Operator’s Manual

Lawnmower for Shane
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Important Safety Instructions

- Familiarize yourself with the controls found within the manual before ever attempting to operate the machine. Keep the manual in a safe place.
- To reduce risk of injury, always operate lawnmower under supervision.
- Wear sturdy, rough soled work boots and close fitting pants and shirts. This will prevent loose clothing from getting caught in moving parts. Never under any circumstances operate the vehicle with bare feet, or in sandals.
- Do not put hands or feet near the cutting deck when mowing.
- Be sure the area being mowed is free of people or animals before mowing, and stop the machine if anyone enters the area.
- Before mowing, be sure the area is clear of rocks, debris, and other miscellaneous objects which can be picked up and thrown by the blade. To prevent injury from objects thrown by the blades, keep observers and children at least 75 feet away whilst operating. Be sure to stop the blades when crossing gravel drives, walks or roads.
- Never carry passengers, the machine is intended for only 1 rider.
- Never leave the machine running while unattended. Always turn off blades, place transmission in neutral, apply the parking break, stop the engine and remove the key when dismounting.
- Always disengage the blades before shifting into reverse. Failure to do this can cause damage to the transmission.
- Never operate the mower without the clipping chute guard in place.
- Only mow during the day time, or under adequate artificial light.
- Never operate the mower during or immediately after foul weather conditions such as rain, snow, sleet, hail, etc.
- Be conscious of the turning radius of the mower at all times, and plan accordingly when navigating around objects, to avoid collisions with the mowing deck or seat transfer platform.
- Be sure the transmission is in neutral, mower deck is off, and the brake is thoroughly depressed before attempting to start the machine.
- Be cautious when operating on sloped surfaces, as the mower can tip if on a steep enough slant.
- When on a sloped surface, operate at slow speeds to take advantage of the engine braking. Never make sharp turns as it can cause the vehicle to become imbalanced and potentially flip.
Parts and Accessories

**Steering**
- Steering gear motor
- Chain
- Sprockets

- Steering column
- Steering wheel

- Rotary encoder
**Throttle**
- Throttle actuator

**Brake**
- Brake actuator
Computer Controls

- Joystick

- Arduino
- RyGen 25A Speed controller

- Firgelli Linear Actuator Controllers (LAC)
Manual Controls

- Power Take Off (PTO) lever

- Transmission lever
- Mower deck height lever

Seat
- Seat
- Armrests

- Armrest brackets
- Transfer platform

Heads up display
- Ignition
- Parking brake

- Systems indicator panel
- Throttle control lever

**Miscellaneous**
- Battery compartment
- Main power switch to computer controls

- Headlights
- Mower Deck

- New Carburetor
Features

- Steering wheel
- Joystick
- Armrests
- Hydrostatic transmission
- Actuated throttle
- Actuated brake
- Adjustable seat
- Safety switches/Killswitches
- Electric starter
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Introduction

1.1 General overview

The lawnmower is a modified Troy Bilt model 609 ride-on lawn tractor. The tractor has a 17 hp Briggs & Stratton Intek OHV motor, and a 42 inch cutting deck; ideal for larger lawns of about 2 acres. The throttle, brakes, and steering are all powered by actuators and motors, which can all be controlled using a single joystick. The actuators are attached directly to their respective accelerator and brake pedals, and provide the needed force to perform each action. The steering operates using a sprocket and chain system connecting a DC motor and the steering column. In order to power all of these systems, the components draw power from a single battery source, located underneath of the driver.

The method of control is through a joystick from Shane’s old Jazzy Select power chair. When the user operates the mower, he or she moves the joystick in the direction desired. Up on the joystick accelerates, left on the joystick turns the steering left, right on the joystick turns the steering right, and down on the joystick deploys the brakes. The flow of command comes from the user, to the joystick, to the microcontroller, to the appropriate driver, and then to the motor or actuator needed. The steering wheel is attached only for aesthetic purposes, and also to serve as a handle when mounting and dismounting the mower. The operator never has to touch anything other than the joystick, the shifting knob, and the Power Take Off (PTO) lever. The PTO lever is what powers the lawnmower blades, which cut the grass. The shifting knob is a simplistic lever which has a forward, neutral, and reverse position. If anything becomes problematic on the lawnmower, the system is designed with multiple safety kill switches located on the brake, PTO, and under the seat. These switches prevent injury by shutting the mower down instantly if a problem occurs. The system is also programmed to reset all motors and actuators to their neutral and inactive positions in the case of a disconnect between the joystick and the control board.

1.2 Checks to perform before each use

Before using the lawnmower the mower should be up to date on its service, and should be checked for suitable amounts of oil and gas to complete the cutting job at hand. Filling the gas tank with unleaded 87-octane gasoline will provide the mower will approximately one and a half to two acres of mowing time. The gas level should always be checked before using the lawn mower. The lawn mower should be serviced before every mowing season, to ensure all parts are operating to their maximum potential.

There are several other key steps which are good habits to keep before operating the mower. A simple task to complete before riding is to ensure all actuators and motors are attached securely to the pedals and steering column. Also, the contacts of the wires should be snugly in their controllers, and if not they should be rewired as in the manual. After doing the thorough systems check, you can move on to the next step.

At this point the mower should be maneuvered out of the storage garage and into the area of grass that is to be cut.
When on the grass, mowing can begin. Throw the PTO lever to activate the mower’s blades in order to cut the grass. The mower blades should only be run when cutting grass, in order to avoid risk of injury.

1.3 Transferring

After determining the mower is tuned to optimal settings, the operator will need to adjust himself to use the seat transfer device. The operator will use the elevated platform located in the garage where the device is stored to achieve the required additional height of nine inches. This elevation will give the operator the necessary height clearance to use the seat transfer device. This elevation when coupled with the wheelchair seat height will give the operator the needed height to mount the vehicle. Once in position the user can transfer to the seat transfer platform. After transferring off the wheelchair and onto the platform, the operator can easily slide across the platform and into the operator’s seat, making sure to fold down the armrests on either side. Time should be taken when using the seat transfer platform, as it is not meant to be a permanent seat, but rather a means of transfer.
1.4 Starting the mower

Once in the operator’s chair, the directions for starting the lawn mower with the electric starter can be followed to activate the mower. The mower should not be powered on in a closed, confined area, as it can be hazardous to inhale fumes from the mower’s exhaust.

In order to start the mower, first flip the power switch to computer controls to the ON position. Now move the joystick down, deploying the brake actuator fully. While the brake is fully applied, flip the power switch to the OFF position. Making sure that the PTO lever is in the OFF position, and the lawnmower is in neutral, set the throttle control lever to the choke position. Turn the key and hold down until the motor starts, then flip the throttle control to the fast position, allowing the engine to idle for a minute. Now flip the power switch to the ON position again, and move to the next step in operation of the mower.
1.5 Mower movement and operation

The next step is to engage the transmission lever, which is located on the left side of the mower. Engage the transmission in the desired direction, this will enable the mower to travel forwards or backwards. Make sure that whenever making changes in direction of the transmission, that the brake is fully depressed. Also make sure that when changing direction that the PTO lever is in the OFF position.
Once the transmission lever is engaged the joystick is ready to control the motion of the lawn mower. If the transmission lever is set to the forward position the joystick will have the ability to move the lawnmower forward, and if the transmission lever is set to the reverse position the forward position of the joystick will have the ability to move the lawn mower backwards. Do not get confused here, although a forward push on the joystick would normally be to move the mower forward, this is only the case when the transmission is in the forward position. Pushing the joystick forward is responsible for engaging the transmission, whether it be forwards or backwards. Before starting to control the lawn mower with the joystick ensure the joystick is in the neutral position and is secured firmly to the armrest.
Figure 4. Joystick neutral position

Figure 5. Joystick to forward position
The joystick also has control over the steering system of the lawn mower. When the operator wants to steer the mower to the left the joystick position should be moved into the left position, and when the desired direction of travel is to the right the joystick should be moved into the right position.
2. Maintenance

2.1 General maintenance tips

Always use extreme care in handling gasoline and other fuels. They are extremely flammable and the vapors are explosive. When transporting fuel, only use an approved container. Never remove fuel cap or add fuel with the engine running. Allow engine to cool at least two minutes before refueling. Replace fuel cap securely and wipe off any spilled fuel before starting the engine as it may cause a fire or explosion. Extinguish all cigarettes, cigars, pipes and other sources of ignition before getting anywhere near the mower. Never refuel the machine indoors because fuel vapors will accumulate in the area. Never store the fuel container or machine inside where there is an open flame or spark, such as a gas hot water heater, space heater or furnace. Never run a machine inside a closed area. To reduce fire hazard, keep the machine free of grass, leaves or other debris build-up. Clean up oil or fuel spillage if they should occur. Allow machine to cool at least 5 minutes before storing, to prevent risk of fire.

2.2 Cleaning

Before cleaning, repairing or inspecting, make certain the blade and all moving parts have stopped. Disconnect the spark plug wire, and keep the wire away from the spark plug to
prevent accidental starting. Check the blade and engine mounting bolts at frequent intervals for proper tightness. Also, visually inspect blade for damage (e.g., excessive wear, bent, cracked). Replace with blade which meets original equipment specifications. Keep all nuts, bolts, and screws tight to be sure the equipment is in safe working condition. Never tamper with safety devices. Check their proper operation regularly. In general it is important to keep all moving parts of the mower free from debris which could get caught and thrown by one of the motors or belts.

2.3 Battery

If the battery should become discharged or need replacing, open the compartment and examine the wires connecting to the battery. Note that the positive battery terminal is marked (+) and has a red wire. The negative terminal is marked (−) and has a black wire. When replacing the battery make sure that the contacts are complete and the screws holding the wires to the battery are securely tightened. Also make sure that the wire leads to the main power switch are properly connected in the same fashion.

![Battery connection diagram](image)

Figure 9. Battery connection diagram

2.4 Electrical

A systems check of all the mower’s electronic switches should be done regularly. The safety switch located under the seat can be tested by starting the mower and then dismounting the seat. If the switch is operating correctly, the mower will shut itself off. The safety switch is pictured below, and is underneath of the spring shown.
2.4.1 Electrical - Circuit

Systems check for the circuitry controlling the actuators and steering motor is very important. The entire system can be tested while the mower is off. Flip the main power to the circuit to ON, and move the joystick in all directions. Make sure that the corresponding appropriate movement for each motor happens when the correct joystick command is given. This will make sure that no wires are crossed, altering the circuit from proper function.

3. Technical Description

3.1 Power supply

The following devices are connected to the positive and negative terminals of the battery with red and black leads. The lawn mower battery supplies the power for all the electronics and is enabled through the power toggle switch. The operating voltage of the battery is 12V and the battery is capable of supplying up to 340 cold cranking amps of currents at zero degrees Celsius. The linear actuator and steering motor both require 12V and 4A of current to run the required load at the desired speed. The joystick is powered from the 5V power source terminal on the Arduino. The Arduino acts as a common ground for the actuator control boards because it specifically states in the datasheet that the control board must be grounded to the ground terminal of the microcontroller, in this case the Arduino.

3.2 Joystick to Arduino
In order for the joystick to control the motion of the actuators and steering motor an Arduino board was used. The control of the mower starting with the user applying a directional force to the joystick will be discussed next. When the user is ready to travel in a certain direction he or she will for example move the joystick in a forward direction. The joystick, which is connected to five volts, to ground, has two potentiometers that can represent the joystick position over the movable joystick plane. The two potentiometers are connected to analog input terminals A0 and A1 on the Arduino board. Each x and y axis potentiometers allow for a certain amount of voltage to be sent as a signal. The sent signal is proportional to where the joystick position is. The signal is on a scale where full joystick extension is represented by allowing all of the five volts to pass through the potentiometer and joystick in the back position allows zero volts to pass through. Based on these signals the Arduino can read with the *AnalogRead* command the voltage being sent through the potentiometer. The *AnalogRead* command writes that voltage based on an 8-bit value scale. The scale ranges from 0-1023 and represents the position of each potentiometer. The highest values are achieved when the joystick is in forward position and when the joystick is to the right. The joystick pins are as follows, only four of the eight total pins are used in the design. The first joystick pin for voltage supply, the second pin is for the x axis potentiometer, the third pin is for ground, and the fourth pin is for the y axis potentiometer.

The Arduino had to be programmed in order to correctly read the voltage from the joystick and then based on what voltage is being put through each potentiometer it must write, with *AnalogWrite*, the correct value to the corresponding speed controller. The *AnalogWrite* command writes a Pulse Width Modulation signal (PWM) signal to a specified digital PWM output terminal. The PWM signal is a proportional signal to the amount of voltage being sent through each potentiometer. As there is an increase in the voltage through the potentiometer there is an increase in the active duty cycle of the PWM signal. This enables the actuator or steering motor to extend or rotate to a certain position at a certain speed.

Adjusting the deadband or neutral range of the joystick was important in getting the lawn mower to run under actuation. The range in which there is no response ready by the joystick was set to range from 400-600 based on the 8-bit signal received by the Arduino. Meaning that the range for the brake actuator is from 0-400 and the throttle actuator ranges from 600-1023. When testing the signal via the serial monitor on the Arduino it was found that they joystick in reality was in the range of 220-400 for the brake actuator and 600-805 for the throttle actuator.

The next step of the Arduino code is for the read analog signal to be converted into a range that can be sent to the motor and speed controller. The *map* function on Arduino’s call libraries was used. This function is able to take the range read for either actuator either 220-400 or 600-805 and scales that value to a range of 0-255, which is the range that the motor can accept. The value of 255 represents full rotation or actuation and a value of 0 indicates there should be no movement by the motor.

### 3.3 Arduino-Speed Controller
The PWM signal from the Arduino is sent to the corresponding speed controller, either the linear actuator control board or the steering motor speed controller, and then the speed controller can output the desired operating current. The Arduino’s digital PWM output terminals are only capable of outputting 40mA of current, which is an insufficient amount of current to run the actuators and steering motor at four amperes. The speed controllers are both able to accept a PWM signal based on a 1 kHz signal and then can output the corresponding desired voltage at the current level needed to move the load. If speed controllers were not used the Arduino board would not supply enough current to cause the actuators or steering motor to move.

The speed controllers have input terminals that connect to the mower’s battery, or voltage supply. The terminal leads of the actuators and motors connect into the appropriate terminal on the speed controllers. The linear actuator control boards have built in terminals for the position potentiometers positive and negative terminals as well as the position potentiometers wiper signal. These will control the position of the actuator enabling them to extend and then stop at the desired extension.

The wiring schematic can be seen below for the joystick to Arduino to speed controllers. The actuator and steering motor are left out for ease of viewing the diagram. The motors simply connect to the appropriate terminal on the speed controller, which can be viewed in the following diagram.

![Wiring schematic](image)

Figure 11. Joystick-Arduino-speed controller wiring
The joystick wiring can be seen above. This is how the Arduino board should look when the joystick and the speed controllers are wired properly to the board. The operator should take note of the specific pins used by the speed controllers. If the appropriate pin is not used, as in the figure above, there will be a cease in the ability for the joystick to control the lawn mower. The Arduino command window can be accessed by plugging in a USB port into the silver terminal in the figure above. Freeware can be downloaded from the internet to run the Arduino command window once the Arduino is plugged into a USB port.

![Speed controller to motor wiring](image)

Figure 12. Speed controller to motor wiring

In the figure above the signal sent from the Arduino board is sent into the terminal labeled S1. The steering motor power supply is connected into the terminals B+ and B- with red and black wires, respectively. The motor terminals are connected to the M1 and M2 terminals on the speed controller and are represented with green and yellow wires in the diagram above. The speed controller is set to accept a PWM signal. This setting can be observed at the site of six yellow switches on a black box. The small switches are oriented in the figure above to accept a PWM signal to the port S1.

The speed controllers also act as a medium where the polarity of the current can be reversed without causing adverse effects to the motor. The speed controllers utilize a four transistor H-bridge system, which can safely reverse the current in order for the motor to change directions. This is needed for both the actuators and the steering motor.
3.4 Motor Feedback

Motor feedback is achieved through the use of a rotary encoder. The rotary encoder has two pins, pinA and pinB. These two pins are wired to the Arduino’s digital outputs pins 11 and 12 respectively. The rotary encoder is also grounded to the Arduino’s ground terminal. The rotary encoder code has 12 steps per 360 degrees of rotation. The encoder Arduino code is written to compare the signal from each pin and then compares each pins value to the last recorded value. Whether the signal from pin A to B is positive or if its negative allows for the direction to be determined. The interpreted scale goes from \(-180\) to \(180\) with \(180\) being one and a half rotations to the right and \(-180\) one and a half rotations to the left. This range is set to prevent the motor from turning the steering column more than it can go. The code is written so that when the Arduino reads the rotary encoder signal at end of the range and input and off signal to the digital output to the steering motor speed controller. The only difference between the actuator feedback system and the steering feedback system is that the steering motor’s feedback signal is sent through the Arduino board and the Arduino code indicated whether the motor should be allowed to continue turning or if the stop command should be initialized. The actuator feedback signal is sent through the speed controller, which compares the signal from the joystick and evaluates that signal as a percentage of 100 of the total duty cycle being sent through on the PWM wave.

3.5 Emergency Power Switch

The emergency power switch is located on the left side of the mower; next to where the cupholder is. This switch is responsible for controlling the power supplied to the electrical components that were added to the lawn mower. The emergency power switch is able to cease the power to the electrical components of the system. This acts as a safety feature but also as needed design requirement. The power switch stops the electrical components from being constantly connected to the mower’s battery, which would result in drainage of the battery. The emergency power switch is also able to kill all power to the actuators and motors and returning them to their original position, which is written into the code. If the mower is stuck with one actuator in the full extension position the power switch can be thrown to turn off the system and then throwing the power switch again will act to re-center the actuators.
This circuit was implemented in the building of the lawn mower’s steering motor feedback system. The pullup resistors that were used were 22k ohms, and pinA and pinB represent pins 12 and 11 on the Arduino board. This circuit was soldered to a PCB board due to the simplistic nature of this circuit. The steady state voltage of the circuit seen above is 3.3V, which is the power pin that the pullup resistors are connected to. The steady state current for this circuit is 40mA.

4 Troubleshooting

4.1 Mower

If you should come in contact with a foreign object whilst mowing, stop the engine, and get assistance from the observer. The observer should remove the spark wire from the engine and thoroughly inspect the mower for signs of damage before continued operation. If there are any strange noises coming from the cutting deck while operating, do not continue operation. Grass catcher components are subject to wear, damage and degradation, which could expose moving parts or allow objects to be thrown. For your safety and protection, frequently check components and replace with the manufacturer’s recommended parts when necessary.

If any of the actuators or the steering motor mounts become loose at any time the bolts securing these device should be checked. Tighten the bolts with a wrench to ensure the actuators and steering motor are secure, which will allow them to perform better.

If at any time the actuators and steering motor do not seem to be performing as they once did the mower should be stopped and the physical mountings and bolts should be checked for
tightness. A loose bolt could have the effect on the actuator or motor from shaking during activation. This would result in the throttle, brake or steering system to vibrate at a higher resonance than desired. Larger amount of vibrations will have uphold the soldering connections as well and may cause the wiring to become loose. This problem may have arose due to a bolt not being fully tighten or if the mowing terrain has been extremely sever. Fix this issue by securing the bolts that connect the actuators to the mower.

If the seat transfer mechanism become loose or dislodged during operation steps can be taken to secure the transfer platform back to the mower. Tighten the bolts that connect the platform to the mower and the issue should be resolved. The armrest may fail at one point. This may occur because something has damaged the hinge mechanism or the armrest may become jammed due to overuse. If a jam occurs try to manipulate the armrest in a way that causes the jam to become loose. If the armrest hinge is damaged the hinge may have to be replaced in order to restore the retractable armrests to full working order.

4.2 Electrical

If when the mower’s electrical components are powered on and here is any motion from the actuators or steering motor, which can be witnessed through a small jerking in one direction of the mower, or viewed by watching the mower’s pedals move forward; the switch should be immediately thrown and the troubleshooting guide should be reviewed. If the switch is thrown and the electronics powered up without activating the mower, it is ready to be used. If this is the case the terminals of the speed controllers should be checked to see if they are accepting the voltage from the battery. This should be done by taking the two leads of the voltmeter and placing the red voltmeter lead with the positive power supply terminal on the speed controller and the black lead of the voltmeter with the negative power supply terminal of the speed controller.

If the reading on the voltmeter is at least 12V now the motor terminals of the device should be tested with a voltmeter. This should be done when the power supply switch is thrown. The risk of electric shock is always present when testing electrical circuits when they are powered on. If there is no voltage going to the motor when the power supply is connected the following steps should be taken.

The outputs running from the Arduino pins to the speed controllers should be tested for a voltage now. When the joystick is in the neutral position the voltmeter should be used between the terminal that accepts the output from the Arduino and the ground pin on the Arduino, and the voltage reading should be zero. If there is a voltage being transmitted when the joystick is in a neutral position this would result in unwanted movement of the actuator or the steering motor. If this is the case and there is a voltage being sent to the speed controller when there is no motion from the joystick the joystick may have become damaged. There are two ways to possibly fix this problem. What has happened is that the joystick’s original deadband range is no longer applicable to this joystick. This could have happened from overuse or a traumatic event that has permanently deformed the joystick. To fix this problem the owner should purchase a new joystick and then rewire it in the same fashion as the old joystick, using the datasheet that can be found for the pin layout. Once this is done the new joystick’s deadband range will have to be calibrated, which can be done through the freeware Arduino proved that is found online.
other option is to not buy a new joystick and attempt to find using the serial monitor on the Arduino command window. It should be noted that the deadband range should encompass a wide enough range to incorporate a potential backlash of the joystick when it is released. When the joystick is released from one direction there can be a tendency for the joystick to rebound into random direction when it is released and returns to the neutral position. This is why the deadband range is adjusted to where it is. The values from 400-600 encompass the possible range of values that could be read when the joystick was released and returned to the neutral position. When a new joystick is selected or the old joystick is attempted to be recalibrated the testing of the rebound range is a very important step that should be carefully done.

Another potential problem that could arise with the motor is lack of control when the joystick is moved and the power switch is activated. The first step that should be taken is to observe the electronic housing unit and observe the wire connections. Refer back to the technical description of this operator’s manual and ensure that all of the wires are properly connected to their appropriate pin. This should be done when the power supply switch is set to off. Ensure that all the wires are secure and fit tightly into their appropriate terminal. The next step is to inspect each soldering connection by tracing each wire to its source and making sure the solder connection is still intact. If a soldering connection is faulty; steps found online should be taken to solder the connection point.

While operating the motor there should be no obvious “clicking” type sounds coming from the actuators or the motor the power switch should be thrown immediately. This sound occurring during turning the mower is particularly bad. What is happening is the motor is continuing to turn despite the rotary encoder communicating with Arduino to stop the motor. The connection between the rotary encoder and the Arduino is probably bad. Ensure the connections between the rotary encoder and the Arduino are secure and not loose. If this is not the case the Arduino board should be plugged into a computer and the serial monitor should be used to check the values of the rotary encoder. Access to determine if the encoder is sending the correct signal. When the joystick is activated to the left or the right the rotary encoder value should either increase or decrease by increments of ten. If this is not the case the rotary encoder may or become damaged and will need to be replaced. Follow the instructions for wiring the rotary encoder, which can found in the technical description.

If there is no motion of the actuator or the steering motor once the joystick is activated. The circuit housing unit should be consulted. The first step when taking a brief overview of the circuit housing is to check all of the green or blue power indicating light on the Arduino and speed controller.

Another potential problem that could arise is that the toggle switch controlling the power to the electrical system could become inactive. In order to test whether the switch wiring has become dislodged or the switch has accumulated particulars the following steps should be taken. As when testing the power supply connection to the speed controllers the voltmeter should be used to check the voltage when the switch is on and when the switch is off. If when the switch is in the on position and the voltmeter is indicating zero voltages are being passed through there is a faulty soldering connection. If after soldering the wire connection the problem is not fixed the toggle switch should be cleaned for any particulars that may have become lodged in the spot between the toggle lever and the toggle switch platform. A voltage of 12V should be sent through the switch when the switch is set to on.

If when starting the mower and throwing the electronic power switch there is no response from the joystick and motors the electrical components may have gotten wet. This could happen
from mowing in the rain or from an accumulation of moisture in a confined space during the summer time. Time should be taken to thoroughly dry out all electrical components. The expected drying time for the wet components is up to one week in duration.