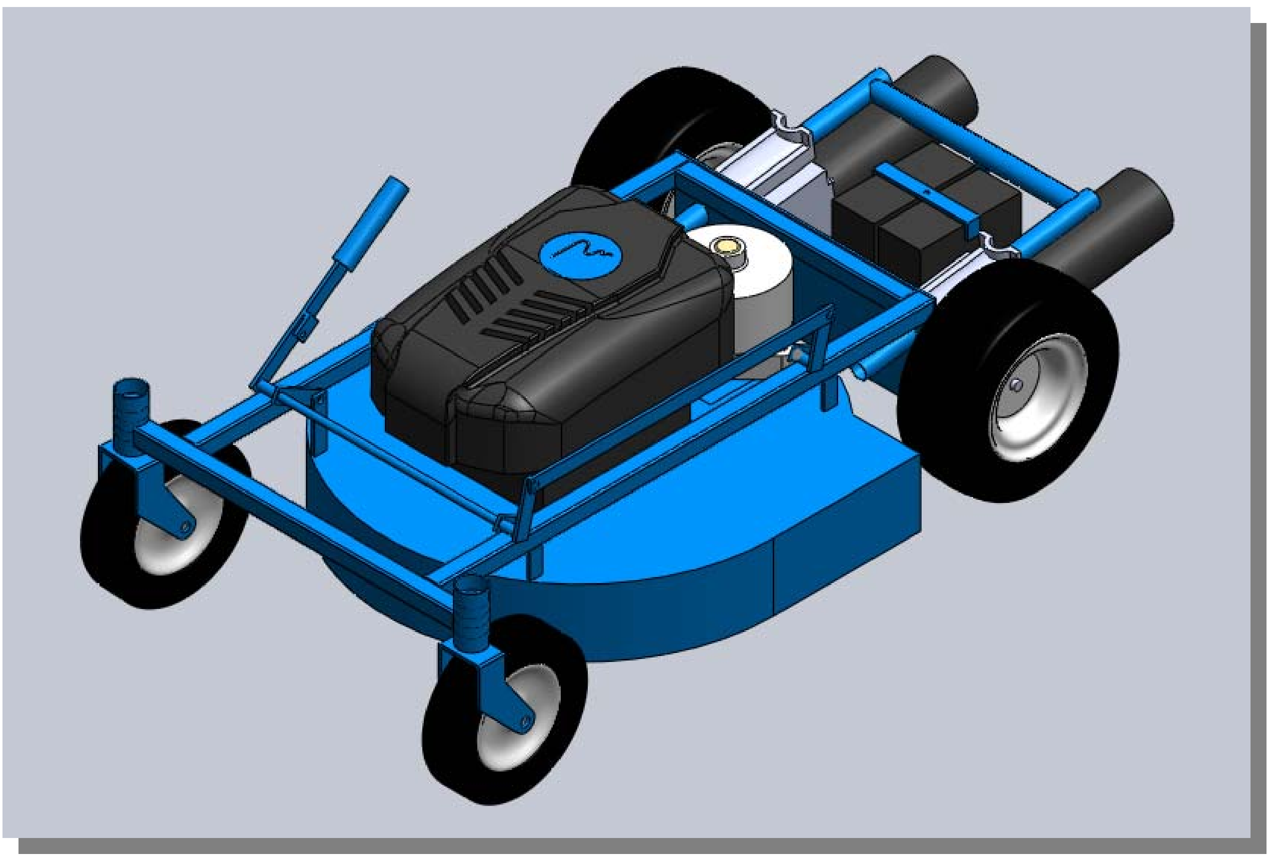
# Grass Shredding Unit

## Georgia Southern University

**The 7th Annual ION Robotic Lawn Mower Competition**

**Design Report**

**May 13, 2010**

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# Table of Contents


**List of Tables** ---------- 3

**List of Figures** ---------- 3

**1. Introduction**

1.1. Background ---------- 4

1.2. Objective ---------- 4

**2. Specifications**

2.1. Cost ---------- 5

2.2. Max Speed ---------- 6

2.3. Dimensions ---------- 6

2.4. Energy Source ---------- 6

**3. System Design**

3.1. Mechanical System ---------- 6

3.1.1. Grass Shredding Unit (GSU) ---------- 6

3.1.2. Electronics Housing ---------- 7

3.2. Electrical System ---------- 7

3.2.1. Microcontroller Unit ---------- 8

3.2.2. DAQ Board ---------- 9

3.2.3. Motor Controller ---------- 9

3.2.4. Stop/Start Controller ---------- 10

3.2.5. Power System ---------- 10

3.3. Control System ---------- 11

3.3.1. Main Program ---------- 11

3.3.2. Manual Mode Operation ---------- 12

3.3.3. Auto Mode Operation ---------- 12

3.3.4. GPS Operation ---------- 13

3.3.5. Laser Operation ---------- 15

3.3.6. Compass Operation ---------- 16

**References** ---------- 18

## List of Tables

Table 1 – Cost ---------------------------------------------------------------------------------- 5

Table 2 – Dimensions ------------------------------------------------------------------------ 6

Table 3 – Energy Sources ------------------------------------------------------------------- 6

## List of Figures

Figure 1 – Mowing Area ------------------------------------------------------------------ 5

Figure 2 – Grass Shredding Unit ---------------------------------------------------------- 7

Figure 3 – System Wiring ----------------------------------------------------------------- 8

Figure 4 – Microcontroller Unit ---------------------------------------------------------- 8

Figure 5 – DAQ Board -------------------------------------------------------------------- 9

Figure 6 – Sabertooth 2X25 Motor Driver ------------------------------------------------ 9

Figure 7 – Stop/Start Controller Circuit --------------------------------------------------- 10

Figure 8 – Voltage Regulator Circuit ------------------------------------------------------ 11

Figure 9 – Main Program Flow Chart ------------------------------------------------------ 11

Figure 10 – Manual Mode Flow Chart ----------------------------------------------------- 12

Figure 11 – Auto Mode Flow Chart -------------------------------------------------------- 13

Figure 12 – Differential GPS Unit ---------------------------------------------------------- 13

Figure 13 – GPS Flow Chart --------------------------------------------------------------- 14

Figure 14 – Laser Unit --------------------------------------------------------------------- 15

Figure 15 – Laser Quadrant Setup ---------------------------------------------------------- 15

Figure 16 – Laser Flow Chart -------------------------------------------------------------- 16

Figure 17 – Compass Flow Chart ---------------------------------------------------------- 17

# 1. INTRODUCTION

## 1.1. Background

As autonomous robots continue to be integrated into the industrial world, it is only subsequent that we start to incorporate their use into residential life. One such task that an autonomous robot could do for the average person would be to eliminate the human element in lawn mowing. Autonomous operation involves self-governing abilities regulated by pre-set laws established in programming which allows it to be independent from outside control. Over the past 100 years, the lawnmower has shown immense evolvement from the simple push lawnmower without an engine to today's luxury riding lawnmowers. The advancement of this technology coincides with the need for people to improve upon older technology designs to create more efficient models to keep up with our fast paced world. Although the riding lawnmower has cut down the amount of labor involved in lawn mowing, the next step in this evolutionary chain would be to have autonomous robotic lawnmowers. Partially autonomous robotic lawnmowers are now being designed and manufactured for use in residential settings; however, they still rely largely on the human element for initial set up and completion of the task.

## 1.2. Objective

For the ION Autonomous Lawnmower Competition the following requirements must be met:

- Design or modify a lawnmower for autonomous operation that is also equipped with both manual and wireless remote emergency stop capability.
- Using the autonomous lawnmower, a set area of grass (shown in Figure 1) must be cut completely and efficiently. The success of the grass cutting will be determined by the lawnmower's ability to avoid and mow around various static and dynamic obstacles. Also, the lawnmower must cut as much of the grass as possible in the process.

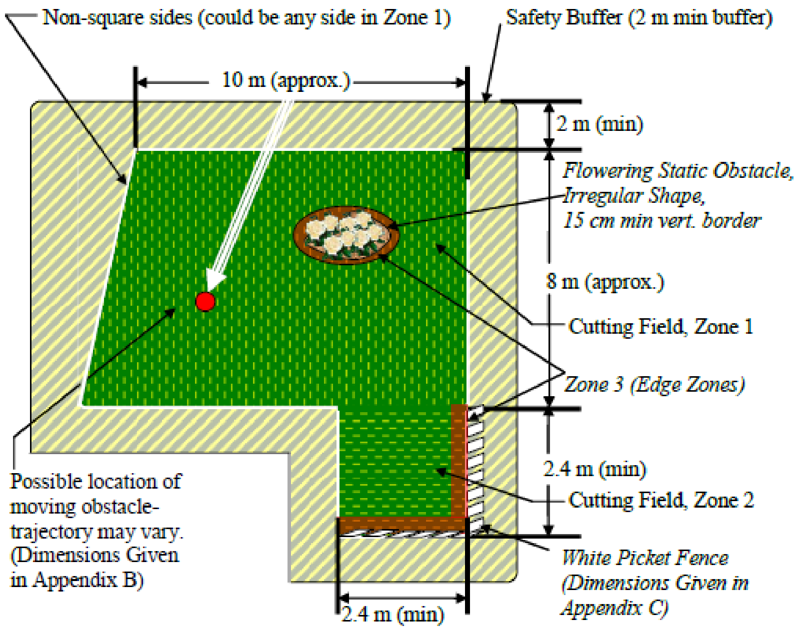


**Figure 1 - Mowing Area**

## 2. SPECIFICATIONS

### 2.1. Cost

Throughout the design and fabrication process of the GSU effort was placed on minimizing the cost by using components available in the Electrical Engineering Department. This effort was very successful in reducing the costs incurred by the team. The table below shows the different components used for the GSU along with their retail cost and cost to the team.

| Item | Retail Cost | Cost to the Team |
|---|---|---|
| Lawnmower | $3,500 | $0 |
| GPS Unit | $5,000 | $0 |
| Laser | $2,500 | $0 |
| Laptop Computer | $750 | $0 |
| Basic Stamp Unit | $100 | $0 |
| Compass | $40 | $0 |
| Motor Driver | $125 | $0 |
| DAQ Board | $1,250 | $0 |
| Misc. Hardware | $300 | $300 |
| **Total Cost =** | **$13,565** | **$300** |

**Table 1 – Cost of the Grass Shredding Unit (GSU)**

## 2.2. Max Speed

The maximum speed of the lawnmower is 10 MPH, but for the competition the maximum speed is set to 6 MPH for safety reasons.

## 2.3. Dimensions

| | | |
|---|---|---|
| Width | 24 | in. |
| Length | 44 | in. |
| Height | 48 | in. |
| Wheelbase | 31 | in. |
| Mowing Deck Adjustment Range | 2-5 | in. |
| Cutting Width | 22 | in. |
| Weight | 180 | lbs. |

**Table 2 – Dimensions of the GSU**

## 2.4. Energy Sources

| | | |
|---|---|---|
| Lead-Acid Batteries | 24 | Volts |
| | 7 | Amp-hour |
| Briggs Stratton Gas Engine | 6.75 | HP |

**Table 3 - Energy Sources of the GSU**

# 3. SYSTEM DESIGN

## 3.1. Mechanical System

### 3.1.1 *Grass Shredding Unit (GSU)*

The main mechanical system of the Grass Shredding Unit (GSU) is a commercially available RC controlled lawnmower from Evatech [4]. This system was bought to minimize costs and time of designing and building a system from scratch. The 6.75 HP gas engine is connected to an alternator using a simple belt drive. With this setup the alternator will charge the batteries as long as the gas engine is running (Sec. 3.2.5). This power arrangement will supply all of the electrical power needed for the system which is explained in more detail in section 3.2.5.

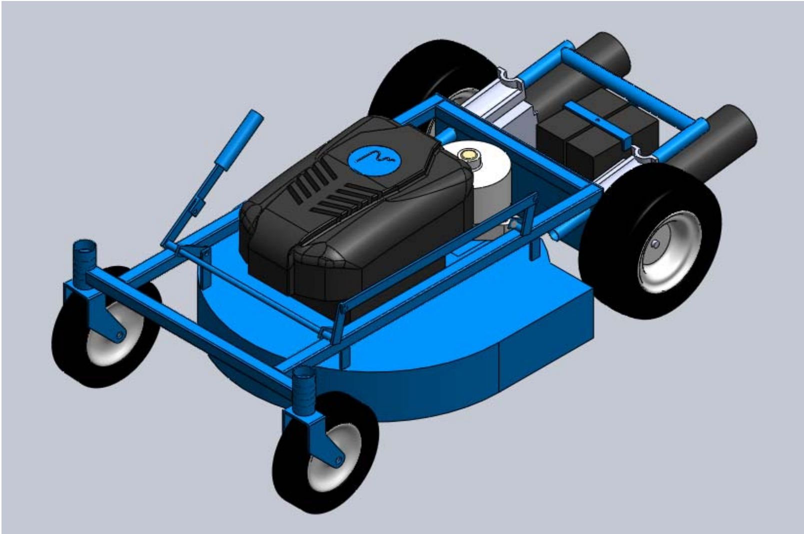

**Figure 2 - Grass Shredding Unit (GSU)**

### 3.2.2 *Electronics Housing*

On top of the battery frame of the GSU, a metallic box is attached that will serve as the housing for all the electronic components of the lawnmower. This is vital as to prevent grass or dust from interfering with the electronic components’ ability to perform. This housing is made out of sheet metal and has a hinged opening at the top for easy access to the components.

## 3.2. Electrical System

The electrical system of the lawnmower consists of the following components: two DC motors, a motor controller, two batteries, a laptop computer, DAQ Board, emergency stop system, GPS receiver, compass, laser module, and a microcontroller.

The laptop computer is the central component of the whole electrical system. It coordinates the electrical devices required for the operation of the vehicle. Most of the electrical components are located in the electronics housing. A benefit of this is the overall neatness and accessibility of the electrical devices. Figure 3 below shows the wiring schematic of the electrical system.

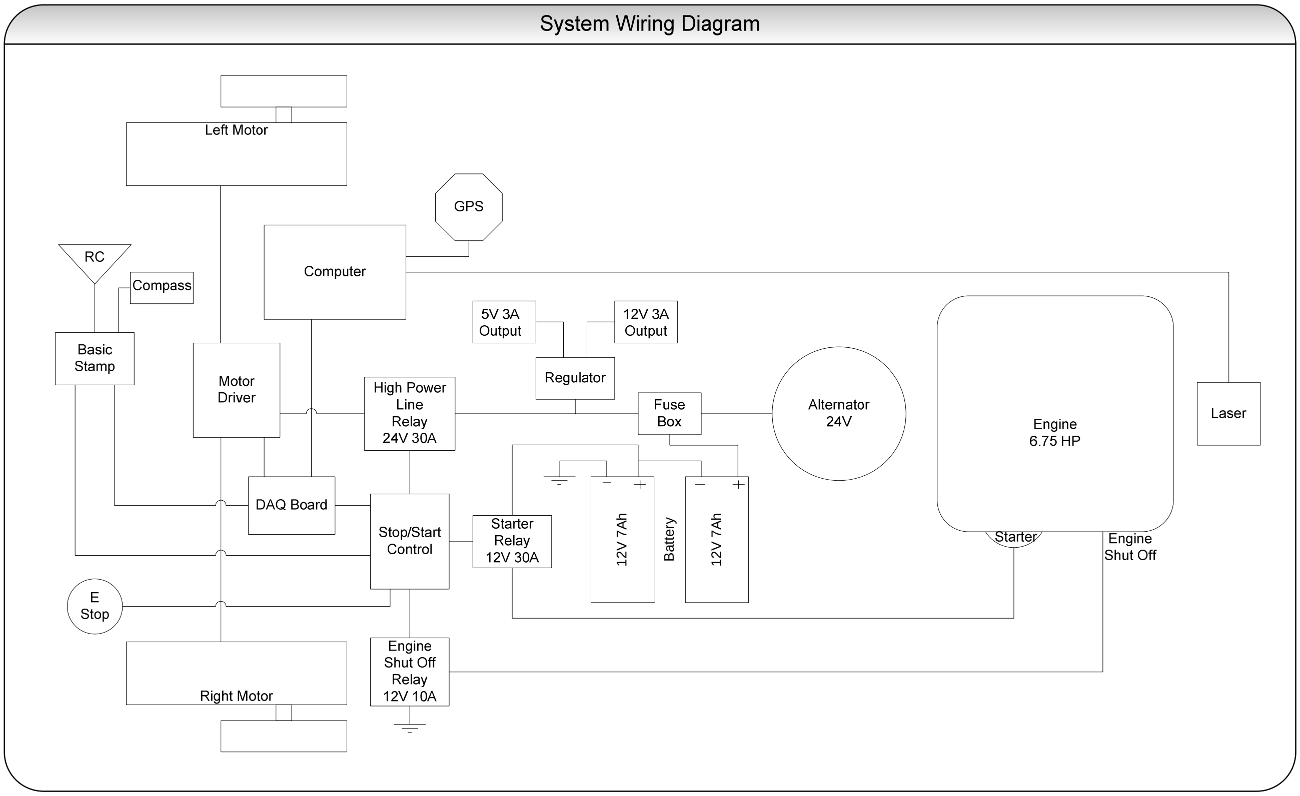


**Figure 3 – The GSU System Wiring**

### 3.2.1 *Microcontroller Unit*

A Basic Stamp Microcontroller [7] is used to read data received from the compass (Sec 3.3.6) and the Radio remote control. This data is processed by the microcontroller, and the function of moving the lawnmower in a specific direction is relayed to the DAQ Board for the laptop to use to produce a response. The Basic Stamp was selected for this application because of its availability in the school labs.

**Figure 4 – Microcontroller Unit**

3.2.2 *DAQ Board*

The Data Acquisition (DAQ) Board is a data sampling and output device that is connected to the laptop to allow communication to and from other devices on the lawnmower. The DAQ used is the NI USB-6216 from National Instruments [8]. Such data will include input from the Basic Stamp (Sec. 3.2.1), and output functions to the Motor Controller (Sec. 3.2.3), and the Stop/Start Controller (Sec. 3.2.4). This board was used because it was available in the instrument lab.


**Figure 5 - DAQ Board**

3.2.3 *Motor Controller*

To drive the Autonomous Lawnmower, the Sabertooth 2X25 motor driver was chosen (Figure 6). The decision to use this device stems from the fact that it is suited for high-powered robots, such as a heavy lawnmower. The Sabertooth 2X25 can control two DC motors rated up to 24V at 25A each. The lawn-mowing system weighs close to 200 lbs, and it is vital that its speed be controlled in an efficient manner. Thus, we used the differential drive capabilities of the Sabertooth 2X25 Motor Controller. Differential Drive is a method of controlling a robot with two motorized wheels. This method allows the robot to accelerate to its rated speed (6 mph) exponentially. As a result, the lawnmower will not jolt upon starting and this will not add high current loads to the DC motors that could be damaged by this action.

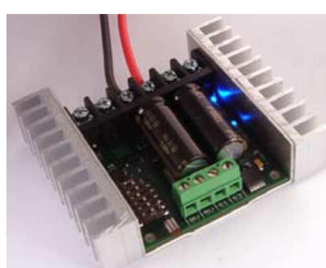

**Figure 6 – Sabertooth 2X25 Motor Driver**

### 3.2.4 *Stop/Start Controller*

An important factor in the designs of the Grass Shredding Unit was to integrate safety precautions into the unit. For this purpose, the lawnmower has a manual emergency push button shutoff and an emergency wireless shutoff in case the lawnmower does not work properly as safety risks could be present. This emergency system is made of OR gates that will trigger a set of relays that will cut off power to the gas engine and the high power line to the DC drive motors if any of the emergency shutoffs is activated. The computer also activates the relays independently from each other. When required in the program the laptop can start or shut off the gas engine and turn off the high power line to the DC drive motors (Sec 3.3). The circuit of the Stop/Start Controller is seen in Figure 7.

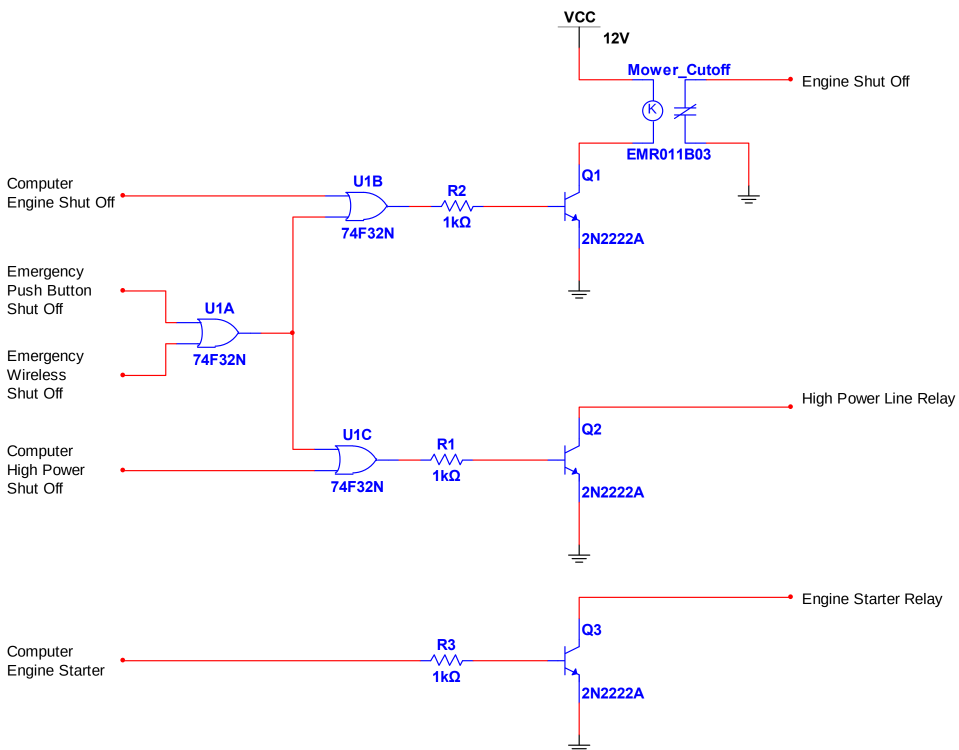


**Figure 7 - Stop/Start Controller Circuit**

### 3.2.5 *Power System*

All of the electrical components and devices have different power requirements. The high power line is 24 Volts, 30 Amps that is produced using the hybrid system of two lead-acid rechargeable batteries and the gas engine's alternator. Also, a regulated 5 Volts, 3 Amps and 12

Volts, 3 Amps are required (Figure 8). The LM1085 voltage regulator chip is used to produce the two output voltages and will allow for all the electrical components and devices to obtain the required power needed to work properly.

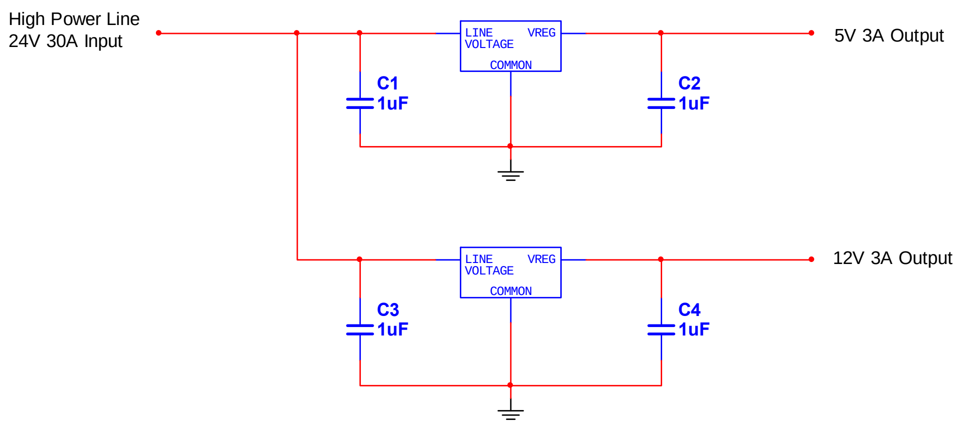


**Figure 8 - Voltage Regulator Circuit**

## 3.3. Control System

### 3.3.1 *Main Program*

The main program of the Grass Shredding Unit is stored in a laptop computer and uses C++. The main program allows the user to use the RC remote to select between Manual and Auto Mode. To run the lawnmower in Auto Mode the user must use the Manual Mode first to define the way-point border of the lawn (Sec. 3.3.2).

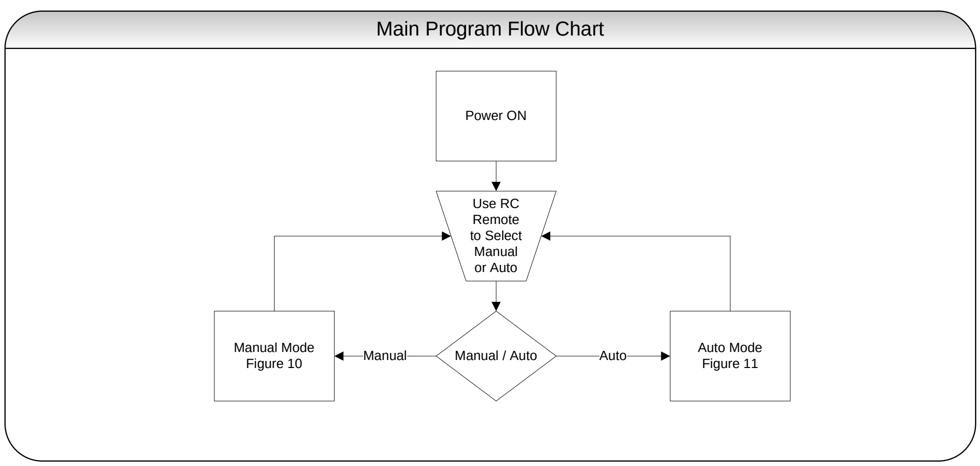


**Figure 9- Main Program Flow Chart**

### 3.3.2 *Manual Mode Operation*

After selecting the Manual Mode using the RC remote the user is able to use the RC remote to move the lawnmower around the lawn. In this Mode the way-points of the lawn's perimeter area are received by the GPS unit and saved to the memory of the computer for use in the Auto Mode. Once the lawnmower has moved all the way around the lawn to the position where it first started, the user of the lawnmower can then end the Manual Mode control by using the RC remote. This allows for the user to stay a safe distance away from the lawnmower. Figure 10 shows the flow chart of the Manual Mode Operation.

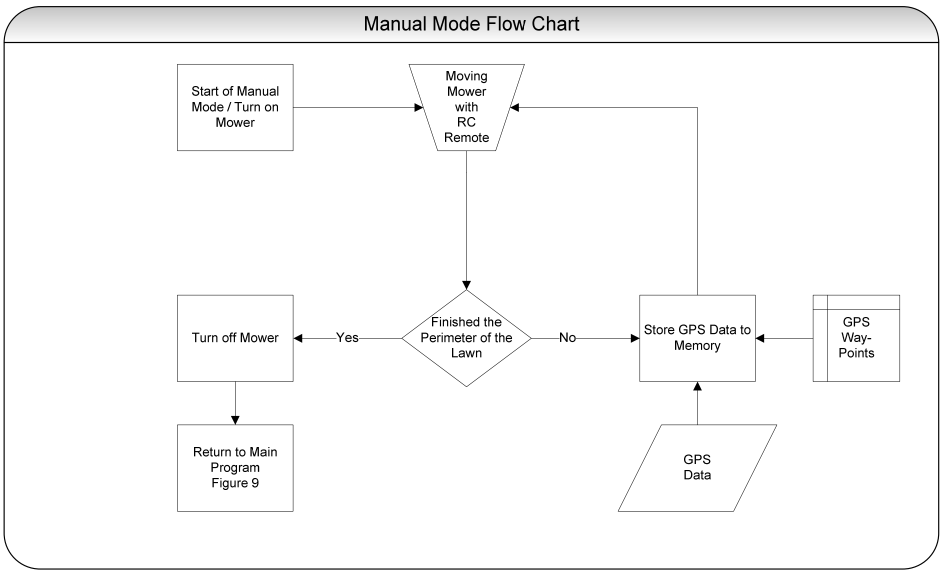


**Figure 10 - Manual Mode Flow Chart**

### 3.3.3 *Auto Mode Operation*

After selecting the Auto Mode of the GSU the electric start for the gas engine is enabled to turn on the blade and also run the alternator. At the beginning of the auto mode, the Basic Stamp unit will save two compass directions to memory for later use. The first compass direction is the initial direction that the lawnmower is facing, and the second is the direct 180° from the first direction. After the compass directions are saved the Auto Mode loop is started as shown in Figure 11. In the Auto Mode loop the program reads the sensors values to determine how to move the lawnmower to mow the lawn and avoid objects. The GPS unit is used to detect the way-point border of the lawn and detect when the lawnmower has mowed the whole lawn. The laser sensor is used to detect object(s) that might be in the path or move into the path of the lawnmower. The compass is used to check the lawnmower's direction to keep it on course. The role of the GPS unit, laser sensor, and compass are explained in more detail later in this document.

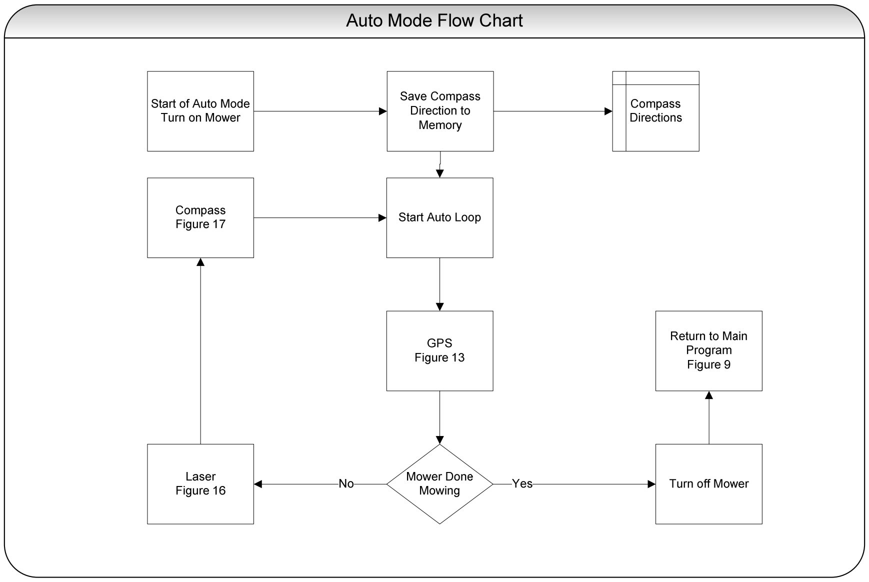


**Figure 11 - Auto Mode Flow Chart**

### 3.3.4 *GPS Operation*

The GPS unit's main use is to read the current position of the robot and detect when a way-point border has been reached. The GPS unit used is a Trimble Differential Unit Pathfinder Pro XRS, which allows for an accuracy of up to 30 centimeters and shown in Figure 12. In order to get the maximum accuracy the receiver would need a Wide Area Augmentation System Signal (WAAS signal), but this requires a monthly subscription of about one hundred and fifty dollars a month. The receiver also has a real time DGPS beacon option, which is the one that was used in our project.


**Figure 12 – Differential GPS Unit**

The flow chart of the GPS block is shown in Figure 13. The computer will take the current GPS way-point that the GPS unit is reading; then compare it to all the saved way-points in memory, and verify for any match or very close points. If the computer doesn't find a match, the lawnmower continues its trajectory indicated in the Auto Mode program. If the computer does find a match to the GPS way-points then the computer will take action. This action will depend on the condition of a flag that is set to "0" or "1". The flag will determine if the lawnmower has to turn one way or the other. If the flag is set to "0" the lawnmower will turn 180° to the right and set the flag to "1". If the flag is set to "1" the lawnmower will turn 180° to the left and set the flag to "0". Each 180° turn sets the lawnmower to start on a new row that still needs to be mowed.

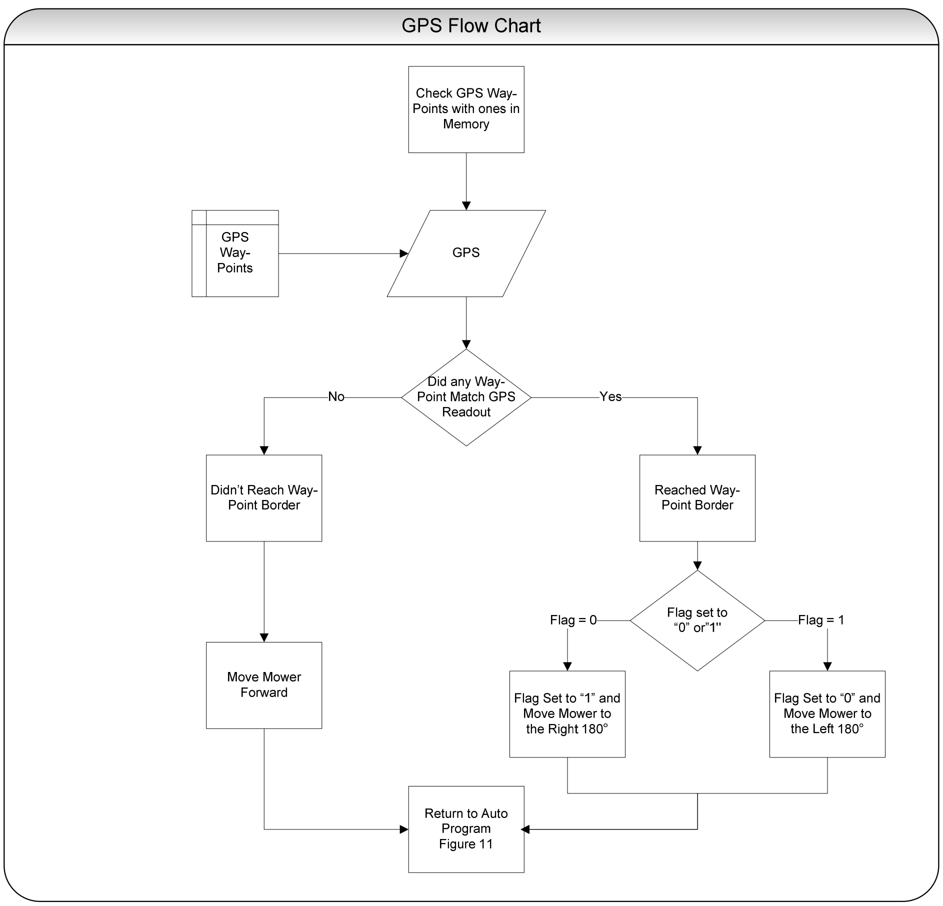


**Figure 13 - GPS Flow Chart**

### 3.3.5 *Laser Operation*

The main use of the laser sensor is to detect object(s) that are in the path or move into the path of the lawnmower. The Laser unit used is the Hokuyo URG-04LX shown in Figure 14. The field-of-view for this detector is of about 240 degrees and the angular resolution is approximately 0.36 degrees with a scanning refresh rate of up to 10Hz. Object distances can be reported from 20mm to 4 meters.


**Figure 14 – Laser Unit**

As the computer works through the Auto Mode loop seen in the Auto Mode flow chart it gets to the laser block (Figure 16). The computer reads the laser values. If one or more of the values are below the threshold value set as a safe distance to approach an object the computer will take action to avoid the object in the lawnmower's way. If there is no object in the way the computer will keep the lawnmower on its path. If there is an object the computer will determine which quadrant of the laser the object was detected in. The quadrants of the laser are setup as seen in the diagram shown in Figure 15.

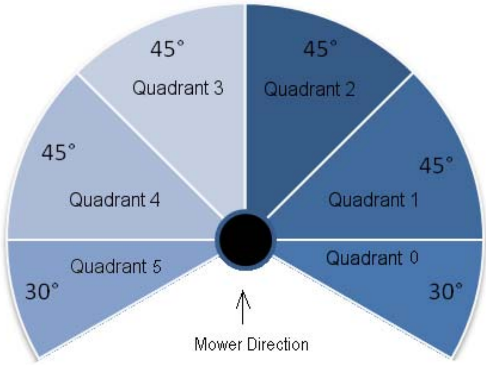


**Figure 15 - Laser Quadrant Setup**

If the object is detected in quadrant 0-2 the computer makes the lawnmower move to the left of the object until it is a safe distance from the lawnmower. When the object is detected in quadrant 3-5 the computer makes the lawnmower move to the right until the object is a safe distance from the lawnmower.  This way the lawnmower will move away from the object to avoid collision.

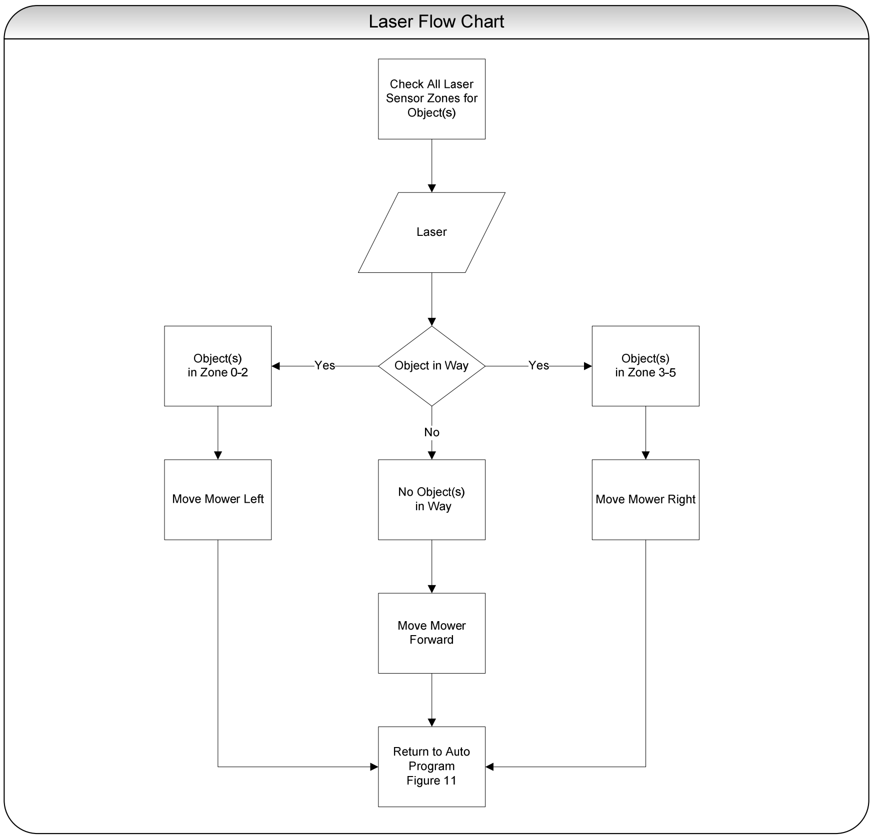


**Figure 16 - Laser Flow Chart**

### 3.3.6 *Compass Operation*

The main use of the compass is to keep the lawnmower on course to mow straight rows. The Basic Stamp unit will read the compass direction and compare it to the saved directions to determine what action to take.  The directions that the Basic Stamp unit uses to compare the current value to were saved in memory at the start of the Auto Mode when the lawnmower first started to mow the lawn. The two values that are saved in memory correspond to one of the conditions of the flag “0” or “1”. When the flag is set to the different condition the compass direction also changes that the Basic Stamp will use to reference the incoming compass values. If the lawnmower is to veer off course the Basic Stamp sends a signal to the computer to correct the lawnmowers direction. If the lawnmower moves off course to the right of the compass direction in memory the computer will make the lawnmower move to the left. When the lawnmower moves off course to the left of the compass direction in memory the computer will make the lawnmower move to the right. If the lawnmower is not off course the computer will continue to run through the Auto Mode loop.

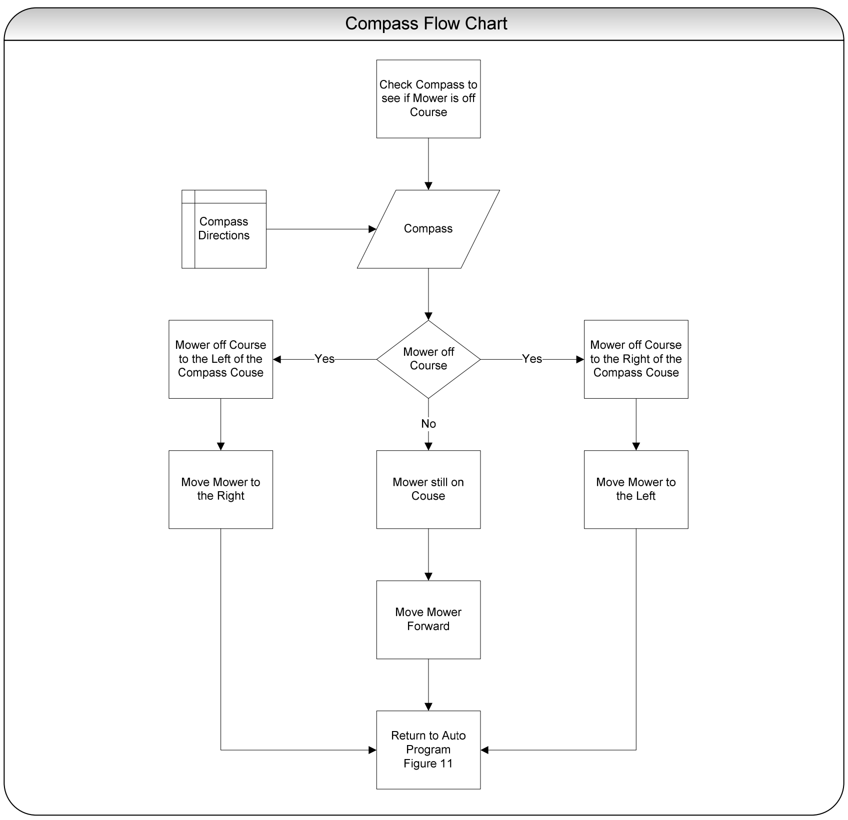


**Figure 17 - Compass Flow Chart**

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