# Autonomous Lawnmower

Max Lesser
Vincent McMasters
Jonathan Poulose
Josh Samaniego

# Interface Control Document

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# Interface Control Document
for
# Autonomous Lawnmower

Team 30

Approved by:

Team Member Date

Prof. S. Kalafatis Date

Pranav Dhulipala Date

# Change Record

| Rev. | Date | Originator | Approvals | Description |
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| **3** | 4/29/2021 | Max Lesser | | Final Report |

# *Table of Contents*

## *List of Tables*



## *List of Figures*

# 1 Overview

The Interface Control Document (ICD) for the entire Autonomous Lawnmower will provide more detail on how the subsystems layed out in the Concept of Operations and the Functional Systems Requirements will be interconnected and produced. The ICD will include physical descriptions, such as mass and dimensions, as well as the electrical interfaces, power requirements, and sensor information.

# 2 References and Definitions

## *2.1 References*

Refer to Section 2.2 of the Functional System Requirements document.

## *2.2 Abbreviations and Acronyms*

| | |
|---|---|
| A | Amp |
| A&G | Accelerometer and Gyroscope (unit) |
| Ah | Amp hour |
| DC | Direct Current |
| FSR | Functional System Requirements |
| GPS | Global Positioning System |
| UI | User Interface |
| I2C | Inter-IC |
| ICD | Interface Control Document |
| IP | Ingress protection rating |
| MCU | Micro controller Unit |
| lbs | Pound weight |
| mA | Milliamp |
| mW | Milliwatt |
| PCB | Printed Circuit Board |
| PWM | Pulse Width Modulation |
| SPI | Serial Peripheral interface |
| TTL | Transistor-Transistor Logic |
| USB | Universal Serial Bus |
| V | Volt |
| VDC | Volts DC |
| VCC | Positive input voltage level of device in question |
| VSS | Negative input voltage level of the device in question (typically ground) |
| W | Watt |
| WiFi | Wireless Fidelity |

## *2.3 Definitions and Naming Conventions*

The term header pin or pin header connector, both male or female, refers to friction fit pins on devices that resemble header pins used in raspberry pis' or other breadboarding applications.

The term pin, as used in section 5.4, refers to the connection point of one wire or signal to a connector or board.

The term MCU, Main controller unit, Controller, Controller board or MCU board are used interchabalby to refer to the PCB that will include the Pic-32 controller, WIFI and GPS module, as well as all connectors and components incidental to their operation. In cases where only the MCU chip, that is exclusively the IC, is referred to the term pic-32 or pic-32 MCU will be used.

The term Bystander is used to describe a person in the vicinity of the lawnmower that is not actively attempting to perform, or engaged in maintenance or operation of the device.

Subsystem owner refers to the person responsible for that subsystem, see table in FSR for subsystem owner names. The subsystem owner carries ultimate authority over their subsystem and all items not specified within FSR or ICD, as well as responsibility to conform with these documents, as outlined in 2.4.

## 2.4 Boundary Cases and Subsystem Non-Compliance with ICD

The interfaces and connections lined out in this document form the standard basis of performance and interconnection of subsystems. All subsystems are expected to interface with each other, and perform under the requirements specified herein. In case the requirements are not met by any subsystem or component the requirements may be changed only with explicit consents form all subsystem owners implicated by the change.

In case any component or subsystem cannot meet the Interface requirements specified, a reasonable attempt by the subsystem in compliance shall be made to accommodate the offending subsystem or component. Ultimate responsibility to resolve the issue however lies with the offending subsystem.

# 3 Physical Interface

## *3.1 Weight*

### 3.1.1 Weight of Autonomous Lawnmower

The autonomous lawn mower will weigh less than 70 lbs. This allows for most people to be able to carry the device, should it need to be moved manually. The Final weight of the unit came in at 35 lbs, well below the stated maximum. A rough breakdown of its makeup is presented below. Note that table entries are approximate weight, but total weight is accurate.

| Component | Weight |
|---|---|
| Blade Motor (1) | 6 oz |
| Drive Motors (2) | 2 lbs ea. |
| Motor Drive | 1.41 oz |
| Proximity Sensor (7) | 7 oz |
| PIC32 MCU + PCB | 2 oz |
| Battery (New) | 2 lbs |
| Accelerometer and Gyroscope | 0.07 oz |
| GPS Module | 1 oz |
| Wheel Encoder | 1 g |
| 5 Volt Relay | 12 g |
| Lawn Mower Shell | Estimate: 15lbs |
| Miscellaneous Hardware, wiring and components | ~ 10 lbs |
| **Total:** | ~35 lbs |

*Table 1: Autonomous Lawnmower Weight Specifications*

## *3.2 Dimensions*

### 3.2.1 Dimensions of Autonomous Lawnmower

The volume envelope of the Lawnmower shall be less than or equal to 30 inches in height, 25 inches in width, and 40 inches in length.

| Component | Diameter | Length | Width | Height |
|---|---|---|---|---|
| Blade Motor (1) | 2 in | 2 in | 2 in | 4.5 in |
| Drive Motor | 4 in | 4 in | 4 in | 5 in |
| Motor Drive | N/A | 4.33 in | 3.07 in | 0.39 in |
| Proximity Sensor (7) | N/A | 1.8 in | 0.84 in | 0.6 in |
| PIC32 MCU | N/A | 20 mm | 20 mm | 1.4 mm |
| Battery (old) | N/A | 7.09 in | 3.03 in | 6.57 in |
| Battery (New) | N/A | 6.5 in | 2.75 in | 2 in |
| Solar Charge Controller | N/A | 4.68 in | 2.95 in | 1.08 in |
| Accelerometer and Gyroscope | N/A | 21.2 mm | 16.4 mm | 3.3 mm |
| GPS Module | N/A | 25.4 mm | 43.2 mm | 9.1 mm |
| Wheel Encoder | N/A | 10.6 mm | 11.6 mm | N/A |
| 5 Volt Relay | N/A | 16.5 mm | 21.6 mm | 19 mm |
| Lawnmower Shell | | 40 in | 23 in | 15 in |

*Table 2: Autonomous Lawnmower Dimension Specifications*

## *3.3 Mounting*

### 3.3.1 Mounting of Solar Panel, Controller, and Battery

The solar panel shall be mounted on the docking station, such that it receives an optimum amount of sun on an average day throughout the year. The solar controller will be underneath the solar panel along with the battery inside of a small housing.

### 3.3.2 Mounting of Sensors

The Ultrasonic sensors were mounted in 2 arrays. A Front array consisting of 5 sensors placed on an aluminum L-iron. The side array was mounted directly to the mower body. All US sensors are attached to custom 3-D printed cases.

The Shaft encoders assemblies have their own housing, consisting of a metal outer shell and a plastic base attached to the motors. The base was super glued to the motors, as bolt patterns did not line up.

The Accelerometer and Gyroscope was mounted in the same box as the Navigation controller.

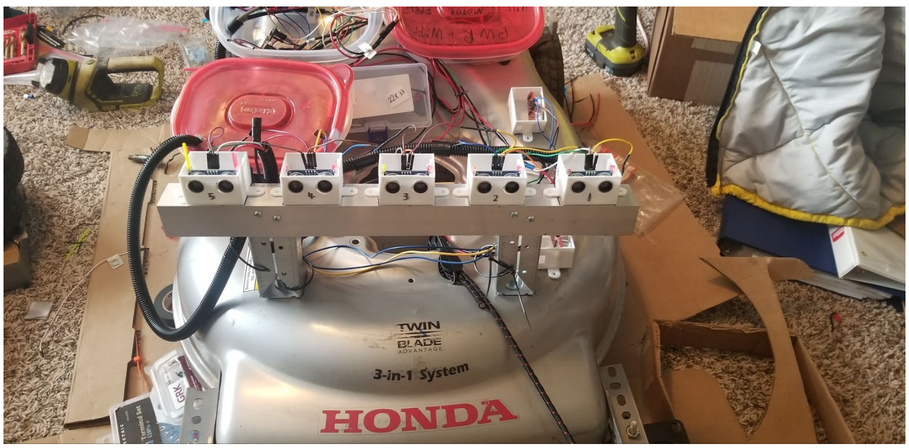


*Figure 1: View of Mounted Front Facing Ultrasonic Sensors*

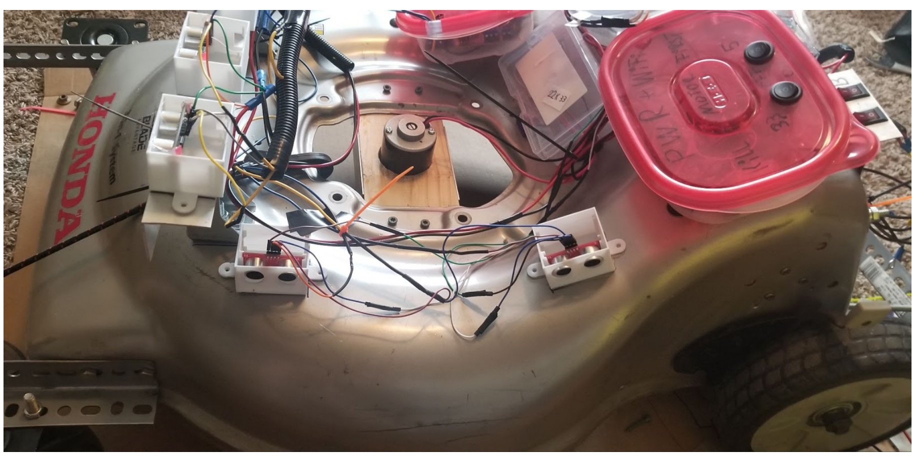


*Figure 2: View of Mounted Side Facing Sensors*

### 3.3.3 Mounting of Microcontroller

The two MCUs and GPS unit, as well as connectors and incidental components were mounted in protective plastic cases, one for the ESP and one for the PIC. The ESP case additionally contained the 2 H-bridges. MCU cases are shown in section 3.3.2 and 3.3.6

### 3.3.4 Mounting of Motors

The 2 Drive Motors were mounted to the frame using 2 L- brackets each. Bolted to the frame on one side and the motors on the other. The blade motor was mounted using a 2x4 with appropriately sized hole to allow the motor to slip through, and L-brackets to hold it in place. The 2x4 was then screwed to the mower. For details on Motor mounts see new Motor subsystem report.

### 3.3.5 Wire Routing

All wires shall be affixed to the mower in such a way that they do not contact hazardous objects, suffer abrasion from vibration, or interfere with operation in any way. Additionally wires shall be routed such that neither regular operation, contact with external objects, such as foliage or obstacles, nor unintentional interference from bystanders may damage or disconnect them. To accomplish this wires were run in Loom where possible, and attached to the body using wire clamps and zip-ties. Future iteration with more time may use a more purpose full wiring scheme, as we had to adapt to changing components and layouts.

#### 3.3.5.1 Power Cable Routing

Power Cables will be routed clear of any hazardous objects, and in protective shielding. Plastic flexible split loom was used. Only during initial testing may wires be routed without additional shielding or mounting. After initial testing the Looms are to be sealed using electrical tape or similar, with seals no more than 12 inches apart, and mounted to the mower. The wire harness was affixed to the mower using plastic clamps and zip ties, at least every 12 inches. Harnesses shall be fixed to the mower as close to the respective end devices as possible. For wire runs less than 12 inches in overall length at least one clamp to the body shall be used in a suitable location. In boundary cases where mounting of the harness is not possible without considerable reconfiguration or increase in wirelength, unmounted harnesses may be used only if no chance of the wire contacting any hazardous object exists. No Power wire longer than 6 inches, or that may make contact with any metal part or the user may be run without protective loom. Due to last minute changes of the battery, and the need for special connectors, power from the battery had to be run across the unit with minimal attachment. The wire run was clear of outside interference, but would need to be improved in the next iteration.

 

#### 3.3.5.2 Signal Interface Routing

Signal interface wires shall be run in protective Looms to prevent damage. The same routing requirements as listed in 3.3.5.1 apply to signal wire connections. Due to the small size of signal cables a different means of attaching looms to the mower body may be needed. There wires were zip tied to the unit and each other as appropriate. Looms were used wherever possible.

### 3.3.6 Case Mounting

No encompassing case was used. However critical components such as MCUs, Motor drivers, and power supplies were mounted in protective cases.

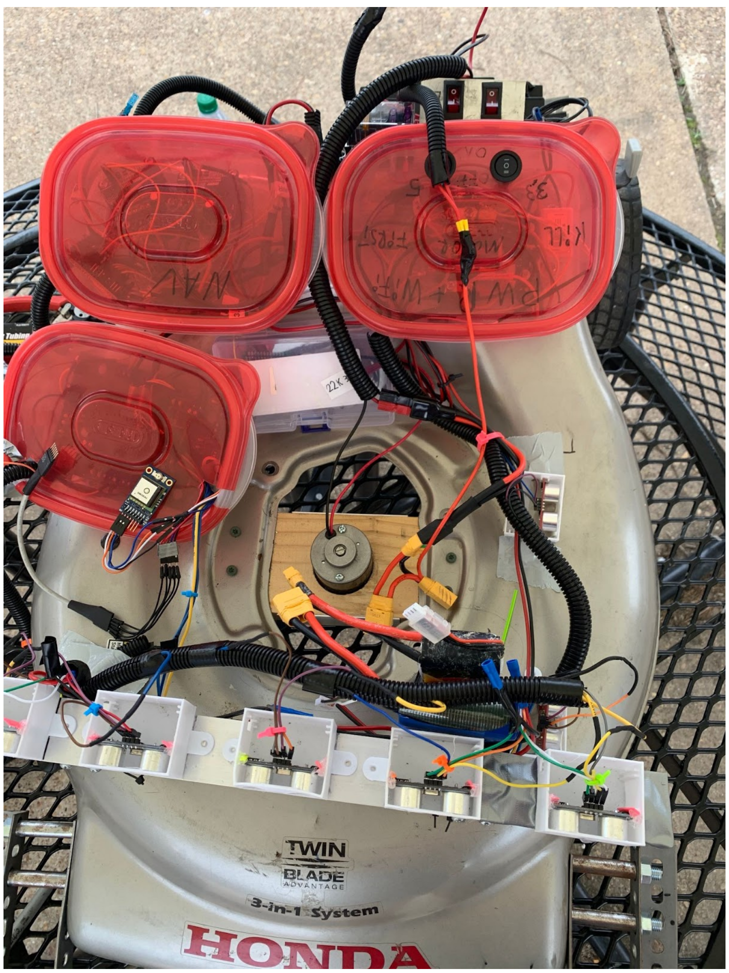


*Figure 3: Top View of Casing used to Protect Critical Components*

# 4 Thermal Interface

## *4.1 Battery Cooling*

The heat generated from the battery should be free to disperse on its own.

## *4.2 Motors*

The heat dissipated by the 3 main motors should be able to escape on its own.

## *4.3 Microcontroller Unit*

The Pic-32 MCU and other components on the MCU board shall include a heat sink as needed. The components will not be mounted in direct sunlight, and operating temperature of the unit is not expected to reach or exceed maximum temperature ratings. Additionally the movement of the mower and blade will create considerable air movement. Ambient cooling was sufficient to maintain the MCUs at an acceptable temperature. Additionally after updating to the new H-bridges with heatsinks, its passive cooling was also sufficient.

## *4.4 Sensors*

The amount of heat the sensors will produce will be very minimal and it is not expected to exceed maximum temperature ratings. During operation heat development by the sensors was minimal, and no cooling beyond ambient air was needed.

# 5 Electrical Interface

Electrical interfaces not specified in the following section shall be determined by consensus of the affected subsystem owners. Additionally, connections that are exclusively internal to their respective subsystems are not listed, and are sole responsibility of the subsystem owner. As The Power distribution system changed toward the end of the semester, we present here first the old diagram, followed by the current “As Built” system.

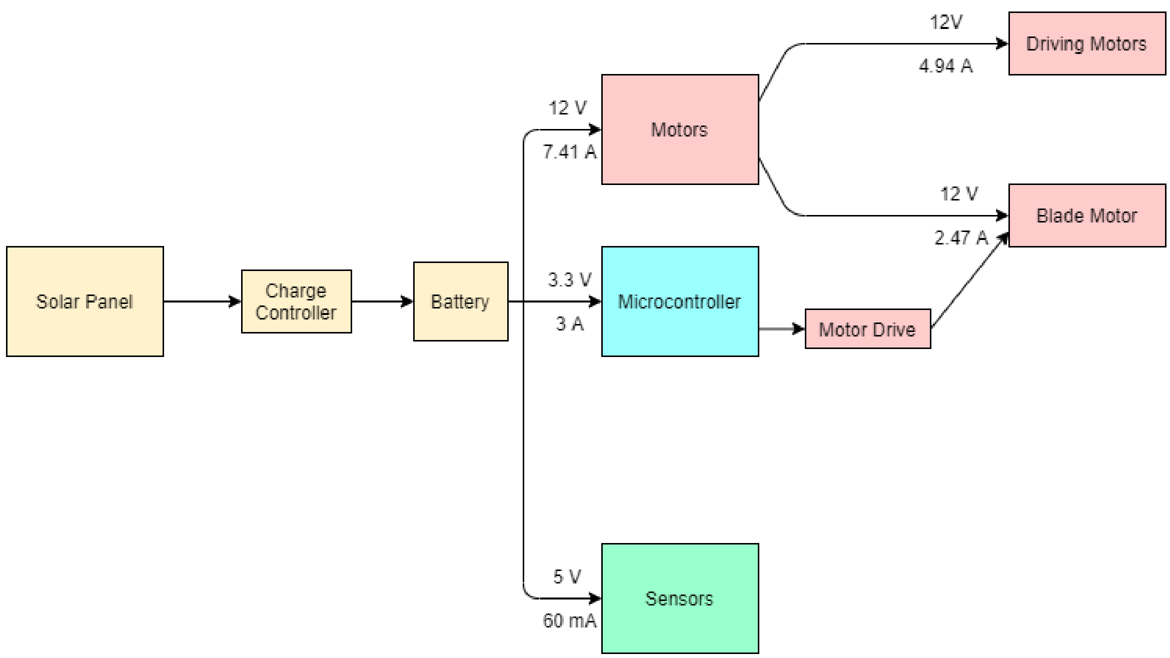


*Figure 4: Power Diagram as Designed in 403*

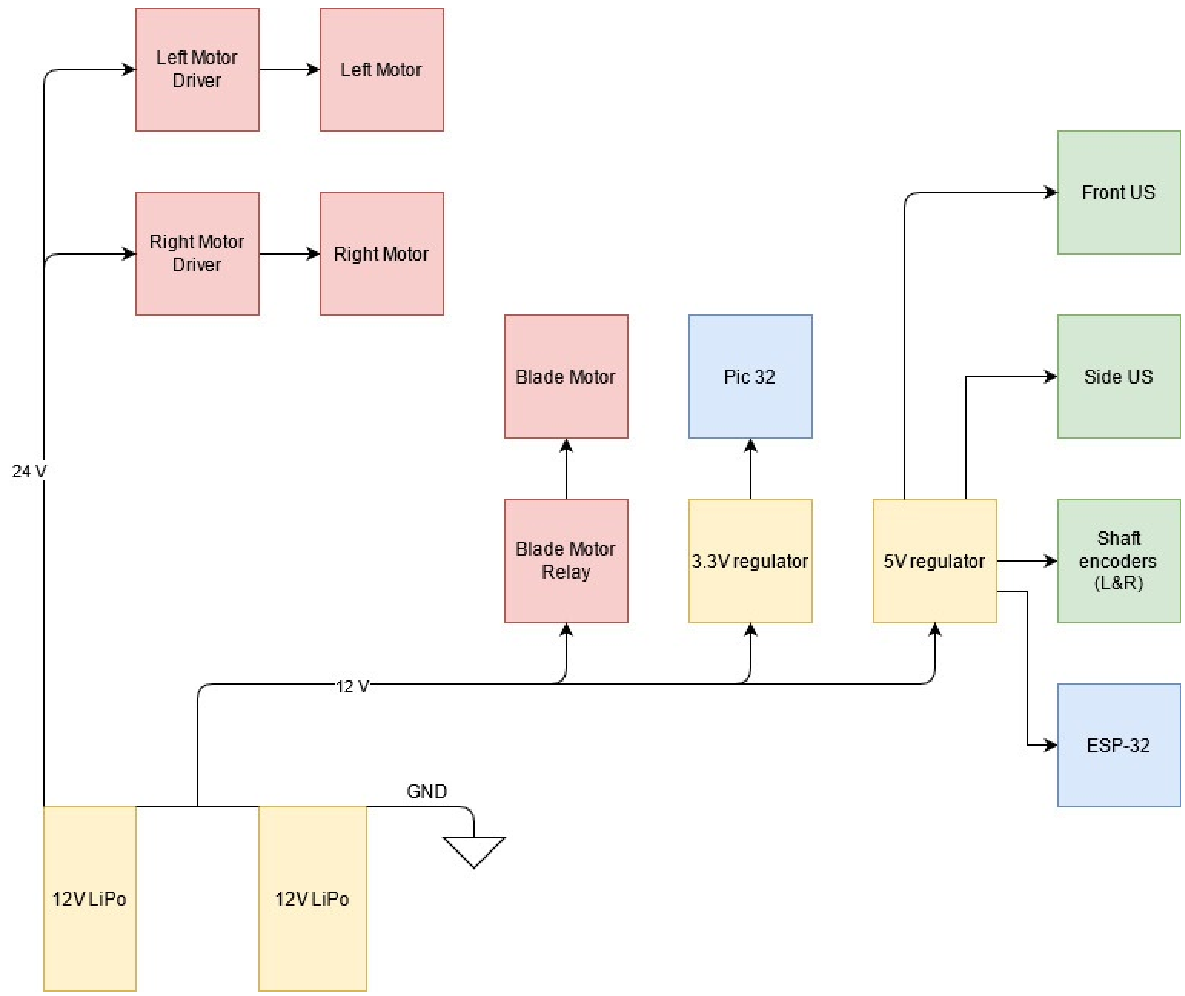


*Figure 5: Power Diagram as Implemented on the Autonomous Lawnmower*

## *5.1 Primary Input Power*

With the intention of our system being autonomous and self-powered, the entire system will be powered by a 12V battery charged via 10W solar panel that feeds into a solar controller during conditions that facilitate Solar charging, and provisions to charge from Wall power otherwise. The docking station shall be able to switch between the 2 sources as needed. The capacity of the 12V battery will be enough to hold the power required to run the lawnmower autonomously off of charge for a period of at least an hour. The battery will be the only source of power to the system, and will power the sensors, motors, MCU, and all other components.

Due to late changes to the system, the above no longer applies. The mower is now powered by 2 12V LiPo batteries, where the drive Motors receive 24V and all other systems 12V. This change was needed due to new motors. See New Motor Subsystem and Power Subsystem reports for details. Unfortunately this new change rendered the Charging station designed by the Power system incompatible with the remainder of the unti.

## *5.2 Voltage and Current Levels*

### 5.2.1 Maximum Values

| Component | Voltage [V] | Current [A] | Power [W] |
|---|---|---|---|
| Blade Motor (1) | 24 | 3 | 80.88 |
| Drive Motor (2) (ea) | 24 | 9.6 | 230 W |
| Motor Drive | 27 | 43 | 1100 |
| Proximity Sensor (7) | 5 | 0.035 | 0.175 |
| PIC32 MCU | 3.6 | 0.2 | 0.720 |
| ESP-32 | 5 | 0.3 | 1.5 |
| Solar Charge Controller | 24 | 10 | 240 |
| Accelerometer and Gyroscope | 6 | 0.0039 | 0.0234 |
| GPS Module | 5 | 0.06 | 0.3 |
| Wheel Encoder | 26 | 0.006 | 0.156 |
| 5 Volt Relay | 30 | 8 | 240 |

*Table 3: Autonomous Lawnmower Maximum Voltage and Current Levels*

The values in table 3 were all found on the individual parts specifications datasheets. Almost all of these values will not be used but are rather simply for reference purposes in order to prevent us from burning out parts unnecessarily

### 5.2.2 Typical Values

| Component | Voltage [V] | Current [A] | Power [W] |
|---|---|---|---|
| Drive Motor (2) | 24 | 5 | 120 |
| Blade Motor | 12 | 2 | 24 |
| Motor Drive | 24 | 10 | 240 |
| Proximity Sensor (7) | 5 | 0.03 | 0.15 |
| PIC32 MCU | 3.3 | 0.150 | 0.495 |
| ESP-32 | 5 | 0.1 | 0.5 |
| Accelerometer and Gyroscope | 3.3 | 0.0039 | 0.01287 |
| GPS Module | 3.3 | 0.045 | 0.1485 |
| Wheel Encoder | 5 | 0.004 | 0.0132 |
| 5 Volt Relay | 5 | 0.0794 | 0.397 |

*Table 4: Autonomous Lawnmower Typical Voltage and Current Levels*

The values in table 4 were found on the individual parts specifications datasheets. Are estimates based on consumption during use.

## *5.3 Power Interfaces and Connectors*

All connections specified in this section shall consist of a positive voltage and ground, making for 2 wired connections to each device, unless otherwise specified. Refer to section 5.2.2 for voltage and current levels. And 5.5 for applicable wires.

### 5.3.1 Battery to Motor Driver Board

Each motor Driver board includes two screw terminals, positive and ground, for power connection to battery and Motors. These will be used to connect the battery to the driver board. The Battery side connection will be made using Anderson Power Poles.

### 5.3.2 Battery to Blade Drive Motor

The battery to blade motor connection will be made using crimp ring terminals. The connection to the battery will be made using Butt splice ring terminals bolted to the battery. The relay will also be connected using a 2 port screw terminal for battery and motor side. This connection will feed directly into the 12 v power pin of the relay.

### 5.3.3 Battery to Ultrasonic Sensors (7)

The Ultrasonic sensors shall connect the power supply using the 5V bus bar of the power supply . The connection to the sensors shall be made using female header pin connectors assembled in a custom wiring harness, along with its signal wires.

### 5.3.4 Battery to Accelerometer and Gyroscope

The Accelerometer and Gyroscope unit is powered directly from the ESP-32, using female header pins.

### 5.3.5 Battery to Shaft Encoders (2)

Shaft encoders are connected to the power supplies 5V bus bar using spade terminals. The sensor side connection uses a custom connector purchased from the same vendor that supplied the sensors.

### 5.3.6 Battery Power to MCU board

Battery Power to MCU shall be connected to the MCU using Screw terminal connectors on the PIC, an extra slot for battery status is provided. Female header pins are used on the ESP. The connection to the power supply side shall use the 3.3V and 5V bus bars, respectively.

### 5.3.7 Charge Controller to Battery Interface

The charge controller shall attach to the battery using screw terminals on the charge controller side, and ring terminals bolted to the battery on the battery side.

### 5.3.8 Solar Panel to Charge Controller Interface

The Solar panel has wires attached from the manufacturer that output in the form of an SAE connector. An opposing SAE connector with wire leads shall be used to connect the SAE output of the screw terminals of the charge controller..

## *5.4 Signal Interfaces and Connectors*

The signal interfaces, for the purpose of this document, are defined as those interfaces carrying information within the mowing unit, between subsystems, on wires. As such most of these terminate or originate in the PIC-32 or ESP-32 MCU. This section will specify protocols used and physical connectors. The total number of signal interfaces for the Pic is 15, for the ESP 14. All connectors to the PIC are PCB mountable Screw terminals with the specified number of pins and female header pins for the ESP unless otherwise specified.

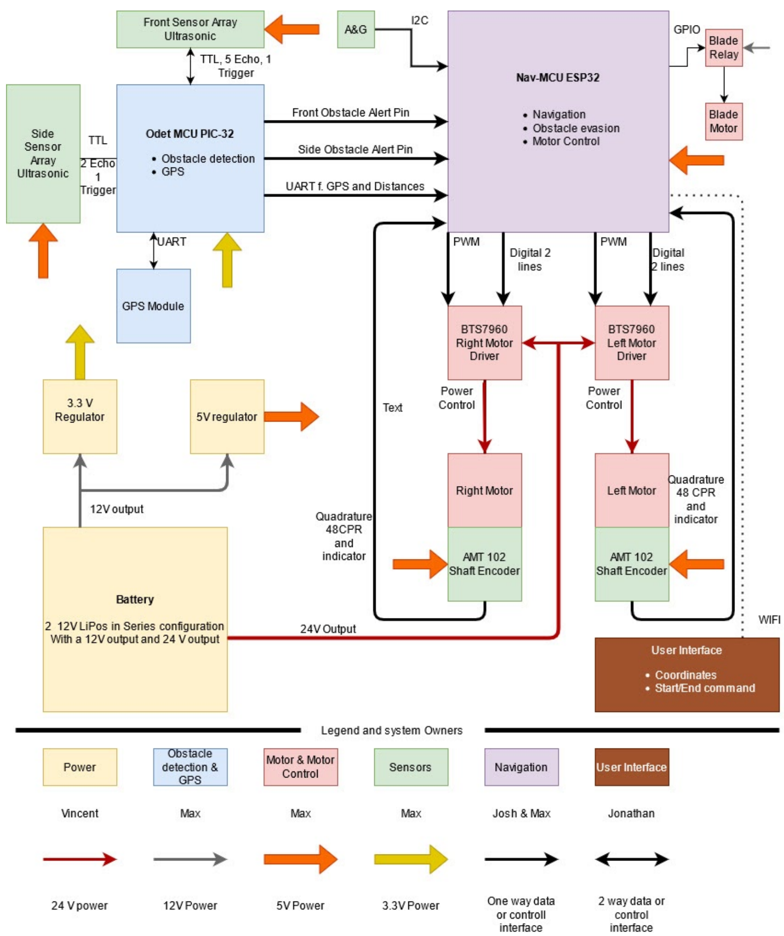


*Figure 6: Signal interfaces with MCU, dashed line indicates subsystem boundary. Blue arrows represent incoming , Green outgoing wired signals. Red represents incoming power, thick black arrow represents bi directional wireless signal, small arrows represent internal signals. Incidental components omitted for clarity.*

### 5.4.1 Accelerometer and Gyroscope Unit

The Accelerometer and Gyroscope Unit shall communicate with the ESP Unit via I2C protocol. Connected by female header pins on both sides

### 5.4.2 Ultrasonic Sensors

The Ultrasonic Sensors shall interface with the MCU using TTL signals. The TTL pulse uses 2 wires per sensor for trigger and echo signals. The front and side array each have a common trigger input, and each sensor has its own echo output. Making for 5 echos and 1 trigger from the front array, and 2 echos and 1 trigger for the side array.

Each sensor shall be connected to the MCU using its own 2 pin connector. The connection on the sensor side shall be made using female header pins.

### 5.4.3 Wheel Encoders 1 and 2

The wheel encoders shall use AB Quadrature pulse train signals to communicate the number of wheel rotations done by the main motors, as well as an Indicator pulse for full wheel rotations. As only the A and indicator channel were used, each SE has 2 signal lines with the ESP-N.

Each shaft encoder shall connect to the ESP-N MCU using 2 female header pins. The connection on the wheel encoder side shall use custom connectors.

### 5.4.4 Motor Control 1 and 2

Motor 1 and 2 shall interface with the MCU accepting pulse width modulated signals fed from the controller through the motor driver. This will allow the controller to vary the speed of the motors individually as needed. Each motor driver accepts 2PWM inputs and 2 digital inputs to select operation for a total of 4 signals per motor. The 2 digital inputs require a logic low and high given as 0 and 3.3V respectively. PWM has a frequency of 5KHz with a duty cycle varining for 0% to 65% during operation.

Each motor driver shall connect to the MCU with 4 female header pins, The connections to the Motor control board shall be made using female header pins as well. Power from battery to H-bridges and H-bridges to motors is provided using screw terminals on the drivers, and Crimp connections elsewhere.

### 5.4.6 Main Blade Control Relay

The relay attached to the blade shall operate at a 5 V signal and interface with the MCU. The MCU shall provide a signal of 3VDC or greater to a relay driver, which then activates the Relay as needed

The Main Blade Relay control connects to the ESP-N via female header pin and uses a screw terminal on the relay driver side. Motor power connection is also made via screw terminal.

### 5.4.7 Main Blade Status

This interface was not implemented, as the underlying feature was not implemented.

The main blade status shall be interfaced with the MCU. The motor will send a 3 volt signal if the blade is functioning properly, or a off (0 V) signal if it is stuck or not working. See section 5.4.6.

The Main blade status signal shall connect to the MCU on the same 2 pin header as the Main blade control relay. The Blade motor side connection shall be made by attaching a splice crimp terminal to the end of the wire. This will ensure the relay has a sturdy connection.

### 5.4.8 Main battery status

This interface was not implemented, as the underlying feature was not implemented.
The main battery status shall be relayed to the MCU by means of a direct connection to the battery, in order to read it’s voltage. The signal will directly relay battery voltage. The Maximum voltage level of this signal is 15VDC, with 0VDC minimum.

Main battery status signal shall connect to the MCU via the same 3-pin screw terminal connector as battery power, on a separate pin. See section 5.3.6

The main battery status signal shall connect to the main battery via ring terminal, by bolting directly to the battery.

## *5.5 Wires*

All wires shall be shielded from hazardous parts, unintended contact by the user or external environment. Wires shall be shielded using plastic wire shields or plastic conduit where applicable. Wires shall be routed neatly and affixed to the mowing unit to prevent wires from coming in contact with dangerous parts or abrasion from vibration. See section 3.3.5 for details. In cases where wires need to be spliced to be extended, Butt splice connectors shall be used, with the connection sealed in heat shrink or similar protective material.

### 5.5.1 Signal Interface Wires

Signal interfaces are made using either 18AWG wire, or breadboard jumper wires. In some cases one or multiple jumper wires were soldered to 18AWG wires in order to multiplex signals and extend wires. Soldered connections were covered either in heat shrink or electrical tape, as appropriate.

### 5.5.2 Power Supply Wires

All power supply wires shall be routed protective shielding, when coming near hazardous parts, or where bystanders may contact them.

#### 5.5.2.1 Power Supply to Motors

Power supply to motors shall be done with 14AWG copper wire, not to exceed 3ft in overall length for any one run.

The Connections to the motor driver boards shall be fused in accordance with it’s data sheet, 30A fuse for the power input and 15A fuse for each motor output. The fuses shall be inline automotive ATO fuses.

Blade and drive motors have separate power switches, allowing power to be safely disconnected.

#### 5.5.2.2 Power Supply to MCU Board and Sensors

The power to the MCU and sensors shall be delivered using 18AWG or larger stranded copper wires.

#### 5.5.2.3 Power Supply to Regulators

The 5 and 3.3V regulators are connected to the battery using 14 AWG wires, where both regulators are fused using ATO automotive fuse rated for 3A each. Each power supply includes its own switch.

### *5.6 User Control Interface*

The only interface with which the user will be able to interface with the autonomous lawnmower is the android-based GUI which will allow the user to view the status of the mower, and usage statistics as well as provide navigational data and scheduling commands wirelessly. No other user interface is required and no other interface will be designed.

### *5.7 MCU Debugging interface*

Inorder to facilitate debugging and programming the Pic-32 MCU will include a debugging port for use with the MPLAB PICkit 4 debugger. The Debugger will interface with 2 I/O pins and the Reset Pin of the MCU, as well as VDD and ground. The connection will be made using female header pin. The Debugger will attach to a Computer using USB. This connection is not intended to be accessed by the user or any other subsystem, and is purly for internal and development use of MCU subsystems. The MCU-board additionally includes a UART port for debug and demo purposes, giving serial access on a screw terminal. This connection may be used to interface with other peripherals via UART or be reconfigured for final operation if need be.

The ESP-32 includes a serial and debug port accessible via Micro USB.

## 6 Communications / Device Interface Protocols

### *6.1 WiFi*

The user interface will communicate with the microcontroller wirelessly through WiFi according to the IEEE 802.11 standards in order to send and receive information.