are behaving properly, the team members will be comparing the input and output voltages of the sensors with the appro-

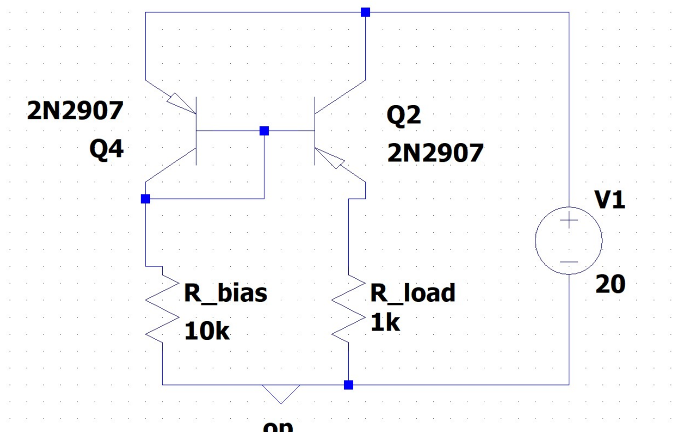


Fig. 7. Current Mirror Circuit

priate voltage intervals listed in the datasheets of the sensors. The team members will be able to simulate each of the sensors by allowing for 3.3 Volt and 5 Volt inputs for the sensors and determining the voltage range which will be output by the sensors from the associated datasheet. Next, the team members will utilize LTSpice simulations to verify that system components are behaving correctly in their subcircuits and that any excess voltage or noise is properly regulated by the designed hardware filters. By cross-examining the appropriate input and output voltages with the listed expectations in datasheets and simulations, the team members will be able to confirm that the subsystem adheres to the provided specifications.

Team members will also be analyzing all functions within the navigation protocol and HD camera protocol branches to determine if the required functionality of each branch of the subsystem has been achieved. For example, the team will analyze whether or not each function within the navigation protocol accepts the correct inputs and produces the correct outputs for what the functions are programmed to achieve. In the case of the HD camera flash function, the team members will simulate the function by inputting an appropriate variable, most likely a time interval for illumination, and then analyze what voltage would be output for the LED as well the time in seconds that the voltage will be constant to simulate a flash for image capture. The previously mentioned analysis process can be repeated for each protocol function by determining the desired inputs and outputs for each protocol and analyzing the accuracy of adherence to those inputs and outputs.

D. Subsystem 4: Movement

Determining the magnitude of torque necessary for moving the robot will force the use of kinematic analysis. A series of calculations involving the robot's normal force, the moment of inertia about the rotating sprocket, the static friction that must be overcome, and gear ratios will be used to identify the correct torque. Also, the voltage and current to be supplied to the motors will be determined by examining the motors' datasheets as well as manual testing on the motor to discover what combination of voltage and current will result in the desired torque to be output to the gear train. This subsystem will then be placed into the model crawlspace to ensure that the robot can maneuver appropriately.

The model crawlspace will be an initial testing ground to test if the robot is capable of navigating a space successfully. The model will be approximately 25 square feet at a height of 3 blocks and contain 2 obstacles for the robot to maneuver around. Additionally, 3 joists made from 2x4 wooden beams will be placed on top of the model in order to test the linear actuator for the wood moisture probe as well as confirm that the robot meets the height requirements to fit within a crawl space. Near the end of the project, the team will work to find a suitable crawl space to test the robot in a controlled, supervised, real-world setting to serve as the ultimate test.

V. Risk Mitigation

A. Critical Unknowns

As part of designing the block diagram, many of the critical unknowns which were causing concern during the initial planning have been resolved. For example, the concern over battery life was resolved when an electric lawnmower was found that can run a large motor for hours with drill batteries similar to the ones the robot will use [6]. The only new critical unknown found during phase 1 is the heat output of the micro-controller. Controllers such as Raspberry Pi's can often overheat when having to run for long periods of time and this could cause damage to the robot's parts or crawlspace. Analysis will have to be performed in phase 2 to ensure the correct heat dissipation methods are used for the amount of heat it will give off.

B. Subsystem 1: Power

The risk of fire from drawing unsafe levels of current is one of the most important risks to address. The first preventative module is seen in the fuses block. The fuses will break the circuit at the adapter if unsafe current levels are exceeded. The maximum for the current will come when specific motors are chosen as they are the suspected largest source of current drain. Block 1.3 will have a backup fuse for redundancy in case one fuse fails there will be a backup. The Switching Voltage Regulator and Linear Voltage Regulator will be selected with worst-case power consumption in mind and rated appropriately. Block 1.6 will provide an additional layer of current protection for the motors and will communicate with the motor control module.

C. Subsystem 2: Environment Sensors

The environment sensor subsystem risks poor performance if there is a failure. The risk mitigation for this subsystem will come from two methods. There will be a modular implementation of the design. The sensors will each have a dedicated micro-controller. This allows the easy replacement of a system in case there is a failure. The second risk mitigation tactic will be extensive testing of each module. The crawlspace environment will be imitated and each sensor tested extensively.

D. Subsystem 3: Navigation

The navigation subsystem risks poor performance in the event of a failure. The most likely risk would leave the robot stranded with no means of returning to the starting location. The crucial risk prevention strategy will be a foundation for a manual override section of the subsystem that would allow the operator to take control of the vehicle directly. Additionally, team members have discussed the inclusion of an interruption protocol which would allow the robot to reverse directions and travel back on the same path to its origin. In the case that the robot is unable to move, an error signal would be sent to the manual control device, thus informing the operator that assistance for movement is needed. The vehicle will also be equipped with light so that locating it in low light conditions will be possible.

E. Subsystem 4: Movement

Failure of this subsystem could have similar effects to the Navigation system. The device could become incapacitated without being able to return to its starting position. The prevention method for this subsystem will be extensive testing of the chassis, suspension, and gear trains in a simulated crawlspace environment. Parts with good environmental ratings will also be chosen to greatly reduce the risk of a breakdown.

VI. Timeline

An updated Gantt chart showing the rest of the semester can be found in the document appendix. Because the system design has a more clear path, the tasks have been updated to more accurately reflect what will be worked on in the coming weeks. It was also decided which part of each subsystem will be signed off on as part of checkpoint one and checkpoint two. This was decided based on which parts would have the most effect on the rest of the system. For checkpoint one, the micro-controller was chosen to be designed as it poses the most risk if it has to be changed at a later date. A second Gantt chart was made to include the assembly tasks which will be needed next semester with estimated completion dates for each task.

VII. Conclusion

Crawl Spaces are an important but often forgotten section of a residential home. The environment and climate of a crawl space not only have a direct impact on those that live in the home but also on the professionals that are exposed to the crawl space environment. The purpose of this capstone project is to provide a safer, more efficient, and autonomous method for collecting environmental data within a crawl space. The Autonomous Crawl Space Inspection Robot will be an effective solution to the problem formulated through the examination of background information, constraints, specifications, broader impacts, and ethical and engineering standards. The design phase one document details the high-level specifications of the design plan and will serve as a guide for the team members as they begin design phase two.

VIII. References

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IX. Appendix

Crawlspace Inspection Robot

Group 1

Jim Camp, J.C. Williams, John Harris, Joseph Thomas

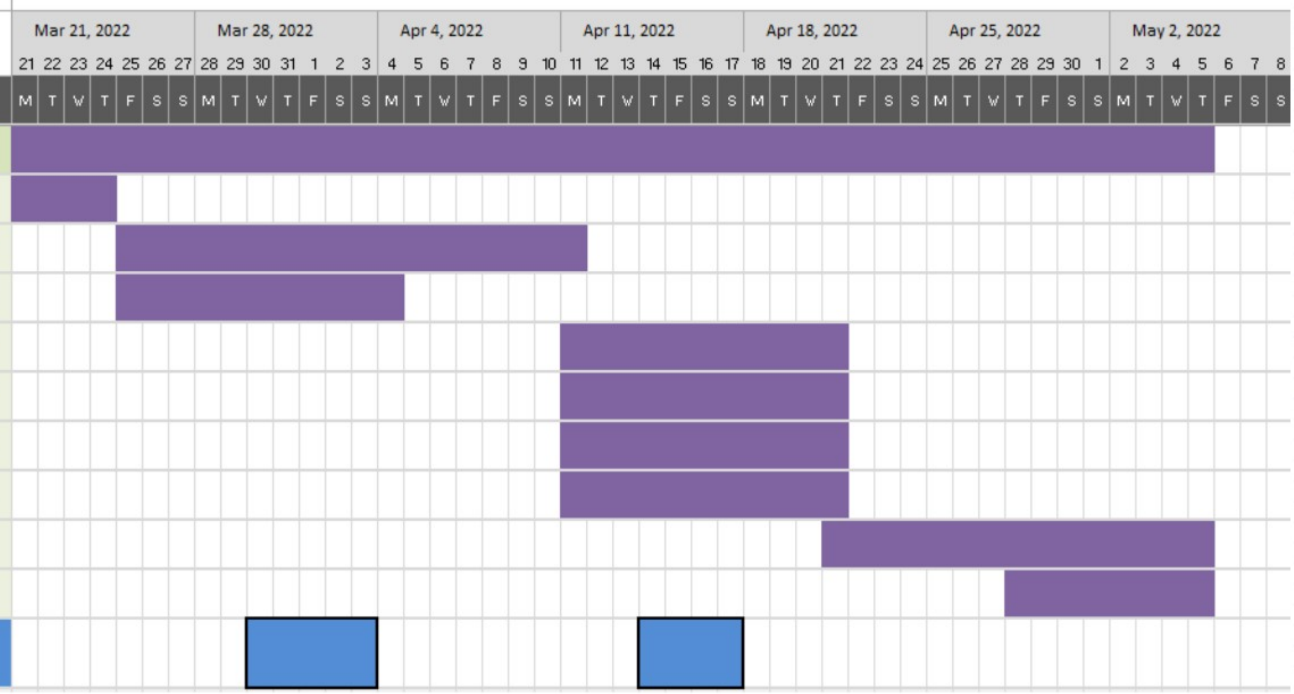
SIMPLE GANTT CHART by Vertex42.com

https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

Project Start: Sun, 3/20/2022

Display Week: 1

TASK	ASSIGNED TO	START	END
Spring Semester		3/20/22	5/5/22
Design Phase 1 Presentation	Everyone	3/21/22	3/24/22
FMEA Video	Everyone	3/25/22	4/11/22
Checkpoint 1: ROS	Everyone	3/25/22	4/4/22
Checkpoint 2: Motors	Jospeh Thomas	4/11/22	4/21/22
Checkpoint 2: Temperature	Jim Camp	4/11/22	4/21/22
Checkpoint 2: Battery	John Harris	4/11/22	4/21/22
Checkpoint 2: Lidar System	J.C. Williams	4/11/22	4/21/22
Phase 2 Draft	Everyone	4/21/22	5/5/22
Phase 2 Draft Presentation	Everyone	4/28/22	5/5/22
Holidays			



Crawlspace Inspection Robot

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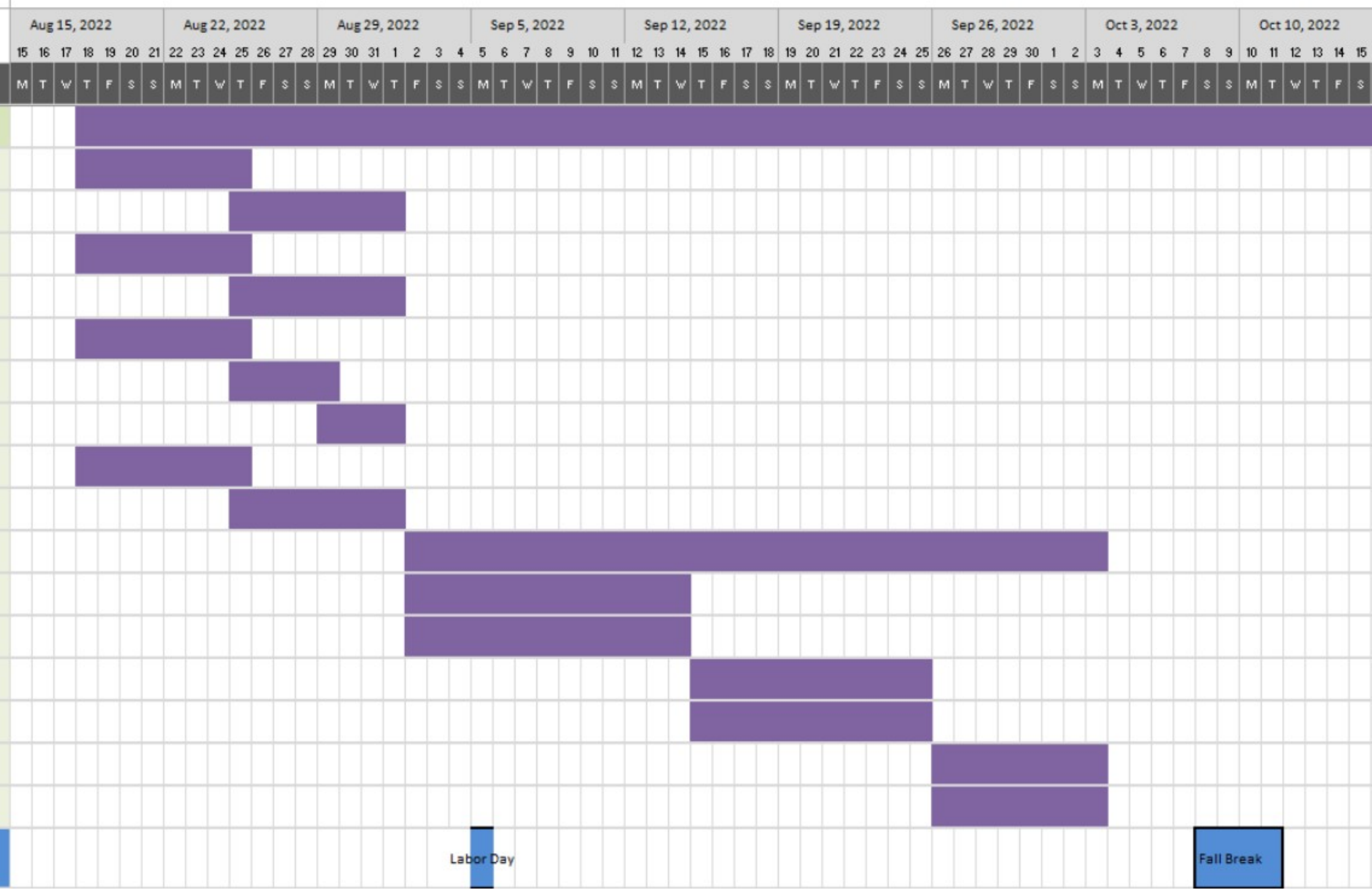
Project Start: Thu, 8/18/2022

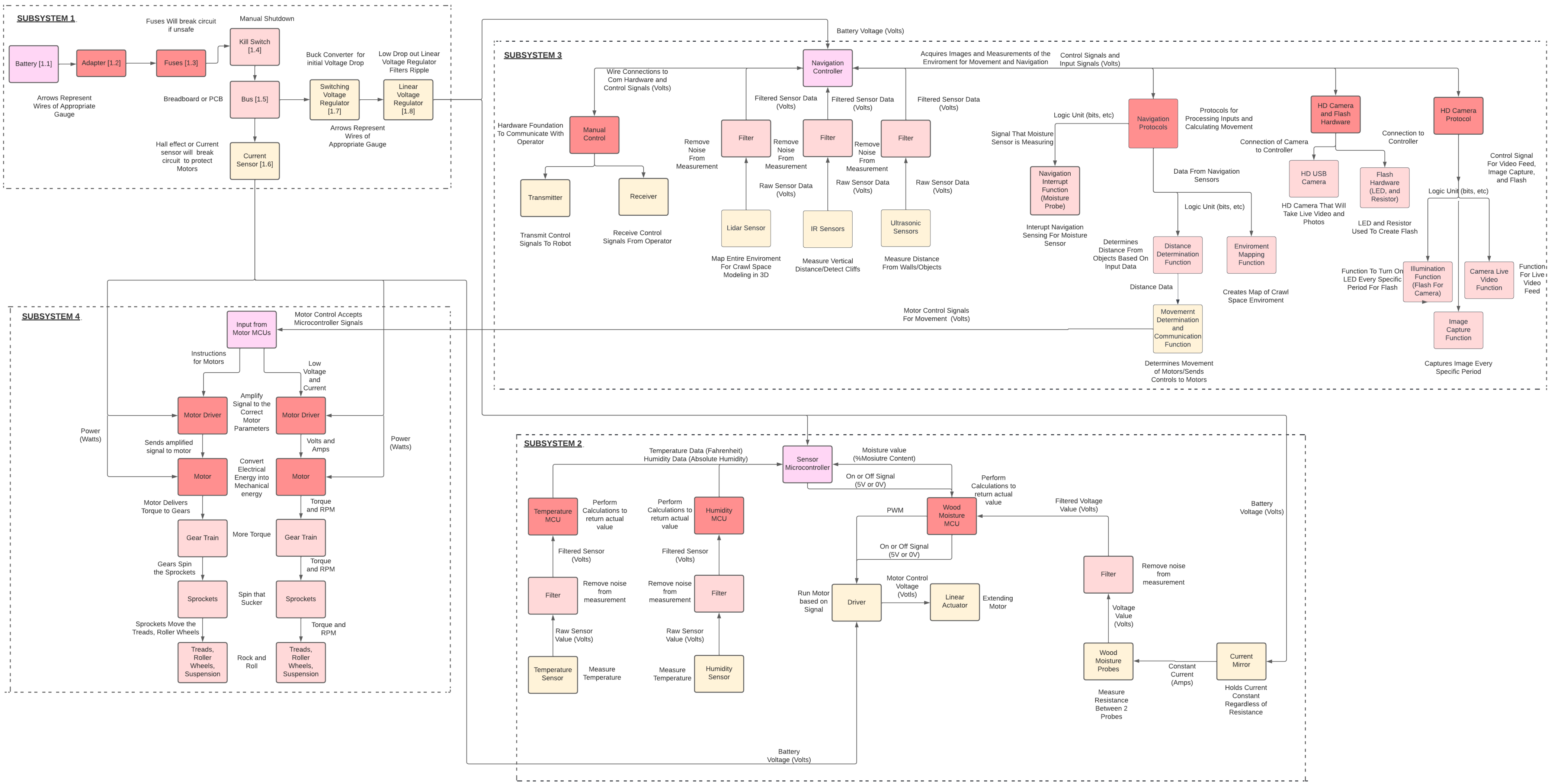
Display Week: 1

SIMPLE GANTT CHART by Vertex42.com

https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

TASK	ASSIGNED TO	START	END
Design Phase 2		8/18/22	12/2/22
Humidity Sensor Signoff		8/18/22	8/25/22
Wood Moisture Sensor Signoff		8/25/22	9/1/22
Mechancal Parts Signoff		8/18/22	8/25/22
Motor Filtering Signoff		8/25/22	9/1/22
Circuit Protection Signoff		8/18/22	8/25/22
Power Filtering Signoff		8/25/22	8/29/22
Power Distribution Signoff		8/29/22	9/1/22
Ultrasonic System Signoff		8/18/22	8/25/22
Camera System Signoff		8/25/22	9/1/22
Assembly Process		9/2/22	10/3/22
ROS Setup		9/2/22	9/14/22
Mechanical Build		9/2/22	9/14/22
Chasis Build		9/15/22	9/25/22
Sensor Setup		9/15/22	9/25/22
Autonomy Testing		9/26/22	10/3/22
Full System Testing		9/26/22	10/3/22
Holidays			




SUBSYSTEM 1
Battery [1.1]
Adapter [1.2]
Fuses [1.3]
Fuses Will break circuit if unsafe
Kill Switch [1.4]
Manual Shutdown
Bus [1.5]
Breadboard or PCB
Switching Voltage Regulator [1.7]
Buck Converter for initial Voltage Drop
Linear Voltage Regulator [1.8]
Low Drop out Linear Voltage Regulator Filters Ripple
Arrows Represent Wires of Appropriate Gauge
Arrows Represent Wires of Appropriate Gauge
Current Sensor [1.6]
Hall effect or Current sensor will break circuit to protect Motors
SUBSYSTEM 3
Battery Voltage (Volts)
Navigation Controller
Wire Connections to Com Hardware and Control Signals (Volts)
Manual Control
Hardware Foundation To Communicate With Operator
Transmitter
Transmit Control Signals To Robot
Receiver
Receive Control Signals From Operator
Filter
Remove Noise From Measurement
Filtered Sensor Data (Volts)
Raw Sensor Data (Volts)
Lidar Sensor
Map Entire Enviroment For Crawl Space Modeling in 3D
Filter
Remove Noise From Measurement
Filtered Sensor Data (Volts)
Raw Sensor Data (Volts)
IR Sensors
Measure Vertical Distance/Detect Cliffs
Filter
Filtered Sensor Data (Volts)
Raw Sensor Data (Volts)
Ultrasonic Sensors
Measure Distance From Walls/Objects
Acquires Images and Measurements of the Enviroment for Movement and Navigation
Control Signals and Input Signals (Volts)
Navigation Protocols
Protocols for Processing Inputs and Calculating Movement
Logic Unit (bits, etc)
Signal That Moisture Sensor is Measuring
Navigation Interrupt Function (Moisture Probe)
Interupt Navigation Sensing For Moisture Sensor
Data From Navigation Sensors
Logic Unit (bits, etc)
Distance Determination Function
Determines Distance From Objects Based On Input Data
Enviroment Mapping Function
Creates Map of Crawl Space Enviroment
Distance Data
Movemernt Determination and Communication Function
Determines Movement of Motors/Sends Controls to Motors
Motor Control Signals For Movement (Volts)
HD Camera and Flash Hardware
Connection of Camera to Controller
HD USB Camera
HD Camera That Will Take Live Video and Photos
Flash Hardware (LED, and Resistor)
LED and Resistor Used To Create Flash
HD Camera Protocol
Connection to Controller
Control Signal For Video Feed, Image Capture, and Flash
Logic Unit (bits, etc)
Illumination Function (Flash For Camera)
Function To Turn On LED Every Specific Period For Flash
Camera Live Video Function
Function For Live Video Feed
Image Capture Function
Captures Image Every Specific Period
SUBSYSTEM 4
Input from Motor MCUs
Motor Control Accepts Microcontroller Signals
Instructions for Motors
Low Voltage and Current
Motor Driver
Motor Driver
Amplify Signal to the Correct Motor Parameters
Power (Watts)
Power (Watts)
Sends amplified signal to motor
Volts and Amps
Motor
Motor
Convert Electrical Energy into Mechanical energy
Motor Delivers Torque to Gears
Torque and RPM
Gear Train
Gear Train
More Torque
Gears Spin the Sprockets
Torque and RPM
Sprockets
Sprockets
Spin that Sucker
Sprockets Move the Treads, Roller Wheels
Torque and RPM
Treads, Roller Wheels, Suspension
Treads, Roller Wheels, Suspension
Rock and Roll
SUBSYSTEM 2
Sensor Microcontroller
Temperature Data (Fahrenheit)
Humidity Data (Absolute Humidity)
Moisture value (%Mosiutre Content)
On or Off Signal (5V or 0V)
Temperature MCU
Perform Calculations to return actual value
Filtered Sensor (Volts)
Filter
Remove noise from measurement
Raw Sensor Value (Volts)
Temperature Sensor
Measure Temperature
Humidity MCU
Perform Calculations to return actual value
Filtered Sensor (Volts)
Filter
Remove noise from measurement
Raw Sensor Value (Volts)
Humidity Sensor
Measure Temperature
Wood Moisture MCU
Perform Calculations to return actual value
PWM
On or Off Signal (5V or 0V)
Driver
Run Motor based on Signal
Motor Control Voltage (Volts)
Linear Actuator
Extending Motor
Filtered Voltage Value (Volts)
Filter
Remove noise from measurement
Voltage Value (Volts)
Wood Moisture Probes
Measure Resistance Between 2 Probes
Constant Current (Amps)
Current Mirror
Holds Current Constant Regardless of Resistance
Battery Voltage (Volts)
Battery Voltage (Volts)