

Liberty SC50



Service Manual

Model Numbers:

56104500 Liberty SC50 X20D (Disc)
56104501 Liberty SC50 X20R (Rev)



Language

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03 - General Information

General Machine Description

The Liberty SC50 machine is a battery-powered commercial floor scrubbing machine with autonomous driving capability, and is suitable for use in hotels, schools, hospitals, factories, shops, offices, rental businesses and similar applications. The Liberty SC50 has a 20" scrub deck to accommodate a variety of disc brushes, and can also be used with several grades of pads.

The machine is powered by either four 6-volt batteries or two 12-volt batteries, connected in series, to provide 24 VDC to the motors and controls. The machine's autonomous processors monitor its surroundings utilizing a 3D vision camera, a 2D scanning laser, 4 infrared dropoff (floor) sensors, and two safety lasers.

Service Manual Purpose and Application

This Service Manual is a resource for professional service technicians. It provides information for understanding how the machine operates, where components are located, basic troubleshooting, maintenance, and mechanical service operations.

Other Reference Manuals and Information Sources

Document Name	Doc. Number	Document Type
Instructions for Use	56091197	Instructions for Use
Parts List	56042654	Parts List
Nilfisk Lithium-Ion Battery Module Service Manual	56043180	Service Manual
UVGI Accessory Instructions for Use	56091255	Instructions for Use
SC50 Autonomous System Error Codes	N/A	EzParts Document

Parts And Service

Repairs should be performed by an Authorized Advance Service Center that employs factory-trained service personnel and maintains an inventory of Nilfisk original replacement parts and accessories.

Call the Advance Dealer named below for repair parts or service. Please specify the Model Number (same as the Part Number) and Serial Number when discussing your machine.

Diagnostic and Service Tools

In addition to a full set of metric and standard tools, the following items are required in order to successfully and quickly perform troubleshooting and repair of Advance commercial floor cleaning equipment.

- Digital voltmeter (DVM) with DC current clamp
- Hydrometer
- Battery load tester for checking batteries
- Set of torque wrenches

These tools are also available from Nilfisk-Advance, Inc.:

- Curtis 1311 hand held programmer, p/n 56409441,
- Vacuum water lift gauge, p/n 56205281.
- Drive Position Encoder Calibration Cable p/n 56122727
- Laser Alignment Kit p/n 56122718

Conventions

All references to right, left, front and rear in this manual are as seen from the Operator's position.

Revision History

Date	Revisions
January 2019	Initial publication
December 2019	Multiple updates
May 2020	Updates related to UI improvements included in MMC firmware revision 4.0
June 2020	Further updated related to MMC firmware revision 4.0 • Additional Autonomous system fault codes • Replace system command 50 with 60
August 2022	• Add Lithium-Ion battery option

Parts and Service

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Call the Nilfisk Dealer named below for repair parts or service. Please specify the Model Number (same as the Part Number) and Serial Number when discussing your machine.

Modifications

Modifications and additions to the cleaning machine which affect capacity and safe operation shall not be performed by the customer or user without prior written approval from Nilfisk, Inc. Unapproved modifications will void the machine warranty and make the customer liable for any resulting accidents.

Nameplate

The nameplate contains important identification information which will be needed when ordering parts: The Model Number (Part No.) and Serial Number of the machine are shown on the Nameplate located on the inside of the battery compartment.

This information is needed when ordering repair parts for the machine.



Safety

Symbols

It is important for you to read and understand this manual. The information it contains relates to protecting your safety and preventing problems. The symbols below are used to help you recognize this information.



DANGER: Indicates a potentially hazardous situation which, if not avoided, will result in death or serious injury.



WARNING: Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.



CAUTION: Indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury.



Note: Indicates an important informational message.

General Safety Instructions

These safety instructions are included to warn you of potential bodily injury or property damage.



CAUTION: Read and understand all safety warnings and instructions. Failure to follow the warnings and instructions may result in electric shock, fire, and/or serious injury.

- To avoid personal injury, this machine should be used only by properly trained and authorized persons.
- Do not operate the machine near toxic, dangerous, flammable and/or explosive materials. This machine is not suitable for collecting dangerous or hazardous materials.
- In case of fire, use a powder fire extinguisher, not a water-based extinguisher.
- Do not use on surfaces having a gradient exceeding that marked on the machine. While on ramps or inclines, avoid sudden stops when loaded. Avoid abrupt sharp turns.
- Disconnect the power source and/or batteries before servicing electrical components
- Never work under a machine without safety blocks or stands to support the machine.
- Do not dispense flammable cleaning agents, operate the machine on or near these agents, or operate in areas where flammable liquids exist.
- When using floor cleaning detergents, follow all safety and handling instructions of the respective manufacturer.
- Battery charging may produce highly explosive hydrogen gas. Charge the batteries only in well-ventilated areas and away from ignition sources or open flames.
- When operating this machine, ensure that third parties, particularly children, are not endangered.
- Take precautions to prevent hair, jewelry, or loose clothing from becoming caught in moving parts.

Property Damage Messages

- *Storage and operation temperature must be above 32°F (0°C) and a humidity between 30% and 95%, non-condensing.*
- *Before use, all doors and hoods should be properly latched.*
- *This machine is not approved for use on public paths or roads.*
- *This machine is only approved for hard surface use.*
- *Use brushes and pads supplied with the machine or those specified in the User Manual. Using other brushes or pads could reduce safety.*
- *Do not wash the machine with direct or pressurised water jets, or with corrosive substances.*
- *Do not allow the brush/pad to operate while the machine is stationary to avoid damaging the floor.*
- *Use only factory authorized parts and accessories.*
- *This machine must be properly disposed of in accordance with local laws and regulations.*

Lithium-Ion Battery Specific Safety Instructions



DANGER: Risk of fire or explosion. Excessive charge or discharge rates can damage the batteries and result in risk of fire or explosion. Exposure to fire or temperature above 130°C may cause explosion.

- *Risk of arc-flash injury. Never short battery terminals together. Keep all metal objects away from the batteries, including tools, jewelry, and other conductors.*



CAUTION: Inspect batteries for damage before each use. Do not use a battery pack that is damaged or modified. Damaged or modified batteries may exhibit unpredictable behavior resulting in fire, explosion, or risk of injury. Follow all charging instructions and do not charge the battery pack outside of the temperature range specified in the instructions. Charging improperly or at temperatures outside of the specified range may damage the battery and increase the risk of fire.

- *Do not mix battery types, brands, or models. Use only Advance/Nilfisk authorized Li-Ion batteries in the machine.*
- *Recharge only with the charger specified by the battery manufacturer. A charger that is suitable for one type of battery pack may create a risk of fire when used with another battery pack.*
- *Do not store, use or recharge in environments with a temperature higher than 45°C. Do not recharge with temperatures lower than 0°C.*
- *Do not modify or attempt to repair the battery pack.*
- *Under abusive conditions, liquid may be ejected from the battery; avoid contact. Liquid ejected from the battery may cause irritation or burns. If contact occurs, flush with water. If liquid contacts eyes, seek medical help.*
- *Before decommissioning the machine, remove the battery.*

Lifting or Transporting the Machine



CAUTION: *Never work under a machine without safety stands or blocks to support the machine.*

- *Drain the recovery and solution tanks to prevent sloshing water from unbalancing the machine.*
- *Lift only from the subframe of the machine, as shown below.*
- *Secure the machine to the transport using the tie down points shown below.*

The actual procedure for transporting the machine will vary depending on the mode of transport. Follow these general guidelines as applicable to the situation.

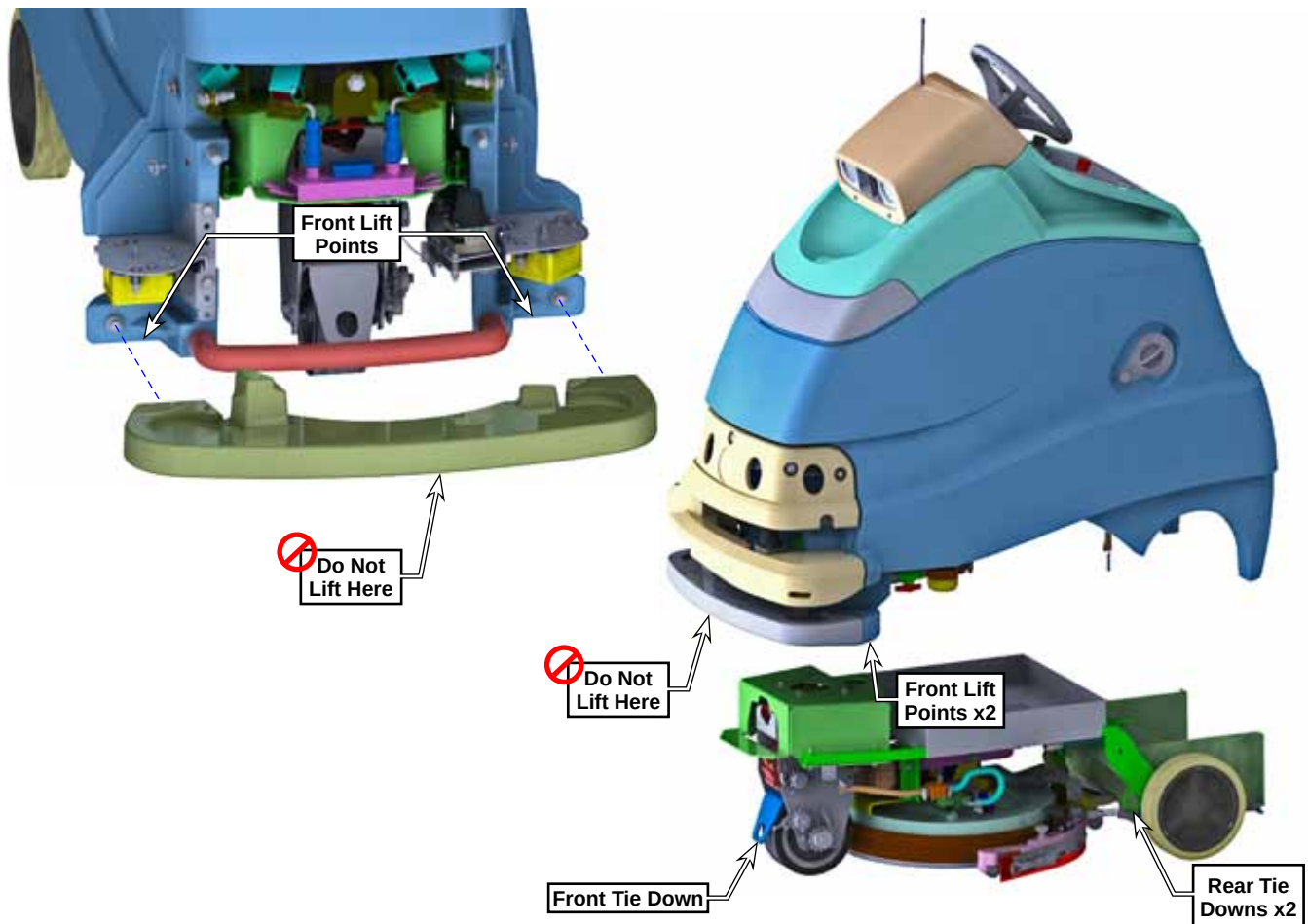
- If transport will occur below freezing temperatures, place a small amount of environmentally friendly antifreeze in the recovery tank, solution tank, and solution lines.
- Make sure all doors, panels, and covers are secure.
- Secure the machine to the transport using both front and both rear tie down points.

Care must be taken when lifting the front of the machine for servicing purposes.

- The front of the machine can be raised by jacking below the flat portion of the solution tank.
- Do not lift the machine by the front crossbar.

Raising the rear of the machine is a little less common.

- The rear of the machine may be raised by the stability (anti-tip) tabs of the solution tank behind the wheels.
- Do not raise the rear of the machine by the operator's platform.



Moving a Disabled Machine

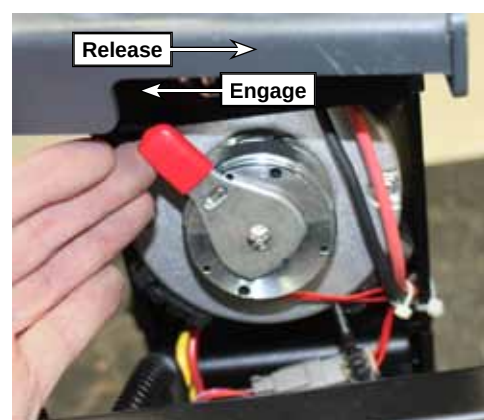
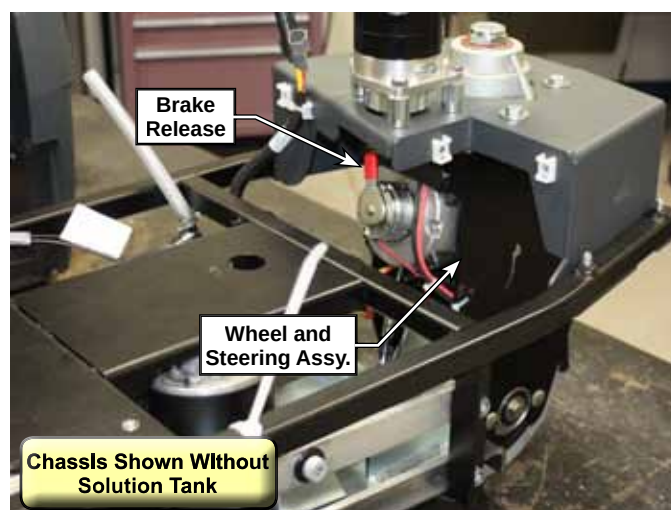
If the machine is not functioning and needs to be moved, it will be necessary to override the electromechanical brake on the wheel drive motor. The brake is an active-off type of brake, which means that the brake is always engaged unless the machine is commanding movement from the drive motor.



CAUTION: Make sure to re-engage the brake after manual transport. The brake will remain disabled until it is reengaged.

The brake release lever is located at the rear of the wheel drive motor. It may be necessary to turn the wheel (manually steer) to the side in order to reach the lever. The lever moves about 1/2-inch (12mm) between the engaged and disengaged positions.

- To release the brake, rotate the lever clockwise (move the lever toward the right side of the machine).
- To reengage the brake, rotate the lever counterclockwise (move the lever toward the left side of the machine).



Control Cover Prop Rod

The upper housing of the machine contains the operator controls and some of the autonomous components, but also serves as a cover for the recovery tank. Opening this cover provides access to many of the machine's subsystems. Whenever the control cover is open, the prop rod should be engaged to prevent the cover from unexpectedly falling.



Specifications

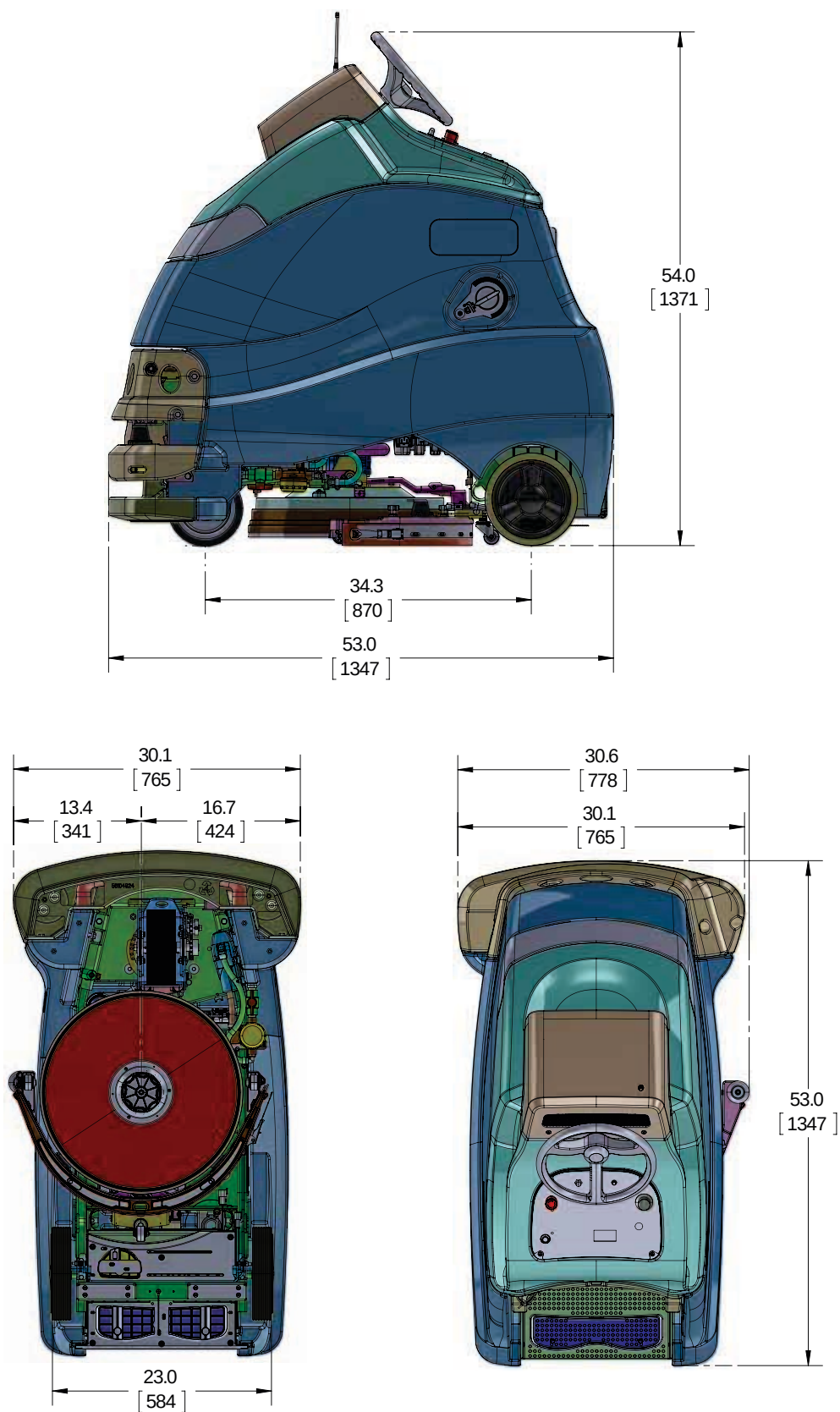
General Specifications

Parameter	Units	Liberty SC50 (X20D)	Liberty SC50 (X20R)
Model No.		56104500	56104501
Voltage, Batteries	V	24V	24V
Battery Capacity (max)	Ah	225	225
Protection Grade		IPX3	IPX3
Sound Pressure Level IEC 60335-2-72: 2002 Amend. 1:2005, ISO 11203, ISO 3744	dB(A)/20μPa	63	63
Sound Pressure level - KpA (IEC 60335-2-72, ISO 11203) Uncertainty	dB(A)	3.0	3.0
Gross Vehicle Weight*	lbs (kg)	994.2 (451.37)	1000.5 (454.33)
Transportation Weight**	lbs (kg)	706.6 (320.51)	730.5 (331.65)
Maximum Wheel Floor Loading (center front)	psi (kg/cm ²)	161.03 (11.32)	161.03 (11.32)
Maximum Wheel Floor Loading (right rear)	psi (kg/cm ²)	105.60 (7.42)	105.60 (7.42)
Maximum Wheel Floor Loading (left rear)	psi (kg/cm ²)	109.33 (7.68)	109.33 (7.68)
Vibrations at the Hand Controls (ISO 5349-1)	m/s ²	0.17	0.17
Vibrations for the Whole Body (ISO 2631-1)	m/s ²	0.01	0.01
Gradeability Transport		15% (8.53°)	
Gradeability Cleaning		9% (5.14°)	
Machine Length	inch (cm)	53.1 (134.9)	
Machine Height	inch (cm)	53.7 (136.3)	
Machine Width	inch (cm)	28.4 (72.1)	
Machine Width with Squeegee	inch (cm)	31.5 (79.9)	
Minimum Aisle Turn Width	inch (cm)	61.5 (156.2)	
Solution Tank Capacity	Gallon (L)	14 (53)	
Recovery Tank Capacity	Gallon (L)	14 (53)	
Transport Speed (Fwd. Maximum)	mph (kph)	3.1 (5)	
Transport Speed (Rev. Maximum)	mph (kph)	1.62 (2.6)	
Battery Compartment Size (approximate)			
Height (maximum)	inch (cm)	12.25 (31.115)	
Width (maximum)	inch (cm)	18.5 (46.99)	
Length (maximum)	inch (cm)	18 (45.72)	
Scrub Brush Diameter	inch (cm)	20 (50.8)	20 (50.8)
Scrub Brush Speed	RPM	157	—
Cleaning Path Width (scrubbing path)	inch (cm)	20 (50.8)	20 (50.8)

*Gross Vehicle Weight: Standard machine without options, full solution tank and empty recovery tank, with removable scrub brushes, batteries installed and 75 kg operator.

**Transportation Weight: Standard machine without options, empty solution and recovery tanks, with batteries installed and no operator.

Overall Dimensions



Fastener Torque Specifications

Standard Torque Specifications (unless otherwise specified)	Size	Plated Steel	Stainless Steel
	#10	42 in.-lb. [4.75 N-m]	28 in.-lb. [3.17 N-m]
	1/4"	100 in.-lb. [11.3 N-m]	67 in.-lb. [7.57 N-m]
	5/16"	17 ft.-lb. [23.05 N-m]	11 ft.-lb. [14.91 N-m]
	3/8"	31 ft.-lb. [42.03 N-m]	20 ft.-lb. [27.12 N-m]
	1/2"	75 ft.-lb. [101.69 N-m]	50 ft.-lb. [67.79 N-m]
	3/4"	270 ft.-lb. [366.07 N-m]	180 ft.-lb. [244.05 N-m]
	M5	61 in.-lb. [6.89 N-m]	36 in.-lb. [4.07 N-m]
	M6	9 ft.-lb. [12.2 N-m]	62 in.-lb. [7.0 N-m]
	M8	22 ft.-lb. [29.83 N-m]	13 ft.-lb. [17.63 N-m]
	M10	44 ft.-lb. [59.66 N-m]	25 ft.-lb. [33.9 N-m]
	M12	70 ft.-lb. [94.91 N-m]	40 ft.-lb. [54.23 N-m]

Maintenance

Maintenance Schedule

Keep the machine in top condition by closely following the maintenance schedule. Maintenance intervals given are for average operating conditions. Machines used in severe environments may require service more often.



CAUTION: Do not pressure-wash the machine

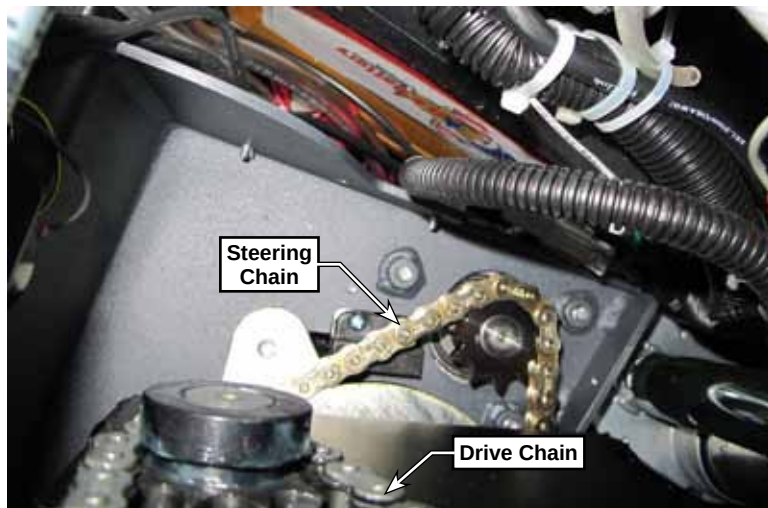
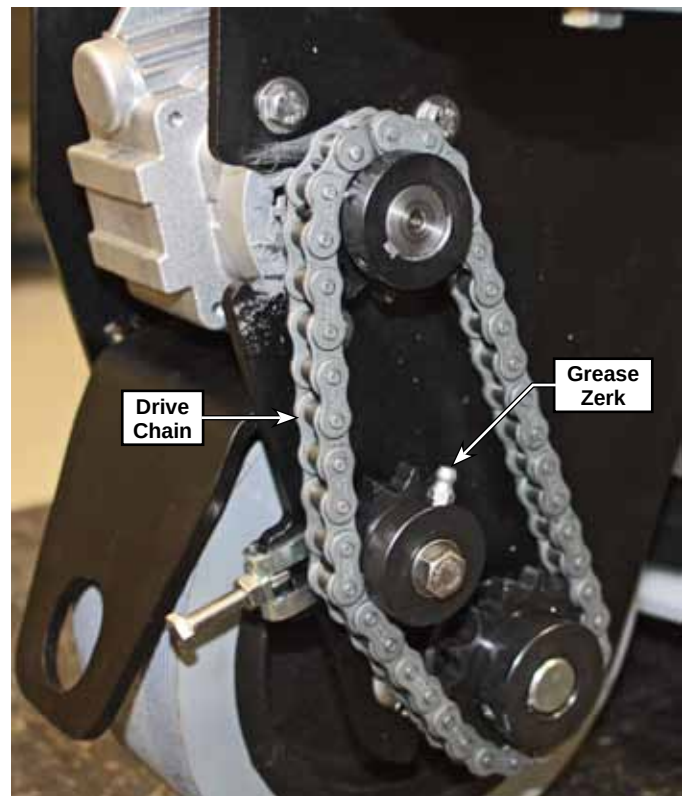
Maintenance Item	Daily	Weekly	Monthly	Yearly	As Needed
Charge Batteries	X				
Check/Clean Tanks & Hoses	X				
Check/Clean the Brushes/Pads	X				
Check/Clean the Squeegee	X				
Clean Squeegee's Front Roller Wheels	X				
Check/Clean Vacuum Motor Inlet Screen	X				
Empty/Clean Debris Catch Tray in Recovery Tank	X				
Inspect and clean rear wheels (tape, gum, debris)	X				
Clean the 3D Camera Lenses					X
Clean the Drop-off Sensors					X
Clean the 2D Mapping Laser					X
Inspect Scrub Housing Skirt		X			
Inspect and Clean Solution Filter		X			
Purge the Detergent System		X			
Lubricate Machine			X		
Check/Replace Vacuum Motor Carbon Brushes				300 Hrs	
Check/Replace Scrub Motor Carbon Brushes				500 Hrs	
Check/Replace Traction Motor Carbon Brushes				500 Hrs	

Maintenance Procedure References

- [Squeegee Blade Replacement](#) described on page 339.
- [Cleaning the Solution Filter](#) described on page 318.
- [Clean and Inspect the Solution Solenoid](#) described on page 319.
- [Vacuum Motor Brushes](#) described on page 349.
- [Motor Brushes \(Disc Deck\)](#) described on page 332.
- [Motor Brushes \(Rev Deck\)](#) described on page 333.
- [Wheel Motor Brushes](#) described on page 172

Lubrication Locations

- Once a month apply Lubriplate® 730-2 or equivalent grease to, or grease the fitting on, the following components. Avoid using too much grease.
 - Drive Chain
 - Drive Chain Idler Grease Zerk
 - Steering Chain



Preventive Maintenance Checklist — Liberty SC50

Customer Information		Machine Information	
Customer		Model	
Address		Applicable Options	
		Serial No.	
		Current Service Date	
		Last Known Service Date	

Pre-Inspection Checklist				
	Task	Description	Interval	Status
1	Technical Service Bulletins (TSB)	Review current TSBs for machine applicability, and prepare implementation as appropriate.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
2	Fault Codes	Review machine fault codes for unresolved issues. Correct faults as appropriate.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
List of significant fault codes, and corrective actions taken:				
3	Operator feedback	Interview/review operator personnel comments and concerns regarding machine operation.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
• Ask operator if he/she has observed a reduction of machine/battery runtime. • Confirm (by inspection and interview) that customer is performing daily/weekly maintenance schedule tasks. List of applicable comments, and corrective actions taken:				
4	Technical Service Bulletins	As applicable, implement any TSBs identified above.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
List of TSBs, and corrective actions:				

Preventive Maintenance Checklist — Liberty SC50

Routine Maintenance Tasks and Inspections				
Task	Description	Interval	Status	
5	General Machine Condition	Inspect the general condition of the machine for evidence of collision, abuse, cleanliness.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
	- Inspect the front bumper, solution tank, and autonomy bay cover for signs of collision - Inspect the operator control panel for cuts and cleanliness. - Inspect the Electrical Bay for spilled detergent and debris - Inspect the recovery tank and components for cleanliness.			
6	Battery Condition	Check that the batteries are fully charged and that they hold charge.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
	- Take a baseline voltage reading of the batteries. (If the machine is being charged, unplug the charger and wait a few minutes before taking the baseline reading.) - Inspect all battery connections for corrosion, and if necessary, clean the terminals and make sure all lugs are properly torqued. - Inspect battery cables, charger cord, and main disconnect for damage and secure connection. - If the machine has been fitted with lead acid batteries, check the water level and specific gravity. - In the Configuration menu, make sure the correct battery type and algorithm is selected. - You must plug the charger into an AC power source and unplug it after a few seconds to wake up the charger so it does not show “offline”. - Use algorithm 43 for OEM batteries - At the conclusion of the PM inspection, recheck the battery voltage to identify a significant voltage drop.			
7	Inspect and clean rear wheels	Inspect and clean the rear wheels for debris and excessive wear. Replace the wheels (in pairs) if the tread on either wheel is completely worn.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
8	Control Panel	Test all of the control buttons, LEDs, and display of the control panel using the Panel Test screen of the service menu.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
9	Public Indicators Inspection	Press the horn button to confirm the horn is working. Use the Output Test screen to test the LED status bar.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
10	E-Stop	Confirm that the E-stop button activates and resets by driving the machine and activating the E-stop.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
11	Front Cover	Remove the front cover (nose) from the machine to gain access to components necessary for the remainder of the inspection.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
12	Electrical Bay	- Inspect wiring for damage. - Inspect high-power connections to ensure they are secure and properly torqued.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
13	Vacuum Motor Brushes	Check the motor brushes for wear. See Vacuum Motor Brushes described on page 349	300 Hr	☐ N/A ☐ Completed ☐ Needs Service
14	Scrub Motor Brushes	Check the motor brushes for wear. See Scrub System chapter on pages 332 or 333 , depending on deck type.	500 Hr	☐ N/A ☐ Completed ☐ Needs Service

Preventive Maintenance Checklist — Liberty SC50

Drive System Tasks and Inspections				
	Task	Description	Interval	Status
15	Drive Operation	Inspect and observe the drive system components for proper operation and condition.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
	• Inspect the drive wheel for damage or impacted debris. • Inspect the operator platform switches for proper operation and that they are free from binding. • Turn the steering wheel and observe the steering motor for proper operation and listen for abnormal sounds. • Drive the machine at varying speeds and listen for abnormal sounds from the drive motor.			
16	Disconnect the Battery	Before proceeding with the following steps, disconnect the main battery connector for safety.	4/yr	☐ Completed
	• After shutting down the machine, observe the Safety Sensor displays to verify they have turned off. Then wait an additional 15 seconds to ensure the Autonomy controller has turned off before disconnecting the battery.			
17	Drive Wheel Harness	Inspect the drive wheel harness (EM Brake and Drive Motor) for damage and that it is not binding as the steering turns.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
18	Drive Wheel Chain	• Apply light grease if necessary • Check the tension (deflection) of the chain. • 0.25 -0.50" (6.5-12.5mm)	4/yr	☐ N/A ☐ Completed ☐ Needs Service
19	Steering Chain	• Apply light grease if necessary • Check the tension (deflection) of the chain. • 0.06 - 0.25" (1.5 - 6.4 mm)	4/yr	☐ N/A ☐ Completed ☐ Needs Service
20	Traction Motor Brushes	As applicable according to the inspection interval, check the motor brushes for wear. See Wheel Motor Brushes described on page 172	500 Hr	☐ N/A ☐ Completed ☐ Needs Service

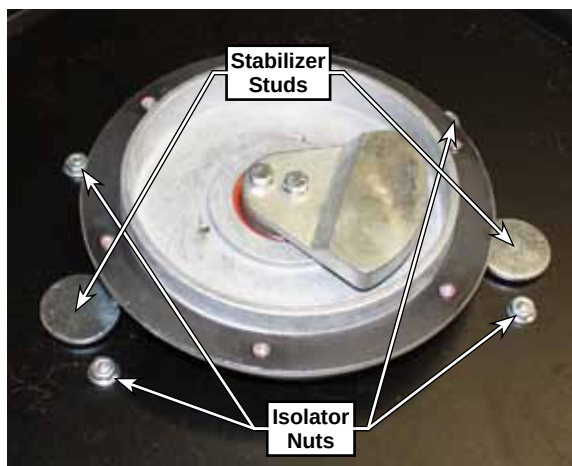
Recovery System Tasks and Inspections				
	Task	Description	Interval	Status
21	Squeegee Frame	- Inspect the squeegee casters for damage or debris buildup. - Inspect the squeegee's vacuum housing for impacted debris that can interfere with suction.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
22	Hoses	- Inspect the suction hose for cuts and leaks. - Inspect the recovery drain hose for leaks or damage.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
23	Recovery Tank	- Inspect the recovery tank gasket for cuts, leaks, and debris that can reduce suction. - Inspect the vacuum motor inlet screen for damage or debris.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
24	Float switch	Using the service menu, confirm that the float switch is functional when elevated.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
25	Suction Test	Perform the Vacuum Suction Test described on page 345. - Sealed - Minimum 39" H2O (9.7 kPa) 1" Open hole - Minimum 8" H2O (2 kPa)	4/yr	☐ N/A ☐ Completed ☐ Needs Service

Preventive Maintenance Checklist — Liberty SC50

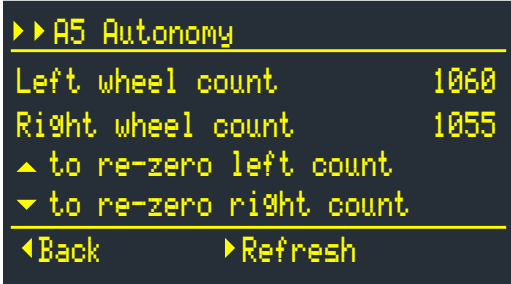
Solution System Tasks and Inspections				
Task	Description	Interval	Status	
26	Leaks	Inspect the solution hoses and components for leaks.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
27	Pump and solenoid	Operate the solution system and observe the solution flow for proper operation, and listen to the solution pump for abnormal sounds.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
28	Detergent System	Purge the detergent system to verify function and flow.	4/yr	☐ N/A ☐ Completed ☐ Needs Service

Scrub System Tasks and Inspections				
Task	Description	Interval	Status	
29	Scrub Deck, General	Observe the operation of the scrub deck.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
	- Using the service menu, cycle the scrub deck actuator through all of its positions and check for proper operation and listen for abnormal sounds from the actuator. - With the scrub deck in the scrub and extended scrub positions, operate the brush motor and observe for normal operation and listen for abnormal sounds from the motor. - Inspect the deck lift linkage for bushing wear.			
30	Disk Deck	Inspect the brush skirt for damage or missing bristles.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
31	Rev Deck	Inspect the rubber isolators	4/yr	☐ N/A ☐ Completed ☐ Needs Service

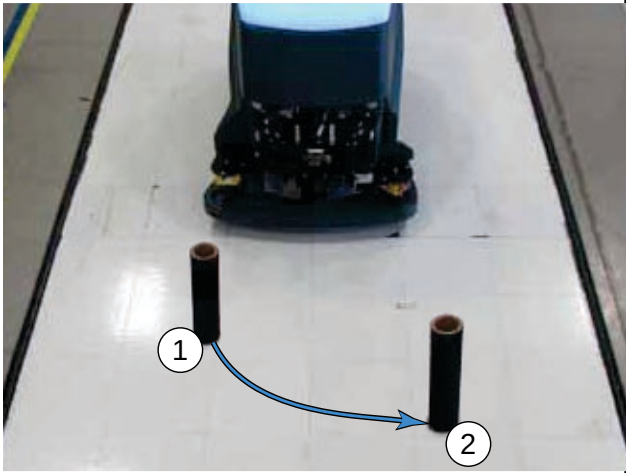
1. Remove the [Scrub Deck](#) described on page 328.
2. Remove the 6 screws that secure the pad driver to the bearing plate, and remove the pad driver.
3. Remove the 2 stabilizer studs.
4. Remove the 4 isolator nuts.
5. Carefully separate the eccentric drive and motor from the scrub deck lift assembly just enough to access the isolators. (Take care with the solution line.)
6. Inspect the isolators for tears or separations.



Preventive Maintenance Checklist — Liberty SC50

Autonomy System Tasks and Inspections				
	System	Description	Interval	Status
32	Clean the Autonomy optical sensors	Using a slightly dampened microfiber cloth, clean the sensor lenses. Inspect the lenses for scratches or damage. Include: 3D Camera, 2D Mapping sensor, and 4x Dropoff sensors.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
33	Dropoff Sensors	Block each sensor with your hand and observe the sensor's display to confirm the value changes.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
34	Rear Wheel Encoders	Verify that the rear wheel encoders are reporting consistent values.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
This operational test confirms that both wheel encoders report similar values while travelling in a straight line. 1. Zero the count of both encoders at the A5 Autonomy Menu, Wheel Counts screen. 2. Drive the machine in a straight line for at least 1 or 2 meters. 3. Refresh the data and confirm that both encoders are within 1% of one another.				
35	Safety Sensor Static Function	Verify that the area numbers for the 2 safety sensors correlate with the drive wheel position, and the sensor is detecting objects.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
1. Observe the area number displayed on each safety sensor while turning the steering wheel from full-right to full-left directions. • The area number should begin at 01 at full right, and increment up to 15 at full left. • The area number should be 08 when the steering wheel is in the center (neutral) position. 2. With the drive wheel pointing forward, move an object toward each sensor and observe the LEDs. • Warning 1 LED turns red when the object nears the sensor. • OSSD 1/2 turns from green to red when the object gets closer to the sensor.				

Preventive Maintenance Checklist — Liberty SC50

Autonomy System Operational Checks			
System	Description	Interval	Status
36 Safety Sensor Function and Communication	Verify that autonomous playback stops when an obstacle is detected.	4/yr	☐ N/A ☐ Completed ☐ Needs Service
This operational test confirms that both safety sensors are functioning and communicating with the Autonomy controller. - Record a straight-line CopyCat plan 2 or 3 meters long. - At the “Send Any Command” menu, issue command #50 to disable obstacle avoidance. - Place a small vertical object, such as the small target cylinder, directly in front of the left safety sensor, and about 1 meter ahead of the machine. - Play back the recorded plan. The machine should stop before it contacts the object. - Move the object in front of the right safety sensor and about 1 meter ahead of the current machine location. - The machine should continue forward, but stop before contacting the object. - Make sure to reboot the machine to clear Command #50.			
37 2D Mapping Laser Level	Verify that the 2D mapping laser is level with the floor. Perform the 2D Mapping Sensor Level Check and Adjust procedure on page 110	1/yr	☐ N/A ☐ Completed ☐ Needs Service
38 2D Mapping and 3D Vision Sensor Validation	Perform the 3D Camera (Vision Sensor) Calibration procedure on page 109	4/yr	☐ N/A ☐ Completed ☐ Needs Service
39	Describe maintenance items requiring further service:		

Work Completed By:

Acknowledged By:

 Service Technician Name

 Customer Name

 Service Technician Signature

 Date

 Customer Signature

 Date

Major Machine Components



04 - Control System

Functional Description

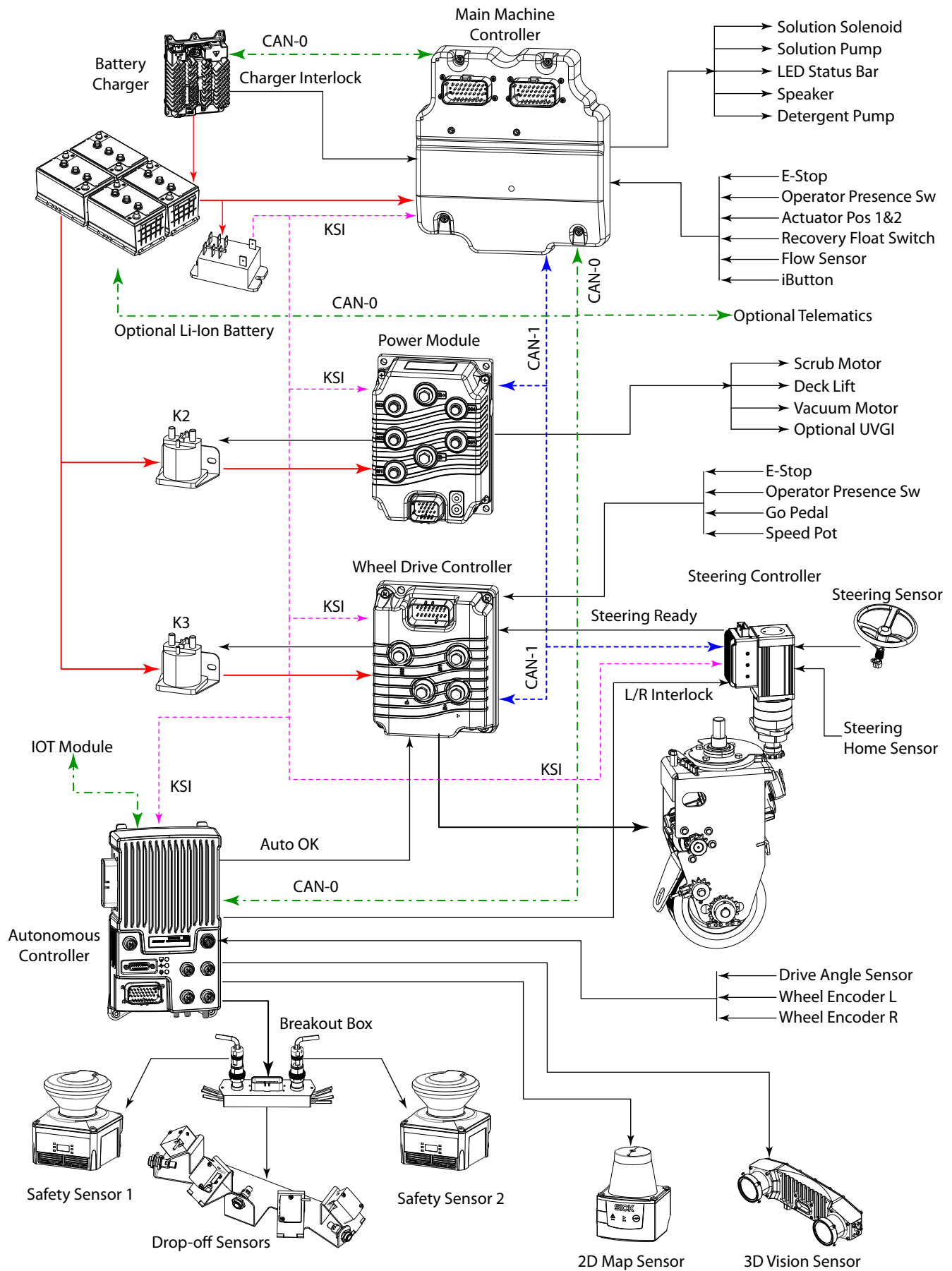
The easiest way to understand the Liberty system is to divide it into its various controllers or modules. Each subsystem performs specific tasks, but also communicate with one another to create a unified control system. However, the Autonomous (self-driving) system is relatively isolated from the other systems, and is discussed in its own chapter.

The division of the Liberty System by logic function starts with the Main Machine Controller (MMC). As the name implies, this acts as the central controller that ties all of the other modules together. These functions are summarized below, and explained in greater detail in subsequent sections.

Module	Bus	Function
Main Machine Controller	CANBus-0 CANBus-1	- Commands the Power Module when and how to operate the brush motor, vacuum motor, and deck lift actuator. - Receives and interprets commands (CANBus-0) from the Autonomous system and conveys this to other systems (CANBus-1): - Commands the Wheel Drive Module when in Autonomous mode. - Commands the Steering Module when in Autonomous mode. - Communicates with the onboard battery charger (CANBus-0)
Onboard Charger	CANBus-0 Interlock	- Monitors and charges the batteries when connected to facility power (AC Mains Power) - Communicates with the Main Machine Controller regarding battery status and charging parameters.
Li-Ion Batteries	CANBus-0	- Communicates with the on-board charger for charge profile and status. - Communicates with the MMC for battery status.
Power Module	CANBus-1	- Receives commands from the MMC regarding motor operation. - Provides status to the Main Machine Controller regarding motor operation.
Drive Module	CANBus-1 Auto-OK Steering OK	- Controls and monitors the wheel motor. - In manual mode, receives go and speed information directly from the operator controls. Receives direction control from Main Machine Controller. - In autonomous mode, receives all commands from the Main Machine Controller (CANBus-1) - In either mode, receives enable/disable commands from both the autonomous system and steering system.
Steering Module	CANBus-1 Steering OK	- In manual mode, receives steering command from the steering sensor. - In autonomous mode, receives steering commands from Main Machine Controller. - Enables the Wheel Controller when steering is ready.
Autonomy Module	CANBus-0	- Receives information about the surrounding environment from sensors. - Receives scrubbing machine information from the MMC. - Sends autonomous driving and scrubbing commands to the MMC.
Telematics (Optional)	CANBus-0	- Uses the cellular network to communicate with remote data logging system. - Uses the GPS system for positional data logging. - Receives status and data from the Main Machine Controller for data logging.

Functional Block Diagram

The Functional Block Diagram on the following page represents a high-level overview of the system interactions and communications. It is not intended to show every component or connection. For a more detailed examination of system interconnections, refer to the [“Wiring Diagrams”](#) on page 268 of the Electrical System Chapter.



Onboard Charger

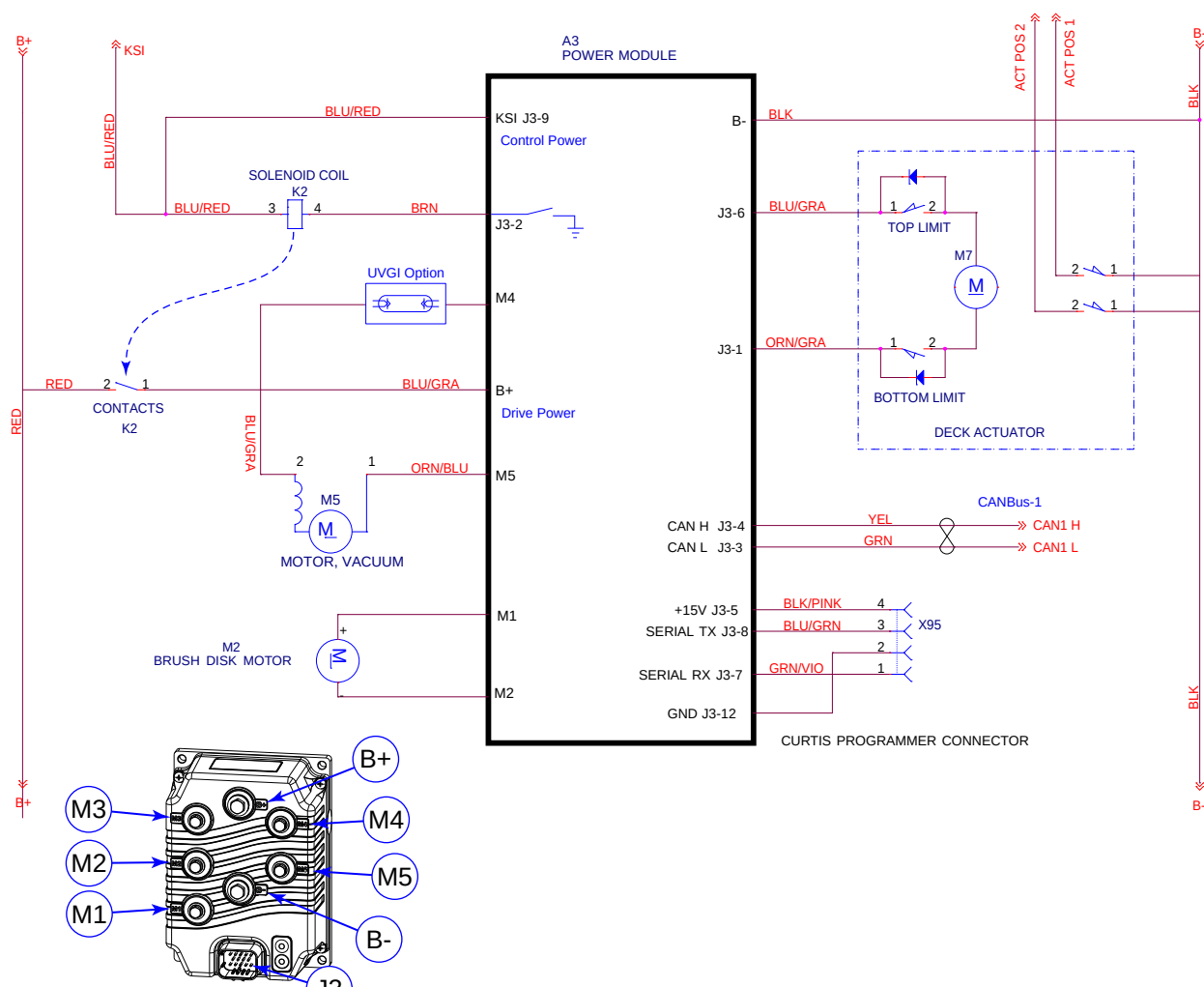
The onboard charger communicates with the Main Machine Controller on CANBus-0 to receive battery-type information, and convey battery status. The charger also has an interlock circuit input to the main control board which disables all machine functions whenever the charger is plugged into facility power. Specifics of the battery charger itself are discussed in [“Battery Charger”](#) on page 267 of the Electrical Chapter.

Power Module

As the name suggests, the power module handles the high-power output functions for the machine. It receives its commands from the main machine controller via the CAN Bus network. The power module provides basic motor control and protection, but the main machine controller controls the actual operation commands for the motors.

The power module receives its logic power from the KSI relay, which is controlled by the main machine controller. The power module has control of its own high-power input from the K2 relay. Unlike the drive module, the power module has no direct inhibit input signals (i.e. seat switch or E-stop), except by commands on the CAN Bus.

The power module has 2 types of outputs. The higher power outputs are non-reversing PWM control. The lower power outputs are reversing PWM control. The power module is capable of monitoring the output amperage from each of the outputs, and reporting this information to the main machine controller via the CAN Bus.



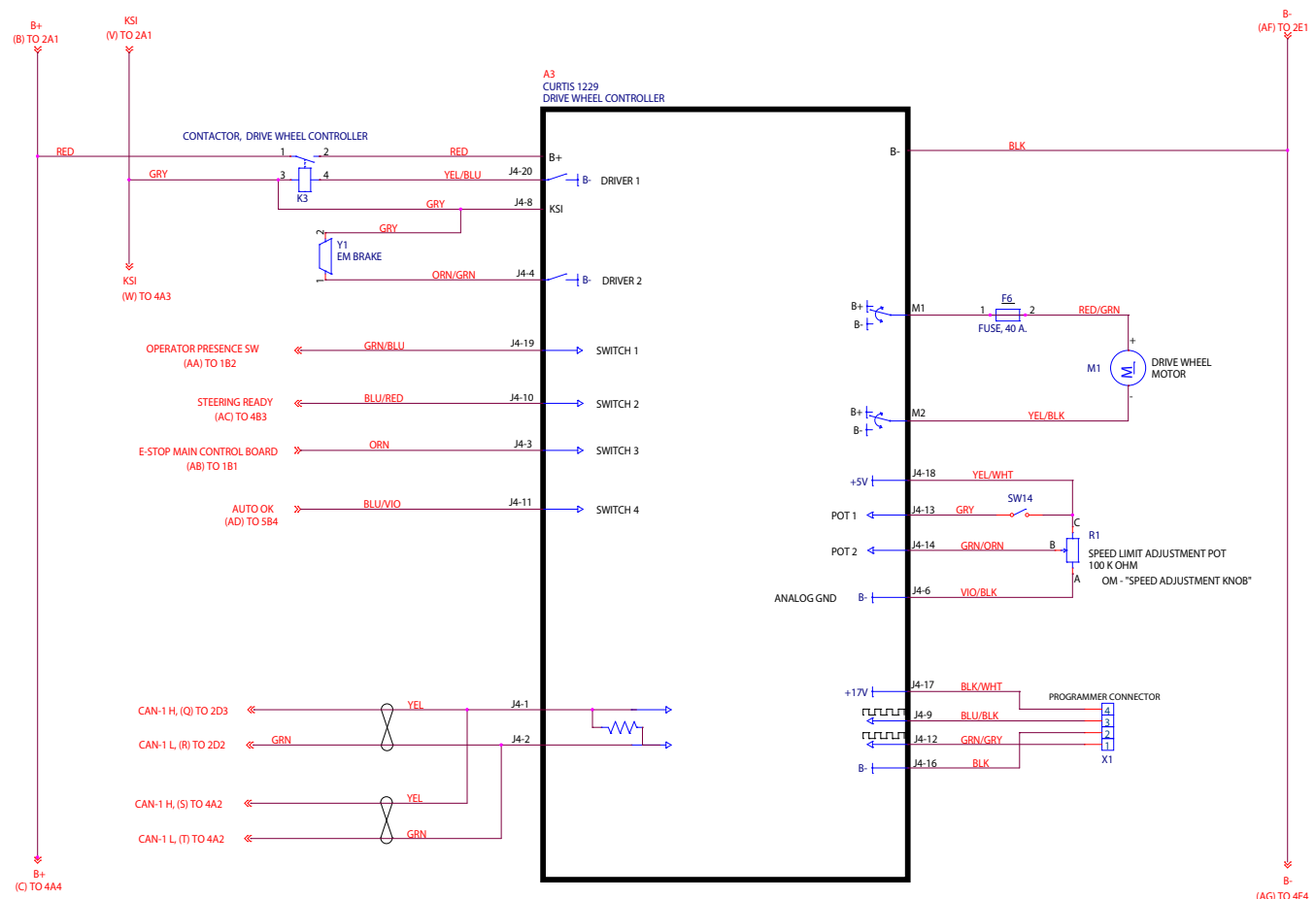
Wheel Drive Controller

The wheel drive controller operates and monitors the wheel motor. It generates a reversible Pulse Width Modulated (PWM) power control to the wheel motor. The drive controller receives its control power from the KSI relay, which is controlled by the Main Machine Controller. The drive controller controls its own drive power using the K3 relay.

The drive controller has four inputs that can inhibit its function.

- **E-Stop:** This is a normally-closed switch that inputs 24 volts to the controller for it to be enabled. The E-stop switch is in series with the KSI relay, so it is automatically opened when KSI is not active, which disables the drive controller. The E-stop will disable the controller in either manual or autonomous modes.
- **Steering Ready:** This is an input from the steering controller to signify that the steering module is ready for machine movement. This input can disable the drive in either manual or autonomous mode.
- **Auto-OK:** This is an input from the autonomous system. When this input is pulled high, the drive controller is enabled.
- **Operator Deadman:** This is an input from the Operator Present foot switch, and will enable the drive controller when operated in manual mode.

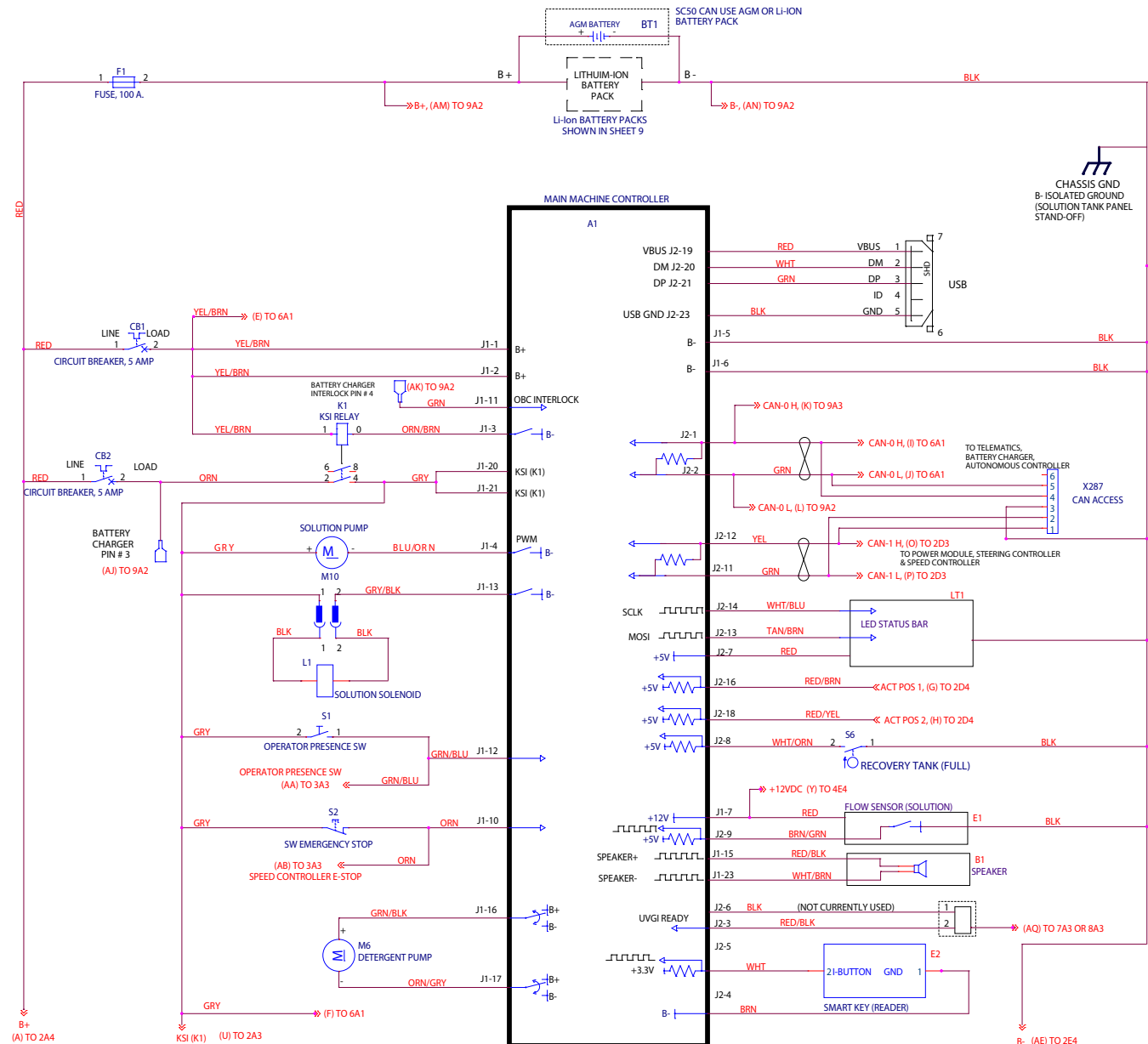
The Main Machine Controller determines whether the system is in manual mode or autonomous mode and communicates the mode via the CANBus. In manual mode, the drive controller receives drive commands from the operator's Go switch and speed potentiometer. In autonomous mode, the drive controller receives this information via CANBus messages.



Main Machine Controller

As the name implies, the Main Machine Controller (MMC or Main Machine Controller) is the primary controller for the system. The MMC functions as the primary interface for the operator, and directly or indirectly controls the functions of the machine. Because the MMC controls the on/off function of the whole machine, it is always receiving logic power through the 10 amp circuit breaker, but controls the status of the KSI relay to itself and the other controllers.

The MMC communicates with the Power Module, Steering Controller, and Wheel Drive Controller through the CAN-1 Bus. It also uses a second CAN Bus (CAN-0) to communicate with the battery charger, telemetry module, and Autonomous System.



Control Panel

The control panel is an integral component with the Main Machine Controller circuit board. The control panel contains an LCD display, SmartKey reader for the keyswitch, E-Stop, speed potentiometer, and a series of membrane switches for operator control.

Refer to the Operator's Instruction Manual for specifics on the functions of the various membrane switches as they apply to the operation of the machine.



(A) SmartKey Reader: The key reader provides a serial connection between the SmartKey and the main machine controller. The controller checks the serial number of the key to determine if it is authorized to enable the machine's operation. Different keys (operator-blue versus supervisor-yellow) have different levels of access to the control system. Operator keys can be authorized/de-authorized for the machine, so that each operator may have his or her own uniquely identified key.

(B) Power Switch: When a key is in the key reader, pressing the power button will boot up the controller and turn the machine on. Pressing and holding the button for at least 1/2 second will turn the machine off.

(C) E-Stop: The E-stop switch is directly connected to both the main machine controller and the drive controller. The E-stop is a normally closed switch, that when opened, disables the drive controller, and notifies the Main Machine Controller of an E-stop condition, such that the Main Machine Controller can disable all functions under its control.

(D) Speed Potentiometer: The speed potentiometer connects directly to the Drive Controller, and is discussed in the Wheel System - Traction chapter. The potentiometer sets the machine's drive speed for manual mode operation.

(E) Forward and Reverse Buttons: The forward and reverse buttons pass directly into the main control board. The main control board then conveys this directional information to the drive controller via CANBus messages.

(F) Horn: The horn button activates the horn function of the Main Machine Controller, and uses the internal speaker for sound.

(G) Autonomous Program Controls: These buttons are used for setting and using autonomous control of the machine. Their activation is received by the Main Machine Controller, but their purpose is conveyed to the autonomous system via the CANBus.

(H) Manual Steer: The LED will illuminate to signify that the machine is in manual drive mode.

(J) Scrub Function Buttons: These buttons control the scrub functions for solution, vacuum and scrub, and are described in the operator's instruction manual.

(K) Display: The LCD display provides feedback to the operator with various text messages and graphic icons. The main screen shows scrub pressure, solution flow, detergent flow, speed, machine hours, battery charge level, solution tank level, and any fault codes. The display will change as necessary to convey the appropriate information.

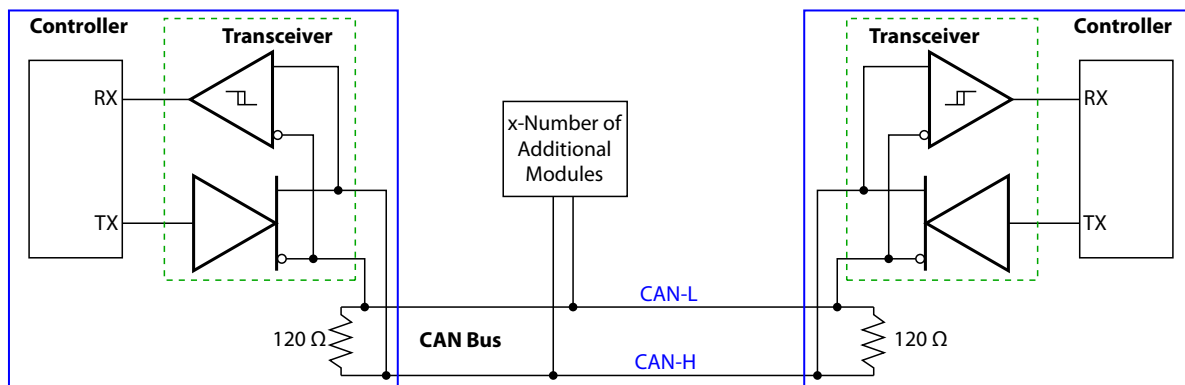
Information (I) and Menu Navigation (J): Pressing the information switch enters or exits the system menus. The navigation switches provide navigation and entry for the menus, and will be discussed in greater detail in ["Menu Navigation" on page 34](#).

CAN Bus Communication

CAN Bus communication was originally created for the automotive industry to allow distributed modules (Nodes) throughout the vehicle to communicate with each other over a single serial channel without any single Node being the Master of the communication channel. This means that each module broadcasts what it has to say, and all other modules on the CAN Bus see the message, but pay attention only to those messages they need to know about.

The Liberty Machine has two separate CANBus channels, where the Main Machine Controller acts as an interface and interpreter between the two. CANBus-0 is primarily for the autonomous system, battery charger, and optional telematics module. CANBus-1 handles all of the other machine functions related to scrub and propulsion.

The CAN bus is a twisted-pair of wires running between all of the modules, with one wire being low and the other wire high, voltage-wise. To send a data bit, the module pulls the high and low wires apart, voltage-wise. All of the other modules monitor this to detect a communication message, which is a string of low and high binary pulses. However, the binary logic states are reverse of typical, in that a logic-1 is recessive, and the difference between CAN_H and CAN_L is low (near zero). A logic-0 is the dominant bit, and the difference between CAN_H and CAN_L is high (approximately 2.5 volts).



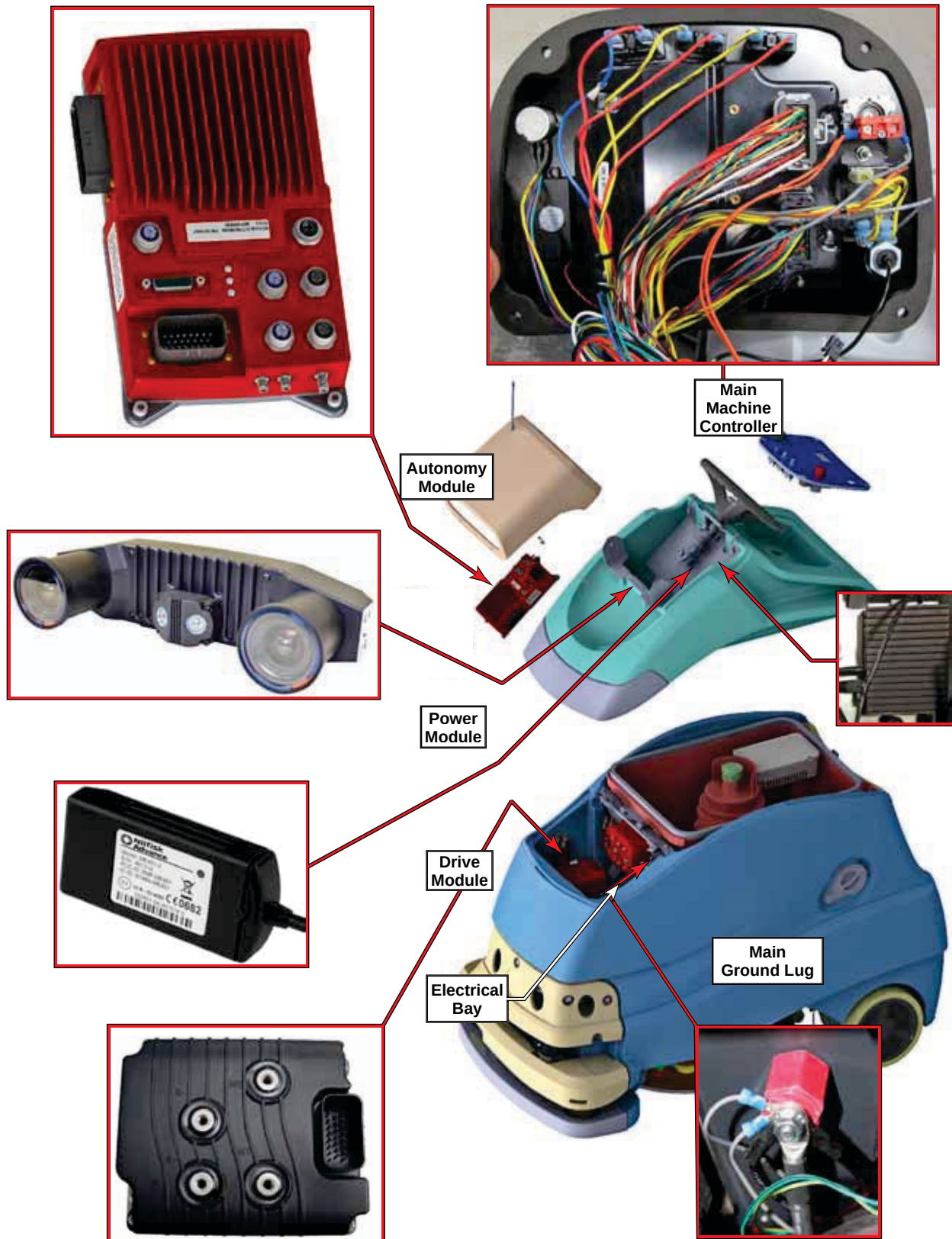
Because none of the modules represent the Master of the bus system, any of the modules can initiate a bus transmission any time there is not already traffic on the bus. When the module detects inactivity on the bus, it transmits a dominate bit, and begins sending the message priority level bits. But at the same time, it is also monitoring the bus itself to detect if a higher priority message was being initiated at the same time. The message with the higher priority level will have the bus high for the longest period, and therefore, that module knows that it is sending the highest priority message. The other module ceases its transmission and waits until the bus is available again.

CAN Bus Information

All CAN Bus messages are either to or from the main machine controller. The table below provides a simplified summary of some of the types of information passed between each module and the main machine controller.

Module	Direction	Information Type
Trackclean	From MMC	Operation Times, Active Faults, unexpected autonomous cut out, Start and stop of (scrub, recovery, solution), Operation Mode, Key ID, Call Key proxy signal
	To MMC	None
Battery Charger	From MMC	Request for AC line voltage, Request service data, Selected Charging Algorithm to use (At configuration), Request algorithm list
	To MMC	AC line voltage, service data, list of algorithms for configuration selection
Li-Ion Battery (Option)	To MMC	Battery status information.
	To Charger	Battery charge requirements
Power Module	From MMC	PWM requested values for Scrub Motor, Vacuum Motor, Deck Actuator
	To MMC	Output Amperage, Motor Mode, Motor State (toggle Scrub Motor, Vacuum Motor, Deck Actuator outputs on or off), Output %
Drive Controller	From MMC	Speed limit value, Go Pedal status, Selected Direction, Autonomous mode, overcurrent shutdown for vacuum and scrub motors.
	To MMC	Drive system service data, Fault codes,
Steering Controller	From MMC	Steering angle in Auto mode
	To MMC	Steering System service data, fault codes, “heart beat,” current vehicle steered position
Autonomous Controller	From MMC	Request Training Mode, Request Autonomous Mode, Cleaning System Information (for use to playback in copycat mode), Horn status, E-Stop, Recovery tank full, out of water, battery voltage, Some faults, operator presence switch status, Play-Pause/Record/Stop/ button, Main Machine Controller Firmware Version, Request start wireless update of Autonomous firmware, vehicle steered position, Wheel Drive data
	To MMC	Firmware Versions, Status Info, Calibration Results, Playback commands, Light bar commands, Location tag status, Start area status, Path presence, Wireless update status, Emergency messages (Faults, Warning, Information), Main Machine Controller Firmware update file, QR code info (Defines URL used to get wireless update)

Component Locations



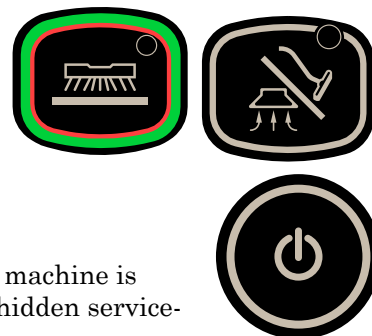
Main Machine Controller Menus

The Main Machine Controller is programmable for machine specific functions and configurations through a text menu system. Various parts of the menu system are hidden, depending on the user level access: User, Supervisor, Technician. The User-level access is limited to just reading operational parameters. The Supervisor-level access is permitted to program keys and access the Options menus. The Technician-level (Service Mode) permits access to the whole menu system.

Service Mode Access (from power-off)

Placing the machine into Service Mode is required to gain full access to all available menus.

1. With the machine powered off, press and hold the Scrub and Vacuum buttons.
2. Press and release the Power button.
3. When the display illuminates and the machine begins the bootup process, you may release the Scrub and Vacuum buttons. The machine will continue the bootup process for a minute or so.



After the machine has finished booting, there will be no outward sign that the machine is operating with service-mode access, until you enter the menu system and the hidden service-level menus are visible.

Service Mode Access (while powered-on)

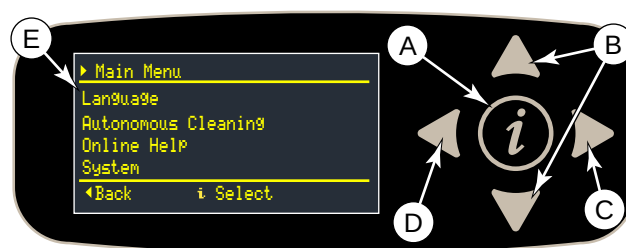
This procedure allows Service Mode to be enabled without rebooting the machine.

1. Press the **i** button and navigate to the System → CRL Safety menu.
2. Press and hold the Scrub and Vacuum buttons, and then press and release the **i** button.
3. Release the scrub and vacuum buttons.
4. The scrub system may start. If necessary turn it back off.

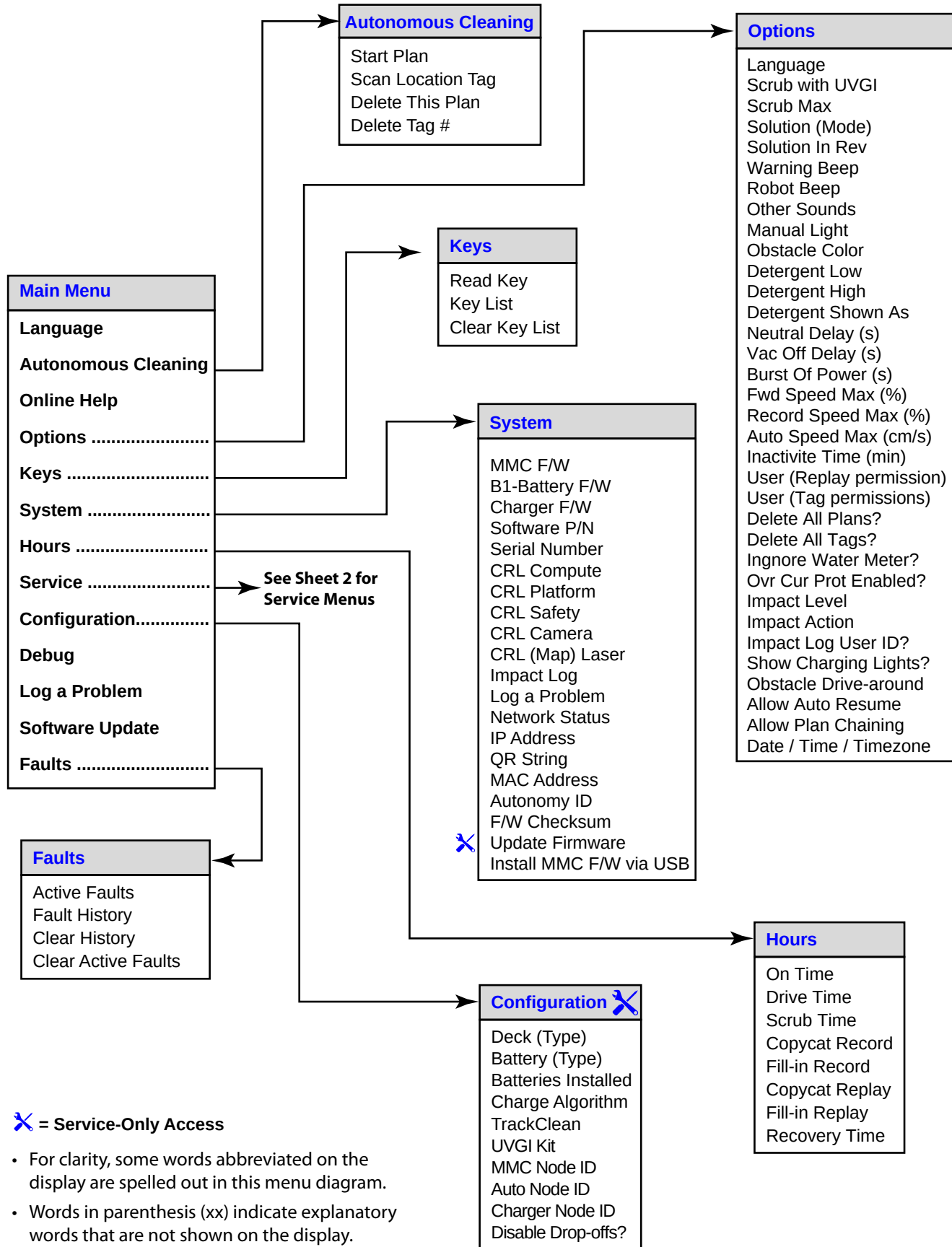
Menu Navigation

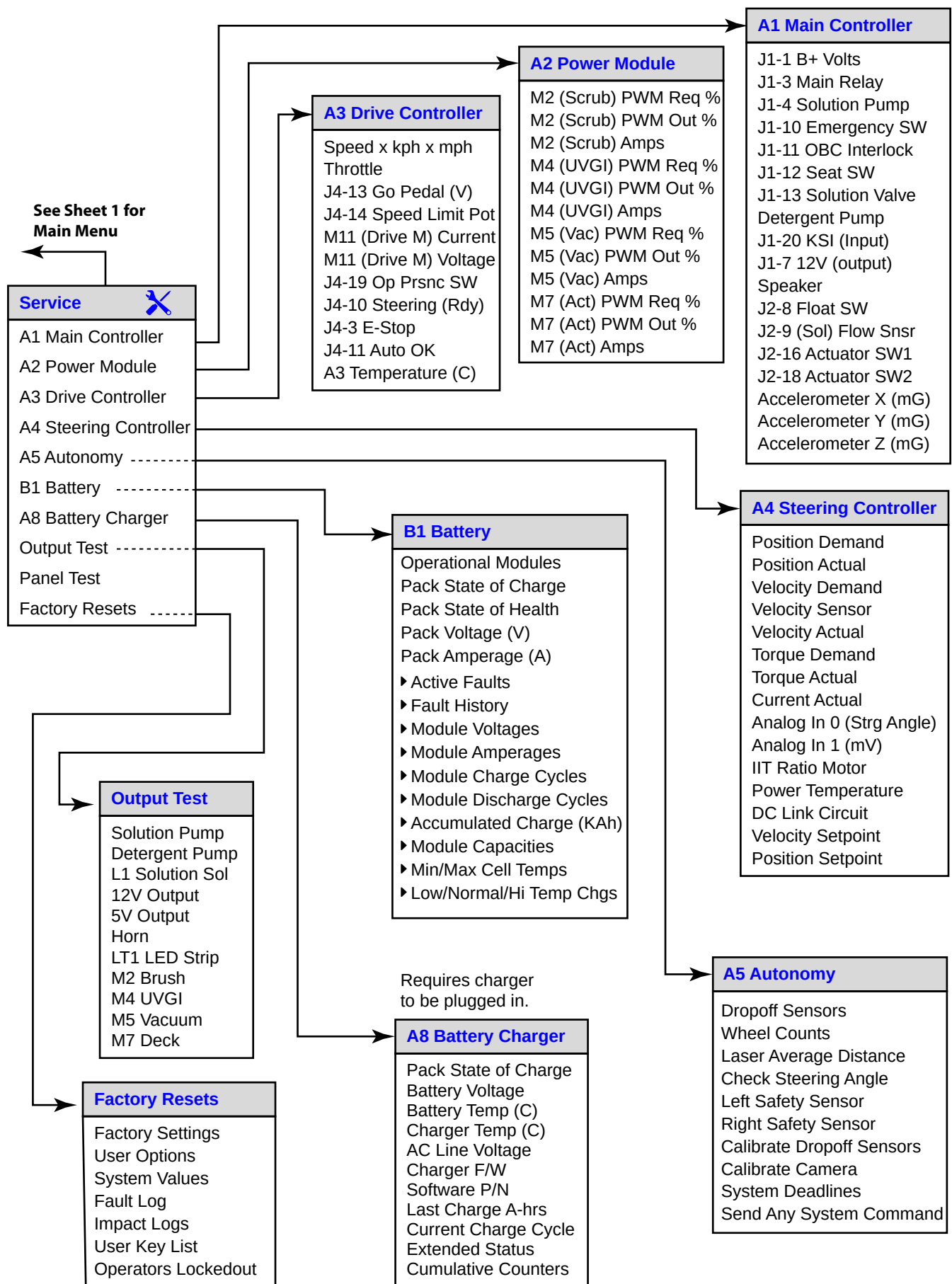
The menu system is accessed by pressing the Information switch (**Y**). The LCD display will show the text-based menu system. Pressing the left arrow (**Y2**) backs out of the menu system. Refer to [“Menu Outline” on page 35](#).

- The Up and Down arrows (**Y1**) scroll through the menu listings. Within a configuration setting, the Up and Down arrows also scroll through the list of configuration choices.
- The backlit row signifies the current position.
- The Information switch (**Y**) will enter the currently identified submenu.
- The left arrow (**Y2**) backs out of any submenu to the previous menu. Within a configuration setting, pressing the left arrow cancels the selection, and exits without saving.



Menu Outline





Hours Menu

The hours menu displays the amount of time the machine has been active in each of the listed categories. The On Time represents the total time that the machine has been powered up, regardless whether it was active or sitting neutral. The remaining times indicate how long the machine was active and performing the specific functions. This information can be helpful when determining which preventive maintenance tasks are due to be performed.

```
Hours
On Time          0035.60
Drive Time       0012.1
Scrub Time       0001.7
CoPyCat Teach    0001.2
◀back, ▶ scroll
```

Faults Menu

The faults menu lists the active or past machine faults.

```
FAULTS
Active Faults    1
Fault History     4
Clear History
Clear Active Faults
◀back, i select
```

```
FaultHistory
2-041           2020/01/19
M1 Scrub Motor Overcurrent
5-F4C7          2020/01/03
Right Side Drop-Off
◀back, ▶ scroll
```

The fault history can also be cleared. This should be done only if all past faults are accounted for or diagnosed.

Keys Menu

The Keys menu displays information about the current key, and also permits the addition or deletion of authorized user keys. User level keys (blue keys) can be authorized or de-authorized to operate the machine. However, if no keys have been authorized, then all user keys will be accepted.

Every key has a Hard-coded ID number (HID). This is the serial number for the key, and is also imprinted on the back of the key. Supervisor level keys also contain a Soft-coded ID number (SID), which determines the key type.

Authorizing User Keys

1. Start the machine with a supervisor key or in service mode.
2. Go to the Keys/Read Key menu function.
3. Replace the key with a user-level key to be programmed.
4. Press the Up arrow switch to add the key, and then the Right arrow switch to save.

```
Read Key
HID          400000017FB0F44
SID
Type
Key List     User
              No
◀cancel, ▲ Add
```

Deauthorizing User Keys

1. Start the machine with a supervisor key or in service mode.
2. Go to the Keys/List Keys menu function.
3. Scroll to the key to be deleted in the list, and press the Right arrow switch to select it.
4. Press the Up arrow switch to delete the key, and then the Right arrow switch to save.
 - If all user keys are removed from the list, then any user key will be authorized to start the machine.

Service Menu

The Service menu provides access to diagnostic tools for troubleshooting the machine. Except for the Panel Test, each of these entries brings up a submenu for the applicable system module or function. To aid in navigating this information, these submenus are hyperlinked below:

- [“A1 Main Machine Controller”](#) on page 38
- [“A2 Power Module”](#) on page 39
- [“A3 Drive Controller”](#) on page 39
- [“A4 Steering Controller”](#) on page 40
- [“A5 Autonomy”](#) on page 40
- [“A8 Battery Charger”](#) on page 41
- [“B1 Li-Ion Battery Menu”](#) on page 42
- [“Output Test”](#) on page 44
- [“Panel Test”](#) on page 45

Menu Name	
A2 Power Module	
M2 PWM REQ %	0
M2 PWM OUT %	0
M2 AMPS	0.0
M5 PWM REQ %	0
◀back, ▶scroll	

Callouts: Schematic Identifier points to 'A2', Description points to 'Power Module', Value points to the numerical values.

A1 Main Machine Controller

In addition to communicating with the other machine controllers, the Main Machine Controller includes some direct input and output functions for sensors and low-power devices. This menu displays the status of the various input and output signals.

Battery Voltage: This shows the actual battery voltage as seen by the Main Machine Controller. This voltage should be slightly less than the actual battery voltage as measured at the batteries due to minor voltage drop in the wiring to the control panel.

Main Relay (KSI Out): This is an output indicator for the KSI relay, which is controlled by the Main Machine Controller. This signifies that the controller is commanding the KSI relay to close.

Solution Pump: This is the output indicator for the solution pump. It signifies that the controller is commanding the pump to be active.

Emergency SW (E-Stop): This is the input signal from the E-stop switch. The E-stop switch is active-open (i.e. normally closed), so this input should normally be a “1” unless the E-stop button is depressed.

OBC Interlock (Charger): This is the input from the Onboard charger. A one indicates the charger is plugged in, and the system should be disabled.

Operator Present Switch: This is the input from the operator present switch to verify the operator is in position to operate the machine. The switch is closed when the operator stands on the pedal.

Detergent Pump: This entry is the output to the detergent pump.

KSI (KSI In): This is a confirmation input from the KSI relay, so that the controller knows that the relay is active when commanded. This input also provides additional battery power for the higher power outputs from the controller.

12V: This is the voltage of the 12-volt power supplied by the Controller to the flow sensor and wheel encoders.

Speaker: This shows the frequency and duty cycle of the speaker output. The duty cycle controls the volume, and the carrier frequency controls the tone of the sound.

A2 Power Module	
M2 PWM REQ %	0
M2 PWM OUT %	0
M2 AMPS	0.0
M5 PWM REQ %	0
◀back, ▶scroll	

A1 Main Control	
J1-11 OBC INTERLOCK	0
J1-12 S1 OPERATOR SW	1
DETERGENT PUMP	OFF
J1-20 KSI	1
◀back, ▶scroll	

A1 Main Control	
J1-7 12V	11.68
SPEAKER	0 HZ 0
J2-8 FLOAT SW	1
J2-9 SOL FLOW	1249
◀back, ▶scroll	

Float Switch (Recovery): This is the float switch in the recovery tank that closes when the tank is full.

Solution Flow: This displays the flow rate from the solution meter in mL/Min.

Actuator Switch 1 and 2: These are the inputs from deck actuator's internal position switches that signify the deck height for squeegee only and normal scrub height positions.

Accelerometer X, Y, Z: These 3 inputs are from the machine's accelerometers for X, Y, and Z directions. These are used to sense machine movement and also register machine impacts. The units are 1/1000 G-force.

```
A1 Main Control
J2-16 ACT SW 1      0
J2-18 SCT SW 2      0
ACCEL X (MG)        313
ACCEL-Y (MG)        -54
◀back, ▶ scroll
```

A2 Power Module

The Power Module menu provides information regarding all of the motors which are driven by the power module. The list of information for each motor is as follows:

- **Requested PWM %:** This is the value (by percent) that the power module has been instructed to apply to the particular motor.
- **Output PWM %:** This is the actual output PWM value (in percent) that the power module is sending to the motor. When a motor is first started, its PWM out will be less than the requested PWM, as the motor speed is gradually increased.
- **Output Amps:** This is the actual amperage the power module is recording for the particular motor.

```
A2 Power Module
M2 PWM REQ %        0
M2 PWM OUT %        0
M2 AMPS             0.0
M5 PWM REQ %        0
◀back, ▶ scroll
```

The motors are referenced by number. The actual motors are listed below:

M2 = Brush

M5 = Vacuum

M7 = Deck Lift Actuator

A3 Drive Controller

The Drive Controller menu provides status information about the drive motor and the drive controller itself. A brief summary of each listing is described below.

Speed (mph/kph): This displays the actual speed of the machine.

Throttle: This indicates the direction of travel. 0 = none, 1 = forward, -1 = backward.

Go Pedal: Shows the voltage input through the Go Pedal switch.

Speed Pot: This displays the wiper voltage from the throttle potentiometer.

Current: This displays the net amperage to the drive motor.

Voltage: This displays the net voltage to the drive motor.

Operator Present Switch: This represents the status of the operator presence switch. A value of "1" indicates the switch is closed and the operator is present.

```
A3 Drive Controller
SPEED      0.0 kph 0.0 mph
THROTTLE    0
J4-13 GO PEDAL  0.0
J4-14 SPEED POT  0.7
◀back, ▶ scroll
```

```
A3 Drive Controller
J4-10 STEERING RDY  1
J4-3 E-STOP         0
J4-11 AUTO-OK       1
A3 TEMPERATURE (C)  22.2
◀back, ▶ scroll
```

Steering Ready: This is an interlock signal from the steering module to disable the drive system unless the steering module is prepared for travel.

E-Stop: This represents the E-stop switch. A value of “1” indicates the E-stop switch is not pushed down.

Auto-OK: This is a signal from the autonomous module that serves as a drive system interlock, to disable the drive system on command from the autonomous system.

A3 Temperature: This represents the internal temperature (°C) of the drive controller itself.

A4 Steering Controller

Position Demand: This is the requested angle for the steering actuator to rotate toward. Depending on the mode of operation, this is either determined from the steering wheel sensor or a CANBus message. If the position requested is beyond the programmed limit of the drive system, the steering controller will move only to its programmed limit.

Position Actual: This is the actual, current steering angle position. This is calculated internally, based on the commutator feedback from the motor and the known ratio of the drive components.

Velocity Demand: This is an internally calculated parameter based on programmed limits and position demand.

Velocity Sensor: This is the internal motor speed based on the commutator sensors.

Velocity Actual: This is the calculated output speed based on the known ratio of the drive system components.

Torque Demand: This is the calculated torque demand based on program parameters and velocity.

Torque Actual: This is the actual torque (amperage) applied to the motor.

Current Actual: This is the actual phase current to the motor.

Analog In 0(mV): This is the analog input from the steering wheel sensor.

Analog In 1(mV): This is the reference input from the 5 volt power supply.

IIT Ratio Motor: This is the amount of work (power over a time period) that the motor is consuming.

Power Temperature(C): This is the steering controller internal temperature.

DC Link Circuit(V): This is the voltage of the internal DC bus.

A5 Autonomy

Dropoff Sensors: This screen displays the raw distance counts from the dropoff sensors. The values represent twice the distance (distance out + distance back) to the floor in mm. The values are not dynamically updated, and the refresh button must be pushed to load new values.

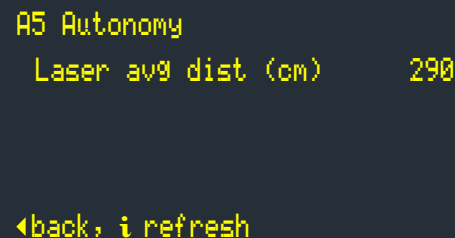
Wheel Counts: This screen displays the raw counts from the wheel encoders. However, it should be noted that these counts include both the rising- and falling-edges of both A- and B-phase square waves. As a result, the counts displayed will be 4-times as many as the number of encoder disk slots that pass the sensor. Every 40 ticks

```
A5 Autonomy
DropOff Side Left      708
DropOff Front Left     714
DropOff Front Right    710
DropOff Side Right     697
◀back, i refresh
```

```
A5 Autonomy
Left wheel count       5142
Right wheel count      5114
▲ to re-zero left count
▼ to re-zero right count
◀back, i refresh
```

represents approximately 75mm of wheel travel, but the exact value will vary with tire diameter. There will be 408 counts per wheel rotation. To verify the function of the encoders, reset both left and right counts, move the machine forward in a straight line, refresh the counts, and then compare the two counts.

Laser Average Distance: This screen displays the average distance reported by the laser for all objects detected in a sweep. The actual value isn't specifically important, but its variations can indicate that the laser is functioning as expected.



```

A5 Autonomy
Laser avg dist (cm)    290

<back, i refresh
  
```

Calibrate Dropoff Sensors: This screen is used for calibrating the dropoff sensors. See [Drop-off Sensor Calibration](#) described on page 108.

Calibrate Camera: This screen is used to calibrate the 3D camera. See [3D Vision Sensor \(Camera\) Calibration](#) described on page 109.

Calibrate Laser: This screen is used to calibrate the mapping laser. See [2D Mapping Sensor Level Check and Adjust](#) described on page 110.

Calibrate Platform Box: Not currently used.

Pair Remote: This screen is used to pair a remote fob to the system.

A8 Battery Charger

This screen provides status information for the battery and charger.

State-Of-Charge: This shows the percent charge status of the main battery.

Battery Voltage: This displays the actual battery voltage, as measured by the charger.

AC Line Voltage: This displays the line voltage when the charger is plugged into power.

Current Charge Cycle: This displays the current charge cycle (type) being used to charge the batteries.

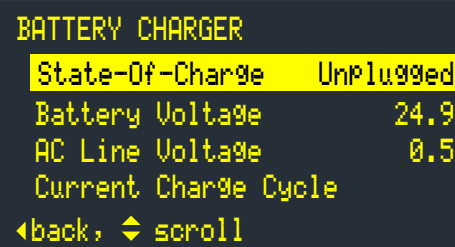
Last Charge A-hrs: This displays the amp-hour rate of charge of the last charge cycle.

Extended Status: Not currently used.

Cumulative Counters: Not currently used.

Battery Temp(C): This displays the battery temperature.

Charger Temp(C): This displays the charger's internal temperature.



```

BATTERY CHARGER
State-Of-Charge    Unplugged
Battery Voltage      24.9
AC Line Voltage     0.5
Current Charge Cycle

<back, < scroll
  
```

B1 Li-Ion Battery Menu

The first 5 rows of the lithium-ion battery menu provides details about the battery pack as a whole. The remaining menu rows, which are indented one space, provide details about the individual battery modules, and as a result, are submenus themselves to list data for each battery.

Definitions

Capacity--Remaining, Full, & Designed: A battery's capacity is how much electrical charge it produces, and is measured in the number of amps delivered over a time period, which has the units of amp-hours (Ah), which is amps multiplied by time.

- The **Designed Capacity** (also referred to as nominal capacity) is a battery's expected, or "designed" capacity, which is 60 Ah for the standard battery modules used in the machine.
- The **Full Capacity** (also referred to as maximum capacity) is the actual, measured capacity of the battery when fully charged. When new, a battery's full capacity should be very close to its designed capacity, but may be slightly above or below. As the battery ages, its full capacity is expected to diminish below the designed capacity.
- The **Remaining Capacity** of a battery is the actual capacity of the battery in its current charged or discharged state.
- **Health:** A battery's health is a comparison of its full capacity to its designed capacity. This is reported as the percent-ratio between its full capacity and the designed capacity. A brand new battery should have 100% health, but it may possibly be 99% or even 101%, if the actual capacity is slightly below or above the designed (theoretic) capacity.

Operational Modules: This is the number of modules communicating on the CAN Bus versus the number listed in the configuration.

Pack State of Charge: This value represents the percent of battery capacity in Amp-Hours (Ah) remaining in the battery pack as a whole. The value is calculated as the current capacity divided by the full capacity, and averaged for all of the modules (up to 6) in the pack.

For reference, a standard battery should have a full capacity of about 60 Ah. So a 50% state of charge indicates that 30 Ah remains.

Pack State of Health: The state of health is a comparison between the full capacity and design capacity. The reported value is the mathematical average of all modules in the pack.

Pack Voltage: This value is reported to the main controller from the battery pack. A significant difference between this value and the MMC's recorded B+ voltage may indicate corroded or loose battery connections.

Pack Amperage: This represents the current flowing into the battery, and therefore, a negative number represents the actual current being supplied by the battery to the machine.

►► BATTERY	(1/15)
Operational Modules	3/3
Pack State-of-Charge	60%
Pack State-of-Health	100%
Pack Voltage	25.450
◀ Back	↕ Scroll

►► BATTERY	(8/15)
Pack Amperage	-2.990
→ Active Faults	
→ Fault History	
→ Module Voltages	
◀ Back	i select

Module Specific Sub-menus

Active Faults: (and)

Fault History: These two entries are similar, except one lists the number of active faults for each module, and the other lists past faults for each module.

Pressing the information button lists the specific lower-level faults for that module and the number of occurrences per event. For the histories, it lists the last 16 codes.

Module Voltages: The battery voltage is measured by the battery itself and represents the internal voltage of the battery before any diodes or switching transistors. As such, the voltage may be different than the main bus voltage of the entire battery pack.

Module Current: The module current shows the actual current from the battery. Negative values indicate current leaving the battery and positive values indicate current entering the battery (charging). When the machine load is light, some lower voltage modules will contribute less amperage or even none at all. This is normal.

1-3 of 3	Active Faults
1: S/N 501530	(0)
2: S/N 501541	(0)
3: S/N 501531	(2)

1-4 of 16	S/N-501531
1: 0x3f	(5x)
2: 0x09	(1x)
3: 0x3e	(6x)
4: 0x3e	(4x)

1-3 of 3	Internal Voltage
S/N 501530:	25.459
S/N 501541:	25.420
S/N 501531:	25.397

1-3 of 3	Average Amperage
S/N 501530:	-0.961
S/N 501541:	-0.961
S/N 501531:	-0.948

Battery Charge Screens

Battery Charge Cycles: This screen shows how many times a charge was started for the battery module and how many charges were completed. A charge may be initiated before the module is completely discharged, and the charge may be terminated before the module is completely charged.

Battery Discharge Cycles: This screen shows how many complete discharges the module has experienced. Because machines are commonly recharged before completely discharged, it is expected that the number of discharge cycles will be less than the number of charges.

Accumulated Charge: This screen shows how much charge has passed into and out of the module with units of kiloamp-hours (1000 amp-hours). The charge and discharge numbers should be of similar size for a module, but charge rate is expected to be higher due to charge efficiency and self-discharge of the module.

→Module Charge Cycles	
1-3 of 3	Started/Complete
S/N 501530:	2/1
S/N 501541:	2/1

→Module Discharge Cycles	
1-3 of 3	Discharge Cycles
S/N 501530:	1
S/N 501541:	1

→Accumulated Charge (KAh)	
1-3 of 3	Charge/Discharge
S/N 501530:	0.1/0.0
S/N 501541:	0.1/0.0

Module Capacities: This submenu lists the capacities of the individual battery modules. Each listing shows the Remaining Capacity, Full Capacity, and Design Capacity.

→Module Capacities (Ah)	
1-3 of 3	Rem/Full/Design
501530:	36.1/60.0/60.0
500565:	35.9/60.0/60.0

Min/Max Cell Temps: This lists the current high and low battery cell temperatures within each module. There are multiple sensors within each module, so just the minimum and maximum are given.

Low/Normal/Hi Temp Chgs: This screen shows the number of times the module was charged above, below, and within the normal charging temperate range.

Output Test

The Output Test menu provides manual control of various system functions for troubleshooting purposes. This permits devices to be operated even when prerequisite conditions are not met, such as permitting the solution solenoid to be active without the scrub system active. In addition to output control, each selection also provides status information for the particular device.

Entry	Options
M10 Solution Pump	On / Off
M6 Detergent Pump	Fwd / Rev / 100:1 / Off
L1 Solution Solenoid	On / Off
12 Volt Output	On / Off
5 Volts Output	On / Off
Horn	On / Off
LT1 LED Strip	On / Off / Colors
M2 Scrub Motor	On / Off
M4 UVGI	On / Off
M5 Vacuum	Full / Quiet / Off
M7 Deck Actuator	Up / Dn / SW1 / SW2 / SW3 / Off

→Min/Max Cell Temps

```

1-3 of 3      Min/Max Temp °C
S/N 501530:    21.6 / 22.1
S/N 500565:    21.7 / 22.2

```

→Low/Norm/Hi Temp Chgs

```

1-3 of 3      Low/Normal/Hi
501530:        0 / 2 / 0
500565:        0 / 2 / 0

```

Output Test

```

Solution Solenoid  Off
Solution Pump      Off
LED Strip          Off
Detergent Pump     Off
←back, i select

```

Panel Test

The Panel Test screen provides a means to verify the functionality of all of the control panel buttons, LEDs, and display pixels.

The display shows a graphical representation of all of the control panel buttons. When you depress a button, its representation on the screen highlights to show the press was detected.

Pressing the Down Arrow turns on all of the panel LEDs to verify that they are functional.

Pressing the Up Arrow will turn on (scroll) through all pixels on the display screen to detect if any pixels are dropping out.

The Left Arrow returns to the previous menu, and the Information button exits the menu system.



Factory Resets

The factory resets screen provides access to reset any of the subsystems to their default factory settings. The available parameters are listed below.

- Factory Settings
- User Options
- System Values
- Fault Log
- Impact Logs
- User Key List
- Operators Locked Out

Options Menu

The options menu screens permit a supervisor-level access key to customize the machine to suit the needs of the customer.

Parameter	Options (*=default)	Notes
Language	- English* - Deutsch - Francais	Menu display language
Scrub with UVGI	- No* - Yes	Activates the Ultra Violet Germicidal Irradiation system with the scrub system.
Scrub Max	- Light - Heavy*	Maximum scrub level allowed
Solution (Mode)	- SmartFlow* (proportional to speed) - Fixed	Adjust solution flow to speed, or fixed flow
Solution In Rev	- No* - Yes	Leave solution on in reverse?
Warning Beep	- Backup Beep* - Beep On - Beep Off	Beep when backing up, beep always on when moving, beep off
Robot Beep	- Beep Off* - Beep Low - Beep Medium - Beep High	Beep when scrubbing autonomously – off, low, medium, high volume
Other Sounds	- Normal* - Quiet - Off	Volume of sounds (apart from horn, starting autonomy beep, and backup beep)
Manual Light	- On to Scan* - Always On - Always Off	“On to Scan” means the LED strip will be white with blue corners when the 3-D vision sensor is attempting to read a Location Tag
Obstacle Color	- Orange* - Red	Color of “Obstacle” chasing lights displayed on LED status bar when an obstacle is encountered
Detergent Low	(300,256,200,150,128,100,64,50,32,26):1 - ratio cannot be > Detergent High	Set detergent ratio for detergent low level
Detergent High	(300,256,200,150,128,100,64,50,32,26):1 - ratio cannot be < Detergent Low	Set detergent ratio for detergent high level
Detergent Shown as	xxx:1 or x.x%	Ratio or percentage
Neutral Delay (s)	- Min 0.5* - Max 5.0 - Step 0.5 - Default 0.5	Time to keep brushes on when in neutral (seconds)
Vac Off Delay (s)	- Min 10* - Max 20 - Step 1	Time to keep vacuum on after turning off scrub system (seconds)
Burst Of Power (s)	- Min 60* - Max 300 - Step 60	Burst-of-power (BOP) time span (seconds)

Parameter	Options (*=default)	Notes
Fwd Speed Max (%)	- Min 50 - Max 100* - Step 10	Maximum forward speed as percentage of maximum available speed in manual mode
Record Speed Max (%)	- min = 50% - max = 100%* - step = 10	Maximum forward speed allowed while recording (as percentage of maximum available speed in manual mode)
Auto Speed Max (cm/s)	- Min 50 - Max 150* - Step 5	Sets the maximum autonomous travel speed
Inactive Time (min)	- Min 5 - Max 60 - Step 5 - Default 15	Inactivity time before putting machine in sleep mode (minutes)
User (Replay Permissions)	- Replay Only* - Replay/Train - Replay/Train/Delete	
User (Tag Permissions)	- No Add/Delete Tags* - Add Tags - Add/Delete Tags	User key location tag permissions -- no permissions, can add tags, can add and delete tags
Delete All Plans	- Yes - No*	Deletes all plans
Delete All Tags	- Yes - No*	Delete all tags (and plans)
Ignore water meter	- Yes - No*	Ignore water meter and do constant flow with no feedback loop. Allows operator to keep cleaning in autonomous or manual mode with a broken flow meter.
Ovr CurProt. Enabled?	- Yes* - No	Over Current Protection can be disabled for using the machine on certain rubber flooring where current draw is higher than expected
Impact Level	- High* - Low	Impact detection sensitivity level. If nuisance tripping occurs (i.e. driving over a floor transition), adjust setting to low.
Impact Action	- Log Only* - Log & Lockout	Impact detection status Log Only – Impact is recorded Log & Lock – Impact is recorded and User is locked out of scrub functions (Display shows (X24)) until machine is reset with a Supervisor key.
Impact Log User ID?	- Yes - No*	Whether to record the User ID in the impact log

Parameter	Options (*=default)	Notes
Show Charging Lights?	• Yes* • No	LED status bar will display a visual indication of the batteries level of charge while batteries are being charged (see page 51)
Allow Auto Resume	• Yes* • No	Allows the robot to attempt to resume after a stoppage when not related to a safety stop
Allow Plan Chaining	• Yes • No*	Allows the playback of consecutive copy-cat plans where the end point of one plan is at the start of the next plan
Resume Anywhere	• Yes • No*	Allows the operator to resume a stopped plan forward of the normal resume “circle”
Date / Time / Timezone	• Timezone • Hour • Minute • Second • Year • Month • Day	Set the date, time and timezone Choose timezone that matches machine's location

Configuration Menu

The configuration menu is available only at the service technician access level. This permits the machine To be configured based on installed options and equipment.

Parameter	Options (*=default)	Notes
Deck (Type)	• REV* • DISC	Used to inform the Main Machine Controller which type of deck is on the machine.
Battery (Type)	• AGM* • WET • Lithium Ion	Used to inform the Main Machine Controller which type of batteries are on the machine.
Batteries Installed	1-6	Menu visible only if Li-Ion batteries are installed
Charge Algo	0 to highest numbered algorithm	Used to select the appropriate battery charging algorithm used by the battery charger, based on the type of batteries installed in the machine.
TrackClean	• Yes* • No	Used to indicate whether the TrackClean option has been installed on the machine.
UVGI Kit	• Yes • No*	Used to indicate whether the UVGI option has been installed on the machine.
MMC Node ID	• Use 1 with lead acid batteries • Use 50 with li-ion batteries.	Allows manually setting the node ID to resolve/avoid node ID conflicts with li-ion battery modules.
Autonomy Node ID	• Use 3 with lead acid batteries • Use 53 with li-ion batteries..	
Charger Node ID	• Use 10 for IC650 charger • Use 100 for RC1000 charger	
Disable Drop-offs?	• Yes • No*	The dropoff sensors can be disabled for reflective floors.

Autonomous Cleaning Menu

The autonomous cleaning menu provides interaction with the autonomous system.

Parameter	Notes
Start Plan	Can be used instead of the play/pause button to begin playing back a plan
Scan Location tag	Used to select a tag for recording or playing back plans associated with the tag..
Delete this plan	Used to delete the current cleaning plan (Only viewable when the machine is at a start or resume point and the current user access mode is allowed to delete a plan).
Delete Tag # XXXXX	Deletes the tag currently in use an all of its associated cleaning plans. (Only viewable when the current user access is allowed to delete tags)

Maintenance And Adjustments

MMC Firmware Update via USB

1. Obtain the firmware file and place a copy in the root directory (Not in a folder) of a USB memory stick.
2. Remove the control panel and temporarily plug in the USB port harness PN 56116601 to the X173 USB connector. See [“3D Harness Diagrams” on page 291](#) Main Machine Controller bay area for connector location.
3. Power on the machine into service mode.
4. Press the i button to enter the menu. Record both the configuration and option setting values so that you will be able to restore them later if needed. In most cases this will not be necessary, but depending on specifically what in the firmware is being updated, the configuration and option settings can be reset to their default values when the firmware is updated. If you record them in advance, you will be prepared to restore them.
5. Press the i button to enter the menu. Navigate to System, Install MMC F/W via USB and follow the directions on the screen. It will check for the proper file on the USB and then display the version of the firmware file as the “New Version.”
 - a. Confirm that the New Version is the desired version to be installed
 - b. Press the up arrow to install the file. You will see progress numbers for “Loading,” followed by “Validating,”
 - c. After the file has been downloaded and validated, press the up arrow again to “reset.” This will replace the old firmware with the new firmware version.
 - d. When the install process is complete, the control board will reset and run through its normal startup routine.



CAUTION: Do NOT remove power during the install process or the control board may be permanently disabled

6. If the configuration menu is displayed immediately after the installation process is completed, the Configuration and Option settings will need to be restored to their original values which you recorded in step 2.
7. When complete, go to the Systems menu and verify that the MMC Firmware version displays the appropriate value for what was just installed.
8. Remove the USB port harness and reassemble the control panel

Troubleshooting

Refer to the [Troubleshooting](#) section of the Electrical Chapter on [page 233](#) for general troubleshooting information and procedures.

Any error codes initiated by any module will be sent to the Main Machine Controller via the CAN Bus, and shown on the display and recorded to the log. Each of these codes for the Main Machine Controller and power module are listed in the tables below, along with some basic troubleshooting steps to help isolate the cause.

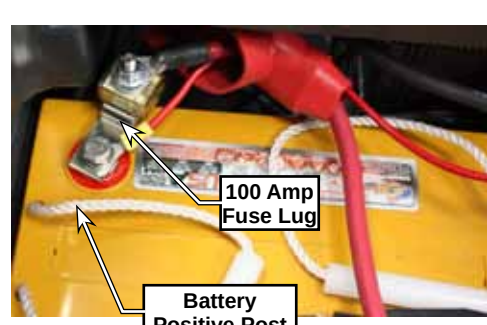
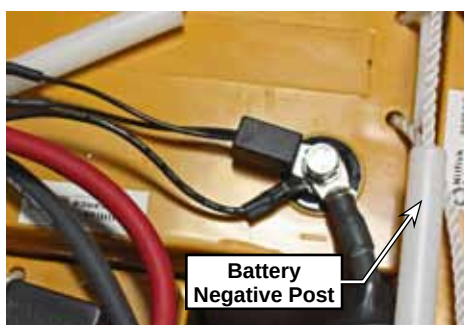
Rebooting

Many troubleshooting procedures are initiated with a machine reboot. However, this may not fully reset all controllers, as they have direct battery power supplied to them, as opposed to only KSI power. This includes the MMC, Steering controller, and Autonomy controller. If a “hard reboot” or “power cycle reboot” is called for, shut down the machine, disconnect the main battery connector for 30 seconds, and then re-power the machine.

Terminology

Voltage measurements are always taken between two points. The first point is the location of interest, and the second point is the reference point. These designations are irrespective of polarity, and the reference point may be at a higher voltage than the test point. Some of the common reference points used in the troubleshooting descriptions are shown below.

- **Main Ground Lug:** This is the main distribution point (node) for all battery negative connections throughout the system.
- **K2 Input Lug:** This is the main distribution point (node) for all battery positive connections throughout the system. (Note that the K2 output lug serves only the Power module.)
- **Battery Posts:** These reference points are generally used only when the two distribution nodes above are suspect.



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Main Machine Controller (E2) Error Codes

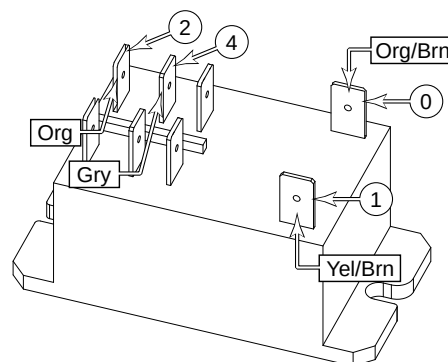
1-001 K1 KSI Rly Coil Open

Description	(K1 KSI Relay Open) The controller has detected that the KSI relay is not responding to a closure command.	
Setting Conditions	The controller has commanded the KSI relay to close, but 24 volts is not detected at the output contacts. (Note, because KSI is not active, this may result in multiple modules to fail to boot, causing unrelated errors to appear.)	When Monitored Always
Possible Causes	• Circuit breaker CB2 is open. • Loose wire at the KSI relay • Faulty relay	

Initial Action Press the CB2 circuit breaker reset button.

Troubleshooting Steps

1. Remove the control board from its mounting, but leave all connections intact.
2. Check the voltage between KSI contact 2 and the main ground lug in the electrical bay.
 - If 24 volts is not present, trace the fault back through CB2 and back to the main battery.
 - If 24 volts is present, continue.
3. Power the machine, and as necessary, use the service menu to ensure the KSI relay is commanded to be energized.
4. Check the voltage between KSI contact 4 and the main ground lug.
 - If 24 volts is present, repair the gray wire between the KSI relay and the Main Machine Controller.
 - If 24 volts is not present, continue.
5. Check the voltage between contact 0 and contact 1 of the KSI relay coil.
 - If the voltage is at or near 24 volts, replace the KSI relay.
 - If the voltage is not near 24 volts, continue.
6. Check the voltage between contact 1 (yellow/brown wire) and the battery ground lug in the electrical bay.
 - If the voltage is not near 24 volts, repair or replace the harness between the relay and the 5-amp circuit breaker CB1.
7. Check the voltage between contact J1-3 and J1-2 at the main control board connector.
 - If the voltage is not near 24 volts, replace the main control board.
 - If the voltage is at or near 24 volts, repair or replace the wiring harness between the control board and the KSI relay.



1-002 K1 KSI Rly Coil Short

Description	The controller has detected a short circuit to the KSI relay coil.
--------------------	--

Setting Conditions	The amp draw exceeds 5 amps	When Monitored
		Always

Possible Causes	Short in the relay coil. Short to battery in the control line.
------------------------	--

Initial Action	None
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Troubleshooting Steps

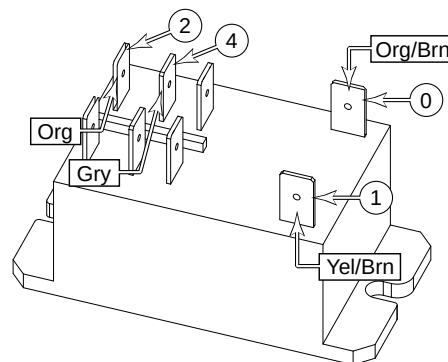
1. Disconnect the spade lugs from the relay terminals, and check if the error persists.
 - If the error clears, replace the relay.
 - If the error persists, repair or replace the wiring between the controller and the relay.

1-003 K1 KSI Contact Weld

Description	The controller has detected that the KSI relay output power is active after the controller has de-energized the relay coil.	
Setting Conditions	Power is detected at contacts J1-20 and J1-21 when the KSI relay is not commanded to be energized.	When Monitored Always
Possible Causes	• Fused relay contacts. • Short to B+ in relay output • Short to B- in relay coil control.	
Initial Action	None	

Troubleshooting Steps

1. Disconnect the spade lugs from the relay coil, and check if the error persists.
 - If the error clears, the relay is functioning correctly. Proceed to step 2 to isolate the cause as either a short or control board failure.
 - If the error persists, proceed to step 3 to isolate the cause as either a short or relay contact weld.
2. Isolate the cause between control wire short to ground, or main control board.
 - a. Shut down the machine, and disconnect the main battery disconnect.
 - b. Disconnect the J1 connector from the main control board.
 - c. Disconnect the spade lugs from the KSI relay coil.
 - d. Check for continuity between J1-3 (or Org/Brn at the relay) and the main grounding terminal in the electrical bay.
 - If the resistance is at or near zero ohms (continuity), repair or replace the Org/Brn wire between the relay and the Main Machine Controller.
 - If the resistance is not near zero (no continuity), make one more confirmation check of the controller. Continue to next step.
 - e. Leave the KSI relay coil terminals disconnected, but reconnect the J1 connector to the main control board, and re-connect the battery disconnect.
 - f. Re-power the machine, verify that the KSI relay is NOT commanded to be on, and verify that the error persists.
 - g. Check the voltage between J1-2 and J1-3 at the main control board.
 - If the voltage is at or near 24 volts, replace the main control board.
3. Isolate the cause between a short to power or the relay contacts welded.
 - a. With the error still being reported, disconnect the output terminal from contact 4 of the KSI relay.
 - If the error clears, replace the KSI relay.
 - If the error persists, trace the gray wire emanating from the KSI relay, to repair a short to battery positive.



1-010 CAN Bus 0

Description	CAN bus 0 is in bus-off state	
Setting Conditions	Main Machine Controller has no response from any other controller on CAN0 Bus	When Monitored Always
Possible Causes	CAN0 wires open or shorted	
Initial Action	Reboot the machine	

Troubleshooting Steps

1. Power down the machine, and unplug the main battery disconnect.
2. Disconnect the J2 connector from the main control board.
3. Check the resistance between contacts J2-1 and J2-2 of the controller harness connector.
 - If the resistance is showing open-circuit, repair or replace the twisted pair wiring between the Main Machine Controller and the autonomous module.
 - If the resistance is showing short circuit, proceed to step 4 to isolate the harness from the modules.
4. If present, disconnect the Trackclean module, and recheck the resistance between J2-1 and J2-2.
 - If the resistance is no longer showing short circuit, replace the trackclean module.
5. Disconnect the battery charger 16-pin connector, and recheck the resistance between J2-1 and J2-2.
 - If the resistance is no longer showing short circuit, replace the battery charger.
6. Disconnect the autonomy module, and recheck the resistance between J2-1 and J2-2.
 - If the resistance is no longer showing short circuit, replace the autonomy module.
 - If the resistance is still showing short circuit, repair or replace the twisted pair wiring between the Main Machine Controller and the autonomy module.

1-011 CAN Bus 1

Description	CAN bus 1 is in bus-off state	
Setting Conditions	Main Machine Controller has no response from any other controller on CAN1 Bus	When Monitored Always
Possible Causes	CAN1 wires open or shorted	
Initial Action	Reboot the machine	

Troubleshooting Steps

1. Power down the machine, and unplug the main battery disconnect.
2. Disconnect the J2 connector from the main control board.
3. Check the resistance between contacts J2-11 and J2-12 of the controller harness connector.
 - If the resistance is showing open-circuit, repair or replace the twisted pair wiring between the Main Machine Controller and the drive module.
 - If the resistance is showing short circuit, proceed to step 4 to isolate the harness from the modules.
4. One module at a time, disconnect the Steering module, Power module, and Drive module; and recheck the resistance between J2-1 and J2-2.
 - If the resistance is no longer showing short circuit, replace the specific module.
 - If the resistance is still showing short circuit, repair or replace the main harness.

1-101 M10 Solu Pump Short

Description	M10 Solution Pump Shorted	
Setting Conditions	Amp Draw is higher than 5 Amps	When Monitored Always
Possible Causes	• Shorted Solution Pump • Control wire shorted to power	
Initial Action	None	
Troubleshooting Steps		
Disconnect the solution pump and check if the error persists. – If the error persists, the control wire is shorted to battery positive power. Repair or replace the harness. – If the error clears, replace the pump.		

1-102 L1 Solu Solenoid Short

Description	Solution solenoid - too much current	
Setting Conditions	Amp Draw is higher than 5 Amps	When Monitored Always
Possible Causes	• Shorted Solution Solenoid • Control wire shorted to power	
Initial Action	None	
Troubleshooting Steps		
Disconnect the solution solenoid and check if the error persists. – If the error persists, the control wire is shorted to battery positive power. Repair or replace the harness. – If the error clears, replace the solenoid.		

1-103 Go Pedal Always On

Description	The MMC has detected the Go Pedal switch was closed at startup. (This is a duplicate to the 3-103 message.)	
Setting Conditions	The Drive controller notified the MMC via CANBus message that the Go Pedal was closed during startup. This is not an error to the Drive controller. The MMC sets the error condition.	When Monitored Bootup
Possible Causes	• Short in the Go Pedal wiring. • Operator standing on the switch during startup.	
Initial Action	None	
Troubleshooting Steps		
Inspect the Go Pedal switch and wiring for proper operation or short circuit.		

1-106 M8 Det Pump Short

Description	Detergent pump 1 - too much current	
Setting Conditions	Amp Draw is higher than 2 Amps	When Monitored Always
Possible Causes	• Shorted Pump (solenoid) Winding M8 • Either control wire shorted to power or ground	
Initial Action	None	

Troubleshooting Steps

1. Disconnect both wires from the detergent pump.
2. Measure the resistance of the solenoid coil.
 - If the resistance is less than 8 ohms, replace the solenoid.
 - Otherwise, continue.
3. With the machine powered, but not scrubbing, check the voltage from each wire of the solenoid and the main ground lug.
 - If either measurement is significantly different from 12 volts (near 0 volts or near 24 volts), that wire is shorted to an alternate power source.
 - If both voltages are near 12 volts, and the error persists while the solenoid is disconnected, replace the Main Machine Controller.

1-201 M2 Brush Mtr Overload

Description	M2 Brush Motor Overload	
Setting Conditions	The brush motor current reported over the CAN Bus from the Power Module is monitored by the Main Machine Controller. If the current is above 26 amps for a given period of time, the fault will be set.	When Monitored Always
Possible Causes	• Motor bearings • Gear box drag (resistance to rotation) • Strapping wrapped around motor shaft • Scrubbing on rubber floor for extended time • Scrubbing on very rough floor with high scrub pressure for extended time	

Initial Action**Troubleshooting Steps**

1. Eliminate the environmental causes listed above (the external drags on the motor).
2. With the scrub pad removed and deck raised, manually activate the scrub motor and observe the amperage load.
 - If the amperage returns to near normal (but returns to high amperage with any load), then the motor windings are likely in early stages of failure. Replace the motor.
 - If the amperage remains high with no load, inspect the bearings and gearbox. Repair or replace as necessary.

1-202 M5 Vac Mtr Overload

Description	M5 Vacuum Motor Overload	
Setting Conditions	The Vacuum motor current reported over the CAN Bus from the Power Module is monitored by the Main Machine Controller. If the current is above 23 amps for a given period of time, the fault will be set.	When Monitored Always
Possible Causes	• Motor bearing failure. • Impacted debris inside the impeller housing.	
Initial Action	The motor and impeller are not serviceable. Replace the vacuum motor.	
Troubleshooting Steps		

1-301 M1 Drv Whl Mtr Ovrlld

Description	M1 Drive Wheel Motor Overload	
Setting Conditions	The drive motor current reported over the CAN Bus from the Drive controller is monitored by the Main Machine Controller. If the current is above 25 amps for a given period of time, the fault will be set.	When Monitored Always
Possible Causes	• Mechanical drag on the motor (Strapping wrapped around axle) • Motor bearings • Gear box drag (resistance to rotation) • Driving up steep incline for extended time • Scrubbing on rubber floor for extended time • Scrubbing on very rough floor with high scrub pressure for extended time	
Initial Action		
Troubleshooting Steps		
1. Eliminate the environmental causes listed above (the external drags on the motor). 2. Inspect the wheel bearings as described in “Drive Wheel and Wheel Bearings” on page 197. Replace if necessary. 3. If the condition persists and all other causes are eliminated, replace the drive motor.		

1-401 *Low Battery*
1-402 *Abort Low Battery*

Description	General low battery fault and/or abort autoscrub for low battery	
Setting		When Monitored
Conditions		Always
Possible Causes	• Low Battery • Loose/corroded connections	
Initial Action	See below	

Troubleshooting Steps

Make sure the batteries are charged, and with the machine powered down, the battery voltage measured at the battery terminals is at or near 24 volts. Record this voltage as “No-Load Bat” for reference. The remainder of this procedure assumes No-Load Bat is normal.

1. Power the machine and activate the vacuum motor for a load. Compare the voltage directly at the battery terminals to No-Load Bat. (test both the main lug and the 100-amp fuse lug)
 - If the voltage significantly lowers, clean and re-torque all battery lugs and connections, and then repeat step 1.
 - If the voltage significantly lowers again after you have cleaned the battery lugs, one or more battery cells are failing. Test and replace the batteries as necessary.
 - If the voltage remains near No-Load Bat, continue.
2. Repeat the load test, but check the voltages at the following locations, and take the corrective action following each location:
 - a. Between the K2 input lug and the battery negative post.
 - If the voltage drops and the K2 lug is tight, replace the wire between the battery and the K2 relay.
 - b. Between the Main Ground Lug in the electrical bay and the battery positive post.
 - If the voltage drops and the ground lug is tight, replace the battery negative cable.
 - c. Between J1-1 and J1-5 at the main control board.
 - If the voltage drops, repair or replace the ground and/or battery wires to the Main Machine Controller.
 - If the voltage remains near 24 volts, and the error persists, replace the main control board.

1-403 ABORT Out of Water

Description	Abort autoscrub due to out of water	
Setting Conditions	Solution flow meter not reporting flow.	When Monitored Auto scrub
Possible Causes	• Plugged filter • Faulty solution solenoid • Faulty solution pump • Faulty flow meter	
Initial Action	Diagnose all other solution system related errors first.	

Troubleshooting Steps

- If this error is accompanied by a failure of the steering system and/or wheel encoders, then the 12-volt power output from the Main Machine Controller is the likely cause.
 - If the voltage between J1-7 and GND is not near 12 volts, replace the Main Machine Controller.
 - If the voltage between J1-7 and GND is near 12 volts and one or more of these systems (plus flow meter) is not responding, repair or replace the wiring harness.
- If water flow is present and the floor is wetted, the flow meter may be at fault. (Otherwise, jump to step 1 below to diagnose no flow.)
 - a. Check the voltage between pins 2 and 3 of the flow meter.
 - If the voltage is not near 12 volts, repair or replace the harness.
 - b. With no flow present, check the voltage between pins 1 and 2 of the flow meter connector.
 - If the voltage is not near 5 volts, replace the flow meter.
 - c. Recheck the voltage with water flow present.
 - If the voltage remains the same as measured above, open the flow meter to look for obstruction. Otherwise, replace the flow meter.
 - If the voltage changes from the 5 volts previously measured, continue to step d.
 - d. Repeat the above steps, except measure the voltage between J1-5 and J2-9.
 - If the voltage when water flow was present did not drop below the normal 5 volts, then repair or replace the harness between the flow meter and control board.
 - If the changes when flow is present and the error persists, replace the main control board.
- 1. Clean and inspect the solution filter.
 - a. Slowly open the shutoff valve to confirm solution flow out of the solution tank.
 - If the condition persists, continue.
- 2. Check the solution pump.
 - a. Manually activate the solution pump in the service menu, and feel the motor body for any vibration from running.
 - If the motor appears to be operating, proceed to step 4 to clean the solenoid, which includes a step for confirming pump activity.
 - If the motor does not appear to be operating, continue to step b.
 - b. With the solution pump still commanded to be active, check the voltage between contacts 1 and 2 of the solution pump.
 - If the voltage is non-zero (PWM input), and the pump is not operating, replace the pump.
 - If the voltage is at or near zero, go to step c to check the controller wiring.

1-403 ABORT Out of Water (continued)**Troubleshooting Steps (continued)**

- c. With the solution pump still commanded to be active, check the voltage between contacts J1-4 and J1-20 at the Main Machine Controller.
 - If the voltage is at or near 0 volts, replace the main control board.
 - If the voltage is non-zero, repair or replace the wiring harness.
3. Check the solution solenoid.
 - a. Command the solution solenoid to be active from the service menu.
 - b. Check the voltage across contacts 1 and 2 of the solution solenoid.
 - If the voltage is at or near 0 volts, proceed to step c to check the controller wiring.
 - If the voltage is non-zero, proceed to step d to clean and inspect the solenoid valve body.
 - c. With the solution solenoid still commanded to be active, check the voltage between contacts J1-13 and J1-20 at the main control board.
 - If the voltage is at or near 0 volts, replace the main control board.
 - If the voltage is non-zero, repair or replace the harness between the controller and solenoid.
4. Clean the solution solenoid.
 - a. Using the procedure [“Clean and Inspect the Solution Solenoid”](#) on page 319 as a reference, separate the solenoid from the valve.
 - b. Inspect the valve for obstruction and debris.
 - c. With the solution shutoff valve open, command the solution pump to operate and confirm flow out of the solenoid valve body.
 - If no flow is present, return to troubleshooting the solution pump, and work backward through the system to check for blockages in the solution tubing.
 - If flow is present, continue with step d to check the function of the solenoid.
 - d. With the solenoid still separated from the valve, command the solenoid to be active, and place the solenoid plunger (and spring) into the solenoid.
 - If the plunger is not pulled into the solenoid, replace the solenoid assembly.
 - If the plunger is activated properly, repeat the procedure to determine where a blockage may still exist.

1-404 ABORT Tank Full

Description	Abort autoscrub due to recovery tank full	
Setting Conditions	Sensor circuit closes	When Monitored Always
Possible Causes	• Tank full • Open circuit	
Initial Action	Empty recovery tank	
Troubleshooting Steps		
1. Gently shake or tilt the float to check if the steel ball is stuck. Make sure the float is dangling vertically from its pendant cord. – Replace the float if the ball remains stuck. 2. Disconnect the float switch electrical connector. 3. Check the resistance between contacts 1 and 2 of the float switch connector (toward float switch). – If the resistance is not at or near 0 ohms, replace the float switch. 4. Disconnect the J2 connector from the main control board. 5. Check the resistance between contacts 1 and 2 of the float switch harness connector (toward controller). – If the resistance is not at or near 0 ohms, repair or replace the main harness between the main control board and the float switch.		

1-405 ABORT Critical fault

Description	Abort autoscrub due to any critical fault	
Setting Conditions		When Monitored Always
Possible Causes		
Initial Action	Diagnose all other codes.	
Troubleshooting Steps		

1-406 **ABORT No Heartbeat**

1-409 **No Heartbeat**

Description	Abort autoscrub (1-406) due to no can bus heartbeat	
Setting Conditions	No CAN Bus activity detected	When Monitored Always
Possible Causes		
Initial Action	Diagnose all other CAN communication errors	
Troubleshooting Steps		

1-407 **ABORT ESTOP**

Description	Abort autoscrub due to ESTOP	
Setting Conditions	The E-Stop circuit opened while in autoscrub	When Monitored Always
Possible Causes	- Faulty E-Stop switch - Disconnected/broken wire in E-Stop circuit	
Initial Action	Cycle the E-stop switch, and make sure the E-Stop is raised and in the off-position	
Troubleshooting Steps		
- With the machine powered down, check the continuity across the E-stop contacts. - If the switch contacts are open when the button is raised, replace the E-stop switch. - Re-power the machine, and trace the E-stop circuit by checking voltage between the main grounding lug and the wire at each of the access points below: - KSI Relay Out (gray) - If 24 volts is not present here, the whole KSI circuit is not functioning, and multiple other KSI-related errors would have been reported. - K2 Relay Coil (gray, W285) - If 24 volts is not present here, the first splice-point in the KSI harness is faulty. Repair/replace harness. - J6-21 KSI at Autonomy module, - If 24 volts is not present here, the second splice-point in the KSI harness is faulty. Repair/replace harness. - E-Stop input (gray) - If 24 volts is not present here, the wire between the second splice-point and E-stop is broken. Repair/replace harness. - J1-10, - If 24 volts is not present here, the wire between the E-stop and controller is broken. Repair/replace harness. - If 24 volts is present here, replace the main control board.		

1-408 ABORT Charging

Description	Abort autoscrub due to battery charging	
Setting Conditions	24 volts is present at the charger interlock input to the Main Machine Controller.	When Monitored Always
Possible Causes	• Faulty charger • Short circuit in interlock circuit	
Initial Action	Make sure charger is not plugged in	
Troubleshooting Steps		
1. Disconnect the X194 connector from the battery charger. (Ignore CANBus error messages) – If the error clears, replace the battery charger. – If the error persists, repair or replace the wire (green) between the charger and Main Machine Controller.		

1-410 ABORT UVGI

Description	Abort autoscrub due to UVGI failure	
Setting Conditions	The UVGI Ready input to the MMC is showing open circuit (internal pull-up to 5V) when UVGI is expected to be active (active low = shorted to chassis ground).	When Monitored Always
Possible Causes	• Burned out bulb • Signal line break (J2-3) or UV module disconnected	
Initial Action	Diagnose power module error codes first.	
Troubleshooting Steps		

1-411 Batt/Chg algo cfg err

Description	The configuration battery value and the configured charger algorithm do not match the expected values	
Setting Conditions	• The battery config is li-ion and the charger algorithm is not 339 • The charger algorithm is set to 339 and the battery config is not li-ion • The charger algorithm does not match the config algorithm and the charger will not accept the config algorithm change	When Monitored Startup
Possible Causes	• Mismatched configuration settings in the service menu. • CAN communication failure between the battery and MMC	
Initial Action	• Check the configuration setting for a type mismatch • Check CAN-0 communications between charger, battery, and MMC	
Troubleshooting Steps		

1-560	<i>EEPROM Config Fault</i>
1-561	<i>EEPROM Options</i>
1-562	<i>EEPROM Sys Values</i>
1-563	<i>EEPROM Fault Log</i>
1-564	<i>EEPROM User Key List</i>
1-565	<i>EEPROM Impact Log</i>
1-566	<i>EEPROM Impact Locked</i>
1-567	<i>EEPROM Signatures</i>
1-568	<i>Image Checksum</i>

Description	Unable to read EEPROM values - using default values
--------------------	---

Setting Conditions	When Monitored
	Always

Possible Causes

Initial Action	Hard power cycle the machine by disconnecting the main bat. If the error persists, replace the Main Machine Controller.
-----------------------	---

Troubleshooting Steps

1-702	<i>Lost Comm-A2 Pwr Mod</i>
1-703	<i>Lost Comm-A3 Drive</i>
1-704	<i>Lost Comm-A4 Steering</i>
1-705	<i>Lost Comm-A5 Auto</i>
1-708	<i>Lost Comm-A8 Charger</i>
1-710	<i>Lost Comm-B1 Battery</i>

Description	CAN Bus communication loss to the respective module(s).
--------------------	---

Setting Conditions	The Main Machine Controller has not detected heartbeat messages from the respective modules.	When Monitored
		Always

Possible Causes	• CAN Bus failure • Module Failure
------------------------	---

Initial Action	• Reboot the machine If the error persists, begin the troubleshooting. • If ONLY the Battery Charger is reporting the error, make sure the charger is connected to the batteries, plug the charger into facility power for 30 seconds, and then reboot the machine. • If only the battery is reporting the error, make sure the configuration isn't set to "Li-Ion" when a different battery type is present.
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Troubleshooting Steps
Continued on Next Page

1-052	<i>Lost Comm-A2 Pwr Mod</i>
1-053	<i>Lost Comm-A3 Drive</i>
1-054	<i>Lost Comm-A4 Steering</i>
1-055	<i>Lost Comm-A5 Auto</i>
1-058	<i>Lost Comm-A8 Charger</i>
1-005	<i>Lost Comm-B1 Battery</i>

Continued from Previous Page

Description CAN Bus communication loss to the respective module(s).

Troubleshooting Steps (Continued)

1. Is more than 1 module reporting the error?
 - No--See step 2
 - Yes--See step 3
2. Only 1 module is reporting the error (Make sure that module is powered up.):
 - a. With the machine powered-down, and all modules still connected to the harness, compare the resistance between CAN-H and CAN-L measured at the CAN test port, and measured at the offending module.
 - If the resistances are not the same, the fault lies in the harness or connector at that module.
 - If the resistances are the same, and no damage is detected at the module's connector, then replace that module.
3. Are all reporting modules on the same CAN Bus (either CAN-0 or CAN-1)?
 - No--See step 4
 - Yes--See step 5
4. Both busses are affected: There are only 2 locations where both CAN Busses are exposed: the main machine controller and the CAN Bus test port adjacent to the Main Machine Controller.
 - a. Inspect the harness and connectors between the MMC and the CAN test port for damage, corrosion, or miswiring.
 - b. If no harness faults are found, the main machine controller is at fault.
5. All reporting modules are on the same Bus.
 - a. Check the resistance between CAN-H and CAN-L from all modules in the following sequence:
 - For Can-0: MMC, Test Port, Autonomous, Trackclean, Charger
 - For Can-1: MMC, Test Port, Drive Ctrl, Power Mod, Steering Ctrl.
 - If the resistance is at or near 0 ohms, isolate the short circuit. See step 6.
 - If all resistances are the same, and not near 0 ohms, then the Main Machine Controller is likely at fault.
 - If a change in resistance is found between any 2 modules in the sequence, an open circuit is located somewhere between them.
6. Isolate a short circuit.
 - a. While monitoring the resistance between Can-H and Can-L at the test port, begin disconnecting each of the modules from the harness.
 - If the resistances changes to not being 0 ohms when a module is disconnected, that module is at fault.
 - If the resistance remains 0 ohms even after all modules are disconnected, the short is in the harness.

1-800 Charging failure: didn't charge

Description	The charger is reporting a complete AGM charge, but charging not complete.	
Setting Conditions	The charger reported charging was complete, but the battery voltage remained below the AGM reset voltage of 25.40V	When Monitored Always
Possible Causes	• Faulty battery temperature sensor input to the battery charger • Batteries – Not properly receiving a charge • Voltage drop in either positive or negative cables between the batteries and the battery charger	
Initial Action		
Troubleshooting Steps		

1-901	<i>Strg Cntrl packet loss</i>
1-902	<i>Drv Cntrl packet loss</i>
1-903	<i>Strg queue congestion</i>
1-904	<i>Drive queue congestion</i>
1-905	<i>Rbt Spam Cmd Over-run</i>

Description	1-901	Losing some messages from the Steering Controller
	1-902	Losing some messages from the Drive Controller
	1-903	Steering Controller sending too many messages
	1-904	Drive Controller sending too many messages
	1-905	Autonomous Controller is sending too many messages
Setting Conditions	Same	When Monitored
		Always
Possible Causes	Internal software issue	
Initial Action	See below	

Troubleshooting Steps

1. Hard power-cycle the machine by disconnecting and reconnecting the battery, before powering the machine back on.
 - If the fault clears, place the machine back into service.
 - If the fault persists, continue.
2. Power down the machine.
3. Disconnect the applicable controller based on the specific error code below:
 - 1-901 Steering Controller
 - 1-902 Drive Controller
 - 1-903 Steering Controller
 - 1-904 Drive Controller
 - 1-905 Autonomous Controller
4. Re-power the machine.
 - If the fault remains, replace the Main Machine Controller.
 - If the fault clears, continue to step 5 to confirm the applicable module is faulty.
5. Reconnect the applicable controller, and re-power the machine.
 - If the fault remains clear, place the machine back into service.
 - If the fault returns, replace the previously disconnected module.

Power Module (A2) Error Codes

Power module error codes will be displayed on the main display. However, the error number is also flashed on the two-color status LED on the module itself. The status LED has 2 colors; red and yellow. The red LED will flash out which digit of the code is coming next, and the yellow LED will flash out the value of that digit.

For example, to flash out an M4 Overload error with a code of 034, the red LED will flash once, followed by the yellow LED flashing 3 times. Then the red LED will flash twice, followed by the yellow LED flashing 4 times.

2-011 Precharge Fail

Description	The capacitor bank failed to charge to the KSI voltage. The K2 relay will not be allowed to close.	
Setting Conditions	The DC bus did not charge to within 5 volts of the KSI voltage within 1.5 seconds.	When Monitored Bootup
Possible Causes	To reduce the amount of arcing inside the K2 relay when it closes, the power module pre-charges the DC bus capacitors using KSI power through a current limiting resistor. If the voltage across this resistor remains more than 5 volts, the power module knows that the DC bus is not charging properly, and something is bleeding power out of the DC bus. This may be caused by: • A device connected to the DC bus has a low to medium resistance path to ground. • Failed power module mosfets	

Initial Action Reboot the machine to confirm the error is repeatable.

Troubleshooting Steps

1. Power down the machine, and disconnect the main battery connector in the electrical bay.
2. Isolate the B+ circuit.
 - a. Wait a few moments for the DC bus to self-discharge, and then confirm full-discharge by carefully shorting the B+ and B- lugs on the power module. (There may be a brief spark.)
 - b. Disconnect the large red wire from the B+ lug on the power module.
 - c. Restart the machine. (Ignore the resulting K2 Contact Open error, 2-014)
 - If the error persists, replace the power module.
 - If the error clears, go to step 3 to isolate the load versus MOSFET failure.
3. Isolate the M5 circuit.
 - a. Power down the machine, and disconnect the main battery connector in the electrical bay.
 - b. Reconnect the main power cable to the B+ lug on the power module.
 - c. Confirm full-discharge of the DC bus by carefully shorting the B+ and B- lugs on the power module.
 - d. Disconnect the wire from the M5 lug on the power module.
 - e. Restart the machine.
 - If the error persists, the vacuum motor circuit has a low to medium resistance path to ground. Diagnose and repair the circuit.
 - If the error clears, confirm the error before replacing the power module. Go to step 4.
4. Confirm MOSFET failure.
 - a. Reconnect the wire to the M5 lug on the power module.
 - b. Confirm full-discharge of the DC bus by carefully shorting the B+ and B- lugs on the power module.
 - c. Restart the machine.
 - If the error returns, the M5 MOSFET is confirmed to be at fault. Replace the power module.
 - If the error doesn't return, place the machine back into service, but monitor it for reoccurrence.

2-012 K2 Overload

Description	Excessive current to the K2 relay coil.	
Setting Conditions	Relay coil current exceeded 2 amps.	When Monitored Always
Possible Causes	Degraded relay coil. Complete failure likely.	
Initial Action	Replace the K2 relay	
Troubleshooting Steps		

2-013 K2 Contact Weld

Description	K2 contacts welded closed.	
Setting Conditions	The power module has detected power on the B+ input lug when the K2 relay was not commanded to be closed.	When Monitored Always
Possible Causes	• Relay failure. • Short to ground at the relay coil control wire.	
Initial Action	None	
Troubleshooting Steps		
1. Confirm that the error is still active. If the error is active, the Power module will not be commanding the K2 relay to close. (This is necessary for troubleshooting.) – If the error has cleared, you will not be able to diagnose the problem. However, repetitive reoccurrence of the error may be indicative of pitting of the relay contacts, and the relay should be replaced. – If the error is still active, continue to step 2. 2. Check the voltage across the relay coil. – If the voltage is 24 volts, inspect the brown wire between the relay and power module for a short to ground. – If the voltage is at or near zero volts, the coil is not energized, continue. 3. Disconnect the Blue/Gray output wire from the K2 relay. 4. Check the voltage between the relay post and the battery ground post in the electrical bay. – If the voltage remains 24 volts, the relay contacts are welded. Replace the relay. – If the voltage is not 24 volts, continue. 5. Check the voltage between the disconnected Blue/Gray wire and the battery ground post. – If the voltage is 24 volts, the wire is shorted to battery positive. Repair the wire. – If the voltage is not 24 volts, and the error persists, replace the power module.		

2-014 K2 Contact Open

Description	K2 Power Module contactor did not close	
Setting Conditions	The power module did not detect power at the B+ lug when the K2 relay was commanded to close.	When Monitored Always
Possible Causes	• Open circuit in the relay coil • Faulty relay	
Initial Action	None	

Troubleshooting Steps

1. Check the voltage between the two coil terminals of the K2 relay.
 - If the voltage is at or near zero volts, continue to step 2
 - If the voltage is at 24 volts, proceed to step 3.
2. Check the voltage between contacts J3-2 and J3-9 at the power module.
 - If the voltage is 24 volts, repair or replace the Brown wire between J3-2 and the relay.
 - If the voltage is not 24 volts, replace the power module.
3. Check the voltage between the output contact of the K2 relay and the main ground lug in the electrical bay.
 - If the voltage is zero volts, replace the K2 relay.
 - If the voltage is 24 volts, continue to step 4.
4. Check the voltage between B+ and B- lugs of the power module.
 - If the voltage is at or near 0 volts, repair or replace the main wire between the K2 relay and the B+ lug.
 - If the voltage is 24 volts, replace the power module.

2-015 Overvoltage Warning**2-017 Overvoltage Cutoff**

Description	Excessive voltage present at Power Module power supply	
Setting Conditions		When Monitored Always
Possible Causes	Faulty power module.	
Initial Action		

Troubleshooting Steps

The machine is battery-powered. There is no common failure that can cause the batteries to achieve a voltage high enough to trigger this error.

2-016 Undervoltage Warning**2-018 Undervoltage Cutoff**

Description	Insufficient voltage present at Power Module power supply	
Setting Conditions	Voltage below 18 volts.	When Monitored Always
Possible Causes	Loose or corroded connection	
Initial Action	None	

Troubleshooting Steps

Isolate the cause by systematically checking voltages back to the battery. (Each test below assumes the previous tests indicated an undervoltage condition, and that the current location is the first position where full voltage was detected.)

- If multiple modules are reporting similar errors, the fault lies at or near the main battery terminals, the main ground lug, or the input lug at the K2 relay.
1. Check the voltage between the B+ and B- lugs of the power module.
 - If the voltage is at or near 24 volts, replace the power module.
 2. Check the voltage between the B+ lug at the power module and the main ground lug in the electrical bay.
 - If the voltage is at or near 24 volts, repair or replace the ground wire leading to the power module.
 3. Check the voltage at the output lug of the K2 relay and the main ground lug.
 - If the voltage is at or near 24 volts, replace the positive wire between the K2 relay and the power module.
 - If the voltage is below 24 volts, replace the K2 relay.

2-021 M1 Scrub Motor Open**2-022 M2 Scrub Motor Open**

Description	Scrub motor is open circuit.	
Setting Conditions	The power module has detected no current on the M1 or M2 output lugs. The scrub motor uses both lugs. So these errors should be reported together.	When Monitored Always
Possible Causes	• If only one of these errors is reported, there is either a misplaced wire, or a short to battery power (and a short circuit error should also be reported.). • Disconnected motor. • Worn carbon brushes	
Initial Action	Check Fuse F4.	

Troubleshooting Steps

1. Unplug the brush motor connector.
2. Check the resistance between contacts 1 and 2 of the brush motor. (The static resistance should be very low.)
 - If the resistance is high (open circuit), inspect the [Motor Brushes \(Disc Deck\)](#) described on page 332 or [Motor Brushes \(Rev Deck\)](#) described on page 333.
 - If the resistance is low (0.5 to 1.0 ohms), repair or replace the wiring harness between the motor and the power module.

2-024 M4 UVGI Open

Description	The UVGI ballast is open circuit.	
Setting Conditions	The power module has detected no current on the M4 output lug.	When Monitored Always
Possible Causes	- Faulty wiring - Failed ballast	
Initial Action	Check Fuse F7	
Troubleshooting Steps		

2-025 M5 Vacuum Motor Open

Description	The vacuum motor is open circuit.	
Setting Conditions	The power module has detected no current on the M5 output lug.	When Monitored Always
Possible Causes	• Faulty wiring • Worn carbon brushes	
Initial Action	Check Fuse F3	
Troubleshooting Steps		
Because accessing the vacuum motor connector requires nearly the same level of disassembly as inspecting the carbon brushes, the first step is to inspect the carbon brushes, as they are the most likely cause. If preferred, this examination may be completed out of sequence. 1. Inspect or replace the Vacuum Motor Brushes described on page 349. – If the brushes are not the cause, continue the examination for an open circuit. 2. Reconnect the vacuum motor, but leave access to the last connector located near the motor. 3. Power up the machine, command the vacuum motor to run, and systematically examine voltages back to the power module. a. Check the voltage at the connector adjacent to the vacuum motor. b. Check the voltage at the harness connector adjacent to the battery charger. c. Check the voltage between the K2 input lug and the M5 output lug at the power module. – If all of the voltages were at or near 24 volts (any voltage not near 0 volts), replace the vacuum motor. – If none of the voltages were at or near 24 volts, replace the power module. – If some of the voltages were not near 24 volts, the open circuit lies in the harness upstream from the first 0 volt reading.		

2-027 M7 Actuator Motor Open

Description	The power module has detected an open circuit in the deck actuator circuit.	
Setting Conditions	The power module examines the circuit for voltage drop, which should be near 0 volts when the motor is not commanded to operate.	When Monitored Bootup
Possible Causes	• Loose connection • Failed limit switch diode (internal fault)	
Initial Action	Check Fuse F5	

Troubleshooting Steps

1. Use the Service menu, Output test to confirm that the actuator is non-functional in either direction.
 - If the actuator is functional, and the error is still reported, replace the power module.
2. Disconnect the J3 connector from the power module.
3. Disconnect the deck actuator from the main harness. (X190, 6-pin connector).
4. Check the harness for open circuit.
 - a. Check the resistance between J3-6 at the power module to contact 1 at the actuator connector.
 - b. Check the resistance between J3-1 at the power module to contact 2 at the actuator connector.
 - If either reading is open-circuit, repair or replace the harness.
 - If both readings are at or near 0 ohms, replace the deck actuator.

2-031 M1 Scrub Motor Overload**2-032 M2 Scrub Motor Overload**

Description	M2 Scrub Motor Overload	
Setting Conditions	The brush motor uses both the M1 and M2 outputs. So these errors should be reported together. The power module detected current above 70 amps to the brush motor, but less than a short circuit amperage.	When Monitored Always
Possible Causes	Because the overcurrent condition has reached the maximum permissible amperage of the power module, but not short-circuit level, it is likely that the motor is in a locked-rotor condition.	
Initial Action	None	

Troubleshooting Steps

Inspect the scrub deck for causes of locked rotor, such as debris wrapped around the shaft or failed output bearings. If the output is not locked, replace the brush motor.

2-034 M4 UVGI Overload

Description	M4 UVGI Overload	
Setting Conditions	The power module has detected current above 80 amps in the UVGI circuit, but less than a short circuit amperage.	When Monitored Always
Possible Causes	Because the overcurrent condition is higher than the F7 fuse capacity, it is likely a problem near the power module.	
Initial Action	Check the F7 fuse	
Troubleshooting Steps		

2-035 M5 Vacuum Motor Overload

Description	M5 Vacuum Motor Overload	
Setting Conditions	The power module has detected current above 70 amps in the vacuum motor, but less than a short circuit amperage.	When Monitored Always
Possible Causes	Because the overcurrent condition has reached the maximum permissible amperage of the power module, but not short-circuit level, it is likely that the motor is in a locked-rotor condition.	
Initial Action	Replace the vacuum motor	
Troubleshooting Steps		
Note that an obstruction in the suction hose will actually reduce the motor amperage, not increase it. So that is not a likely cause.		

2-037 M7 Deck Act Mtr Overload

Description	M7 deck lift actuator motor overload.	
Setting Conditions	The power module has detected excessive current in the deck lift actuator, but less than short circuit amperage.	When Monitored Always
Possible Causes	Because the overcurrent condition has reached the maximum permissible amperage of the power module, it is likely that the motor is in a locked-rotor condition, such as the leadscrew nut being driven into the gear housing.	
Initial Action	Check the Scrub Deck Actuator Adjustment described on page 325	
Troubleshooting Steps		
If the actuator is properly adjusted and no signs of binding are observed, replace the actuator.		

2-041 M1 Scrub Motor Overcurrent**2-042 M2 Scrub Motor Overcurrent**

Description	The power module has detected scrub motor current has exceeded the limitations of the power module.	
Setting Conditions	The power module detected current above 160 amps to the brush motor. This is a short circuit condition.	When Monitored Always
Possible Causes	• Motor short • Wiring short	
Initial Action	None	

Troubleshooting Steps

1. Determine whether 1 or both errors are being reported.
 - If error 2-041 occurs without error 2-042, the M1 output is shorted to battery positive.
 - If error 2-042 occurs without error 2-041, the M2 output is shorted to battery negative.
 - If both errors are reported, continue at step 2 to isolate the cause.
2. Disconnect the scrub motor, and check the resistance of the harness contacts leading back toward the power module.
 - If the resistance is at or near 0 ohms, the M1 and M2 wires are shorted to each other. Repair or replace the harness.
 - If the resistance is not near 0 ohms, then the motor is at fault. Replace the scrub motor.

Note that the scrub motor resistance is normally very low (less than 1/2 ohm), so that is not typically used as a conclusive diagnostic test.

2-044 M4 UVGI Overcurrent

Description	The power module has detected UVGI current above 160 amps, which exceeds the limitations of the power module.	
Setting Conditions	The power module has detected current above 160 amps in the UVGI circuit, which exceeds the limitations of the power module.	When Monitored Always
Possible Causes	Because the overcurrent condition exceeds the F7 fuse capacity, it is likely a wiring problem near the power module.	
Initial Action		

Troubleshooting Steps

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2-045 M5 Vacuum Motor Overcurrent

Description	The power module has detected vacuum motor current above 160 amps, which exceeds the limitations of the power module.	
Setting Conditions	Same	When Monitored
		Always
Possible Causes	Because the overcurrent condition has reached the maximum permissible amperage of the power module, it is likely that the motor or control wiring is shorted.	
Initial Action	None	

Troubleshooting Steps

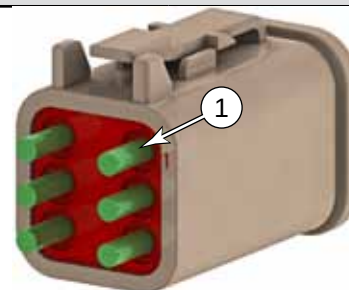
1. Disconnect the vacuum motor connector located down by the battery charger.
2. Check the resistance between the contacts on the harness leading back toward the power module.
 - If the resistance is at or near 0 ohms, repair or replace the harness.
 - If the resistance is not near 0 ohms, continue.
3. Partially remove the vacuum motor to gain access to the electrical connector adjacent to the motor.
4. Check the resistance between the contacts on the harness leading back toward the power module.
 - If the resistance is at or near 0 ohms, repair or replace the sub-harness between the vacuum motor and the previous connector.
 - If the resistance is not near 0 ohms, replace the vacuum motor.

2-047 M7 Deck Act Mtr Overcurrent

Description	The power module has detected deck actuator motor current above 25 amps, which exceeds the limitations of the power module.	
Setting Conditions	Same	When Monitored Always
Possible Causes	- Failed actuator motor - Short between the motor windings.	
Initial Action	None	

Troubleshooting Steps

1. Measure the actuator motor resistance.
 - a. Disconnect the deck actuator connector.
 - b. Measure the resistance between contacts 1 and 2 of the actuator connector.
 - Make sure to check resistance in both forward and reverse polarity, in case the actuator is stopped at a limit switch.
 - If the resistance is less than 250 ohms, replace the actuator.
 - If the resistance is greater than 250 ohms, continue.
2. Test the harness.
 - a. With the actuator still disconnected, power up the machine with Service mode access.
 - b. Navigate to the Output Test menu and command the M7 Deck Actuator to operate in one direction, and then the other. Clear any errors as necessary to continue.
 - If the motor overcurrent error occurs in both directions of travel, the motor wires (BLU/GRY & ORN/GRY) are shorted to one another.
 - If the error occurs in the UP direction but not the DN direction, either BLU/GRY shorted to B-negative, or ORN/GRY shorted to B-positive.
 - If the error occurs in the DN direction but not the UP direction, either BLU/GRY shorted to B-positive, or ORN/GRY shorted to B-negative.
 - Repair or replace the harness as appropriate.



2-051	M1 Mosfet Short	2-055	M5 Mosfet Short
2-052	M2 Mosfet Short	2-056	M6 Mosfet Short
2-053	M3 Mosfet Short	2-057	M7 Mosfet Short
2-054	M4 Mosfet Short	2-058	M10 Mosfet Short

Description	The power module has detected a short circuit in the output mosfet.	
Setting Conditions	The power module has detected that the output switching transistor for the respective motor is not switching off when expected. If the condition persists, the likely cause is that the power module has failed and needs replacement.	When Monitored Always
Possible Causes	Failed power module	
Initial Action	Replace the power module	
Troubleshooting Steps		

- 2-061 *M1 Current Sensor Fault*
 2-062 *M2 Current Sensor Fault*
 2-063 *M3 Current Sensor Fault*
 2-064 *M4 Current Sensor Fault*
 2-065 *M5 Current Sensor Fault*

Description	Power module current sensor fault.	
Setting Conditions	The power module has detected unexpected results for the applicable output current sensor. If the motor appears to be operating correctly, the power module may be damaged.	When Monitored Always
Possible Causes	Same	
Initial Action	Replace the power module	
Troubleshooting Steps		

2-066 *OverTemp Cutoff*

Description	The temperature of the power module has exceeded the permissible operating temperature.	
Setting Conditions	Same	When Monitored Always
Possible Causes	Ambient air temperature too warm. Excessive motor loading for prolonged periods.	
Initial Action	Power down machine, open hood, and let cool.	
Troubleshooting Steps		

2-067 *UnderTemp Cutoff*

Description	Internal temperature is below -40C	
Setting Conditions	Same	When Monitored
		Always
Possible Causes	Power module failure	
Initial Action	If the error doesn't clear, replace the power module	
Troubleshooting Steps		

2-071 M1 Scrub Motor Overload Trip**2-072 M2 Scrub Motor Overload Trip**

Description	M2 Scrub Motor Overload Trip	
Setting Conditions	The brush motor uses both the M1 and M2 outputs. So these errors should be reported together. The power module detected current above 70 amps for more than 5 seconds to the brush motor, but less than a short circuit amperage.	When Monitored Always
Possible Causes	Failing brush motor Obstruction to rotation, such as failed bearings or material wrapped around the motor shaft	
Initial Action	None	
Troubleshooting Steps		
Inspect the scrub deck output bearings. If the bearings are not faulty, replace the brush motor.		

2-074 M4 UVGI Overload Trip

Description	M4 UVGI Overload	
Setting Conditions	The power module has detected current above 70 amps for more than 5 seconds in the UGVI circuit, but less than a short circuit amperage.	When Monitored Always
Possible Causes	Because the overcurrent condition is higher than the F7 fuse capacity, it is likely a problem near the power module.	
Initial Action	Check the F7 ffuse	
Troubleshooting Steps		

2-075 M5 Vacuum Motor Overload Trip

Description	M5 Vacuum Motor Overload	
Setting Conditions	The power module has detected current above 70 amps for more than 5 seconds in the vacuum motor, but less than a short circuit amperage.	When Monitored Always
Possible Causes	Failing vacuum motor	
Initial Action	Replace the vacuum motor	
Troubleshooting Steps		
Note that an obstruction in the suction hose will actually reduce the motor amperage, not increase it. So that is not a likely cause.		

2-077 M7 Deck Act Mtr Stall

Description	M7 deck lift actuator motor overload.	
Setting Conditions	The power module has detected excessive current in the deck lift actuator, but less than short circuit amperage.	When Monitored Always
Possible Causes	• Improper deck actuator adjustment • Failing actuator	
Initial Action	Check the Scrub Deck Actuator Adjustment described on page 325	
Troubleshooting Steps		
If the actuator is properly adjusted and no signs of binding are observed, replace the actuator.		

2-081 EEPROM Fault

Description	EEPROM checksum error	
Setting Conditions		When Monitored
		Always
Possible Causes		
Initial Action	Reboot the machine. If the error doesn't clear, replace the power module.	
Troubleshooting Steps		

2-082 PDO Timeout Fault

Description	Did not receive PDO message from the Main Machine Controller in the timeout period	
Setting Conditions	Same	When Monitored Always
Possible Causes	This error likely won't be reported by the Main Machine Controller, as it would indicate a communication failure.	
Initial Action		
Troubleshooting Steps		

2-083 CAN Bus Fault

Description	Internal CAN bus error
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Setting Conditions	
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When Monitored

Always

Possible Causes

Initial Action	Reboot the machine. If the error doesn't clear, replace the power module.
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Troubleshooting Steps

2-084 Internal Comm Timeout

Description	Internal master did not receive slave controller message in timeout period
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Setting Conditions	
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When Monitored

Always

Possible Causes

Initial Action	Reboot the machine. If the error doesn't clear, replace the power module.
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Troubleshooting Steps

2-085 KSI Sequence Fault

Description	KSI, Interlock, and startup requests occurred out of order.
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Setting Conditions	
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When Monitored

Always

Possible Causes

Initial Action	Reboot the machine
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Troubleshooting Steps

2-086 *Over Temp Cutback*

Description	Internal temperature exceeded cutback temperature - output current will be reduced	
Setting Conditions		When Monitored Always
Possible Causes		
Initial Action	Shut down the machine and let it cool. If the error persists, replace the power module.	
Troubleshooting Steps		

2-087 *Under Temp Cutback*

Description	Internal temperature is below -25C - output current will be reduced	
Setting Conditions		When Monitored Always
Possible Causes		
Initial Action	If the error persists after the machine has warmed, replace the power module.	
Troubleshooting Steps		

2-088 K2 Coil Open

Description	Main contactor coil not detected	
Setting Conditions	Same	When Monitored Always
Possible Causes	• Disconnected K2 relay coil • Faulty relay	
Initial Action	None	

Troubleshooting Steps

1. Leave the machine powered.
2. Check the voltage between the Gray wire at the K2 relay coil and the main ground lug in the electrical bay.
 - If the voltage is not at or near battery voltage, repair or replace the gray wire.
3. Check the voltage between the brown wire at the K2 relay coil and the main ground lug in the electrical bay.
 - If the voltage is at or near 0 volts, and the K2 relay is not active, replace the K2 relay.
 - If the K2 relay is active, and the error is still being reported, replace the power module.
 - If the voltage is at or near battery voltage, continue.
4. Check the voltage between contact J3-2 and the main ground lug in the electrical bay.
 - If the voltage is at or near 0 volts, repair or replace the brown wire.
 - If the voltage is at or near 24 volts, and the error is still being reported, replace the power module.

2-091 M1 Hardware Fault**2-092 M2 Hardware Fault****2-094 M4 Hardware Fault****2-095 M5 Hardware Fault**

Description	Output hardware is defective	
Setting Conditions	Internal hardware fault	When Monitored Always
Possible Causes		
Initial Action	Disconnect the respective motor and reboot the machine. if the error persists, replace the power module.	

Troubleshooting Steps

--

2-096 *Parameter Change*

Description	Invalid parameter change	
Setting Conditions		When Monitored
		Always
Possible Causes		
Initial Action	Reboot the machine	
Troubleshooting Steps		

2-098 *M7 Act Out Current Sensor*

Description	Current sensor has invalid value	
Setting Conditions	Internal error	When Monitored
		Always
Possible Causes		
Initial Action	Reboot the machine. If the error persists, replace the power module	
Troubleshooting Steps		

2-102 *Temperature Sensor Fault*

Description	Internal temperature sensor has invalid value	
Setting Conditions	Same	When Monitored
		Always
Possible Causes		
Initial Action	Reboot the machine. If the error persists, replace the power module	
Troubleshooting Steps		

2-103 K2 Coil Short

Description	K2 Power Module contactor coil is shorted
Setting Conditions	When Monitored Always
Possible Causes	
Initial Action	
Troubleshooting Steps	
1. Disconnect the Brown wire from the K2 relay coil. 2. Check the resistance across the relay coil terminals. – If the resistance is at or near 0 ohms, replace the relay. 3. Check the resistance between the loose brown wire and the Gray wire on the relay coil. – If the resistance is at or near 0 ohms, repair or replace the wiring between the relay and power module.	

Troubleshooting Steps

Removal and Installation

Control Panel/Main Machine Controller

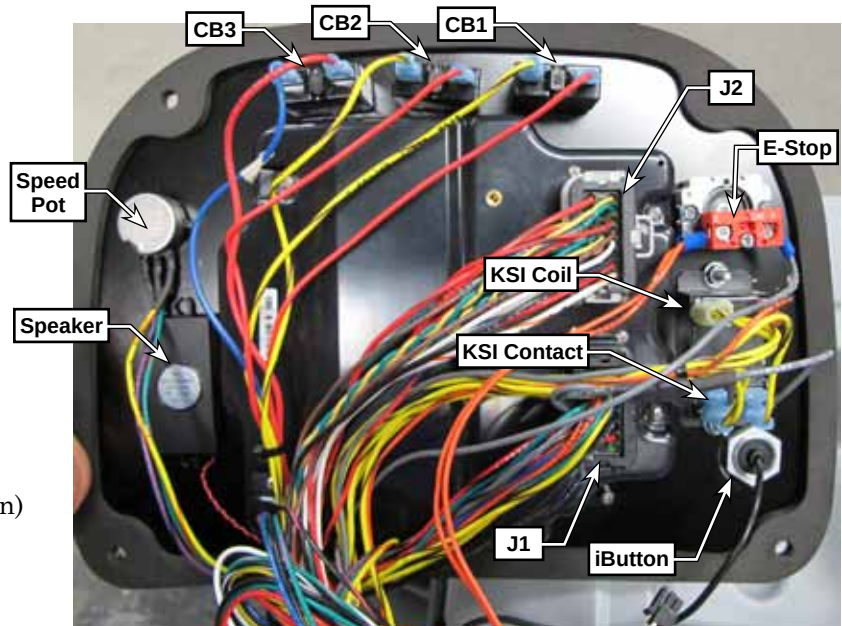
The MMC and the operator's control panel display are integral components to one another and cannot be separated.



CAUTION: *The control board is always receiving power, even when the machine is off. Make sure to disconnect the main battery connector before working on the control board.*

1. If this procedure is being performed to replace a defective control board, and if that control board is functional enough to do so, go to the [Options Menu](#) and [Configuration Menu](#) and write down the existing parameters.
2. Turn the machine off and disconnect the main battery connector in the electrical bay.
3. Lift the speed control knob off the potentiometer, and remove the retaining nut and lock washer.
4. Remove the 4 screws that secure the control board to the hood.
5. Lift the control board away from the hood, taking care not to stress the wiring harness.
6. Remove the following terminals and connectors:

- J1 Connector
- J2 Connector
- Speaker Connector
- iButton Connector
- Circuit Breaker 1 (Red and Yellow/Brown)
- Circuit Breaker 2 (Red and Orange)
- Circuit Breaker 3 (Red and Blue/Green)
- E-Stop Switch (Gray and Orange)
- KSI Coil (Orange/Brown and Yellow Brown)
- KSI Contact (Orange and Gray)



7. Remove the control board from the machine.
8. After replacing the control board with a new one, restore the original machine settings in the [Options Menu](#) and [Configuration Menu](#).
9. If available, re-authorize user level keys as described on [page 37](#).

Specifications

Sample Shop Voltage Measurements

The following tables contain some “real world” shop voltage measurements to help you recognize what “normal” looks like.

- Unless otherwise noted, all voltage readings are referenced to the main ground lug in the electrical bay.
- Some pin numbers are listed out of sequence when measurements require pin-to-pin voltage references instead of the main ground lug
- Values of “+Bat” mean the result is direct battery voltage without any resistive device in the circuit.
- Values of “≈24V” represent full battery voltage, regardless of the circuit path.

Main Machine Controller J1 Connector					
Pin#	Wire	Color	Function	Condition	Value
1	W159	YEL-BRN	Battery+		≈24V (25.4)
2	W160	YEL-BRN	Battery+		≈24V (25.4)
3	W162	ORN-BRN	KSI Coil Out	Relay Active	0.58V
				Relay Inactive	25.4V
4	W288	BLU-ORN	Solution Pump PWM Out	Pump Active, High flow output test	20.5V
				Pump Inactive	25.5V
5	W147	BLK	Battery-	Vacuum Motor on	≈0V (0.040V)
6	W146	BLK	Battery-	Vacuum Motor on	≈0V (0.040V)
7	W270	RED	12V Power Out		11.74V
8					
9					
10	W178	ORN	E-Stop In	Inactive, Raised	+Bat (25.5V)
				Active, Depressed	0.017V
11	W245	GRN	Charger Interlock In	Charger Unplugged	0.047V
				Charger Plugged In	25.5V
12	W279	GRN-BLU	Operator Presence In	Open, Pedal Raised	0.006V
				Closed, Pedal Pressed	25.5V
13	W163	GRY-BLK	Solution Solenoid Out	Solenoid Active	0.14V
				Solenoid Inactive	+Bat (25.2V)
14					
15	W358	RED-BLK	Speaker+ Out	Off, Ref to Pin 23	0V
				Horn On, Ref to Pin 23	Momentary rise, then drops off
				Off, Ref to B-	2.46V
				Horn On, Ref to B-	Momentary increase to 3V, then back down to 2.4V

Main Machine Controller J1 Connector					
Pin#	Wire	Color	Function	Condition	Value
16	W290	GRN-BLK	Detergent Pump Bi-Directional Out	Inactive, Ref to GND	12.4V
				Active Ref to GND	Too fast for voltmeter.
				Inactive, Ref 16 to 17	0V
				Active, Ref 16 to 17	Momentary increase when active
17	W289	ORN-GRY	Detergent Pump Bi-Directional Out	Inactive, Ref to GND	12.4V
				Active, Ref to GND	Too fast for voltmeter.
18					
19					
20	W167	GRY	KSI In	Power Off	0V
				Power On	25.1V
21	W168	GRY	KSI in	Power Off	0V
				Power On	25.1V
22					
23	W359	WHT-BRN	Speaker- Out	Beep, Ref to Pin 15	

Main Machine Controller J2 Connector					
Pin#	Wire	Color	Function	Condition	Value
1	W473	YEL	CAN0 H		2.52V
2	W472	GRN	CAN0 L		2.51V
3					
4	W185	BRN	Smart Key B-	with or without key	0.006V
5	W220	WHT	Smart Key Signal (+3.3V)	with or without key	3.3V
6	W416	BLK	Battery-	Vacuum on	0.027V
7	W437	RED	Light Strip +5V		4.95V
8	W191	WHT-ORN	Float Switch In	Inactive, Hanging	0.012V
				Active, Horizontal	4.93V
9	W271	BRN-GRN	Flow Sensor In	Open Switch	4.91V
				While Flowing	2.4V
				Closed Switch	0.019V
10					
11	W471	GRN	CAN1 L		2.54V
12	W470	YEL	CAN1 H		2.60V
13	W440	TAN-BRN	Light Strip Data Out	Light off	2.3V
				Light on any mode.	3.4-3.5V

Main Machine Controller J2 Connector					
Pin#	Wire	Color	Function	Condition	Value
14	W439	WHT-BLU	Light Strip Clock Out	Light off	0.008V
				Light on any mode	0.13V
15					
16	W262	RED-BRN	Deck Actuator Position 1 In	Inactive (transport position)	4.9V
				Active (below vacuum only position)	0.007V
17					
18	W263	RED-YEL	Deck Actuator Position 2 In	Inactive (transport position)	4.9V
				Active (below normal scrub position)	0.006V
19	W204	RED	USB VBUS		4.92V
20	W203	WHT	USB DM		0.398V
21	W202	GRN	USB DP		0.398V
22					
23	W221	BLK	USB GND	Vacuum on	0.051V

Power Module J3 Connector					
Pin#	Wire	Color	Function	Condition	Value
1	W265	ORN-GRY	Deck Actuator Out 1 +/- Deck Actuator Out 2 +/-	Raise, Ref 1 to 6	-23.3V
6	W264	BLU-GRY		Lower, Ref 1 to 6	+23.3V
				At rest	3.19V
2	W019	BRN	K2 Relay Coil Out	Active	2.16V
				Inactive	25V
3	W395	GRN	CAN1 L		2.54V
4	W392	YEL	CAN1 H		2.60V
5	W354	BLK-PNK	Curtis Prog +15V Out		15.8V
			See Above (below pin #1)		
7	W350	GRN-VIO	Curtis Prog Serial Rx		0.005V
8	W353	BLU-GRN	Curtis Prog Serial Tx		0.017V
9	W365	GRY	KSI In		25.1V
10					
11					
12	W351	BLK	Curtis Prog Gnd Out		0.005V
13					
14					

Motor Amp Draw measurements

All motor amp draw measurements were done with no load (free running) using the Service/Output Test function and reading the amperage reported on the control panel display.

Motor	Condition	Amperage (On Display)
Brush Motor (Disc)	Red pad, sealed concrete floor, maximum pressure, high solution flow, stationary, 24±1 VDC, allow time for current to stabilize.	13-17 AMPS
Brush Motor (Cylindrical)		13.5-20.5 AMPS
Steering Motor	Machine Raised (no load)	3 Amps per phase
	Machine stationary, on floor	6 Amps per phase
Vacuum Motor	Unrestricted (max load)	17.2 Amps
	Blocked Hose (min load)	13.5
Deck Actuator Motor	No Load	1.8 Amps
	Full load	7.0 Amps

Device Resistances

Device	Resistance - Ohms	Comments
KSI Relay Coil	355	
K2 Power Module Relay Coil	53.7	
K3 Drive Controller Relay Coil	53.5	
Solution Pump	7.5	
Solution Solenoid	54.7	
Detergent Pump	9.3	
Speaker Coil	8.6	The speaker has 8 ohms printed on it.
Disc Motor		
Rev Motor	0.29	
Vacuum Motor	0.86, 5.4	Different values from two motors
Deck Actuator, Fully Raised	Open or 275	Depends on polarity across internal diode
Deck Actuator, Mid Point	Open	Either polarity
Can 0 Test Point		
Can 1 Test Point	67.8	
EM Brake Coil	58.9	
Traction Motor	0.32	
Steering Motor Stator Pairs	0.18	All three combinations are the same.
Termination Resistor - Main Machine Controller CAN 0	120.5	
Termination Resistor - Main Machine Controller CAN 1	120.5	

Device	Resistance - Ohms	Comments
Termination Resistor - Power Module CAN 1	238.3	
Termination Resistor - Drive Controller CAN 1	Open	
Termination Resistor - Steering Controller CAN 1	438	
Termination Resistor - Autonomous Controller CAN 0	120.1	

05 - Autonomous System

Functional Description

Even though the components of the autonomous system are integrated throughout the machine, the function of the autonomous system is relatively isolated from the rest of the machine. With a couple of safety system exceptions, all communication to and from the autonomous system passes through the **Main Machine Controller (MMC)** on its own dedicated CAN Bus. Understanding this relative isolation should make it easier to better understand the autonomous system itself and how it functions and interacts with the rest of the machine.

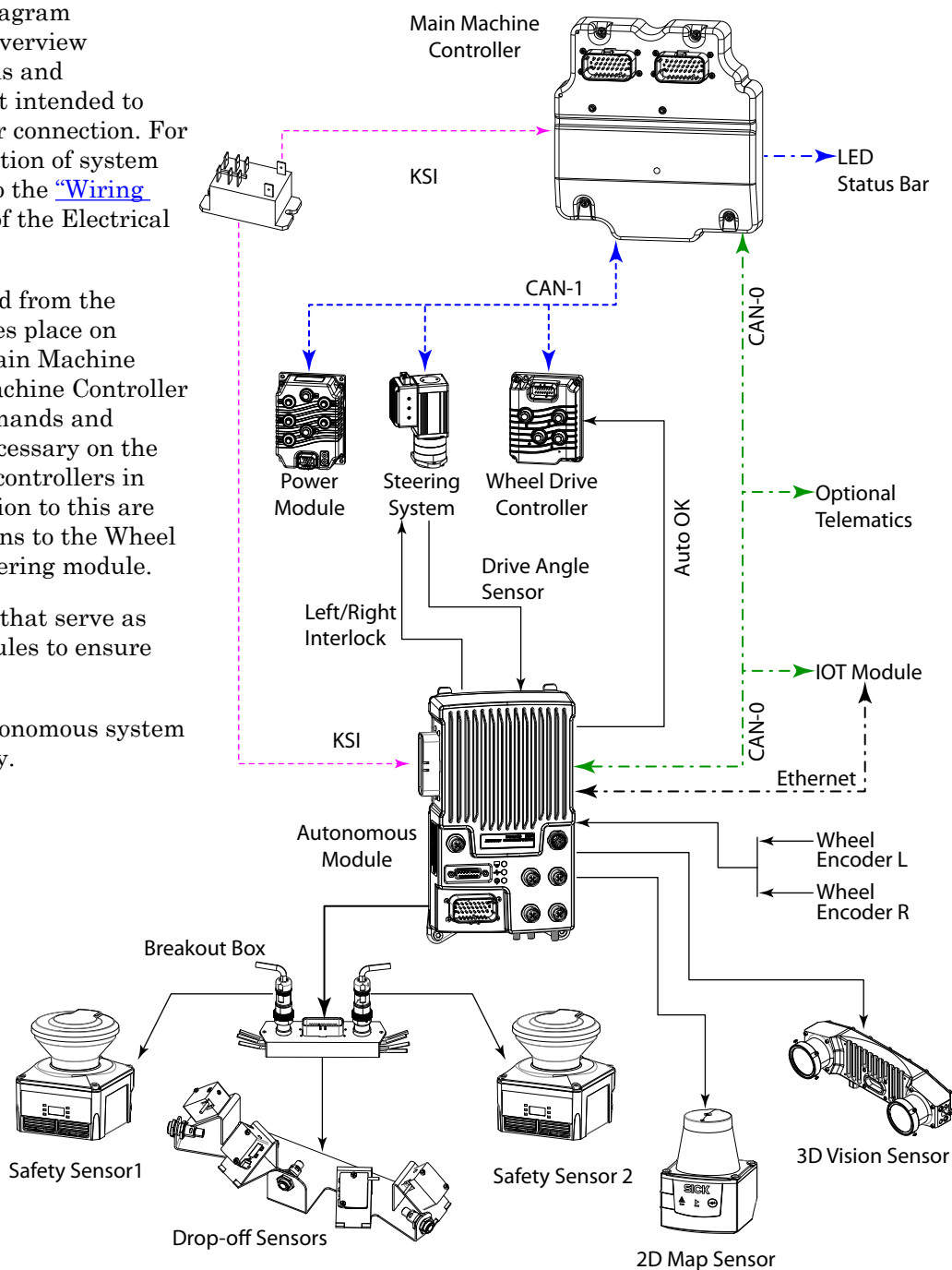
Functional Block Diagram

The Functional Block Diagram represents a high-level overview of the system interactions and communications. It is not intended to show every component or connection. For a more detailed examination of system interconnections, refer to the [“Wiring Diagrams”](#) on page 268 of the Electrical Chapter.

All communication to and from the Autonomous system takes place on the CAN-0 Bus to the Main Machine Controller. The Main Machine Controller then interprets the commands and rebroadcasts them as necessary on the CAN-1 Bus to the other controllers in the machine. The exception to this are the direct wire connections to the Wheel Drive Controller and steering module.

These are safety signals that serve as interlocks for those modules to ensure safe operation.

Control power to the autonomous system comes from the KSI relay.



LED Status Bar

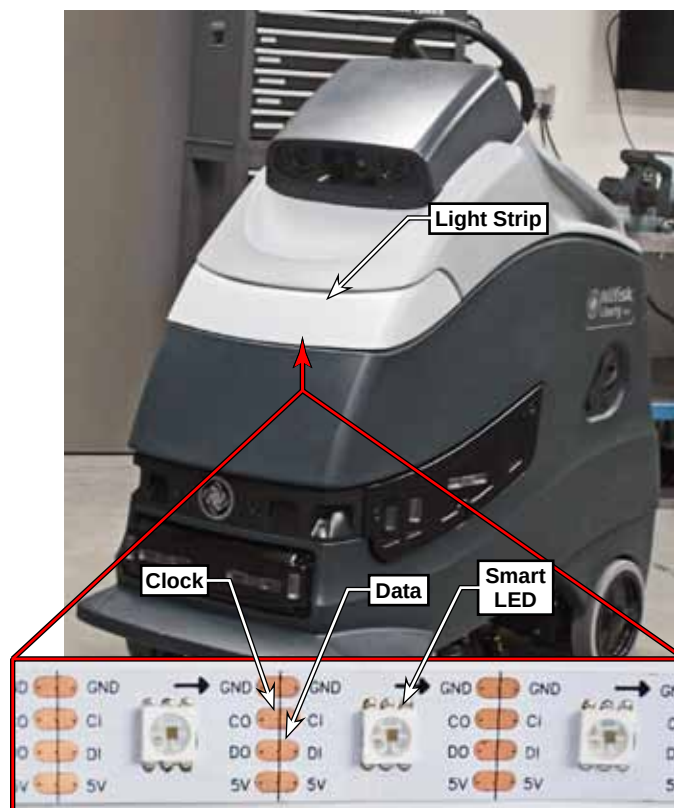
The LED strip lights on the front of the machine serve to notify people near the machine of the machine's presence and status. However, this is not just a simple strip of LED elements. The strip is made up of individual “Smart LED” cells that are separately controlled on their own serial bus.

Each smart LED cell contains a micro controller to interpret the serial data communication, and drive its own Red, Green, & Blue LEDs. Each RGB LED is controlled by PWM, and different colors are created by mixing the ratios between the PWM rates for each.

This allows each LED cell to have its own color (16 million colors), as well as being turned on or off separately, such as displaying flashing turn signals.



Note: For troubleshooting purposes, it is not possible to test the LED strip, nor any of the individual cells, by applying power to them. The LED cells can be activated **only** with a data stream.



Communication takes place sequentially down the ribbon, starting with the first cell, followed by the next, and so on. Communication begins when the first cell receives a 32-bit zero (32 clock pulses with the data line held at zero). This is called the “Start Frame” and it tells the cell that the next “1” bit it receives will be the beginning of its LED data.

The LED data is a 4 byte word. The first byte contains the word start and the global scale for brightness of that cell. The next 3 bytes indicate the PWM rate for each RGB LED.

Word Start	Scale	Blue	Green	Red
111	00000	00000000	00000000	00000000
3+5 bits	8 bits	8 bits	8 bits	8 bits

Once that cell has received its LED data, it then blindly passes all subsequent data on to the next cell. As a result, the next LED data word on the serial bus will program the next LED cell, and so on, until each cell has received its data word.

Each cell continues to drive its LEDs until it receives a new start frame (all 0's) followed by a data command. All the while, each cell continues to blindly retransmit the data stream until it receives a new start frame. This includes the start frame itself. So all of the cells receive the start frame, and await the next “1” bit to begin their next data word. The only time a cell does not retransmit the data stream is while it is receiving its own data word. In this manner, the downstream cells aren't receiving any data while the upstream cells are being programmed.

In short, each cell retransmits the data word to the next cell every time it receives one. The only exception is the very first word it has received following a start-frame. The cell knows that that particular word belongs to itself, and it doesn't retransmit it. This type of data sequencing is referred to as a shift-register.

Note that even if only 1 LED needs to be changed (like with a turn signal), the entire strip must be rewritten, but with the same data it already had, except that one cell has different data. If you viewed the strip light with a high speed camera, you would see each LED successively change/pulse, even if the whole strip was a constant color.

IOT (Communication) Module

The IOT module is a wireless data communication system for the connectivity of devices without direct human interaction. This provides connectivity of the SC50 to support systems via the internet. The IOT module uses cellular transmission to download system updates, and also to communicate machine status to a central repository.

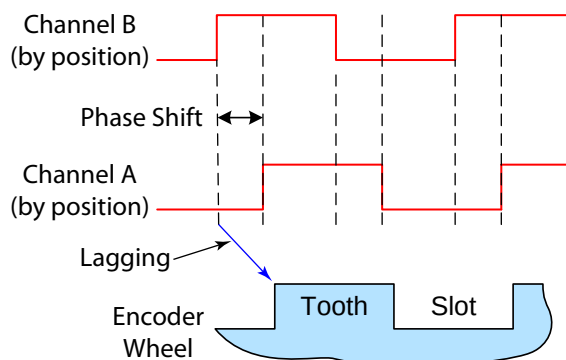
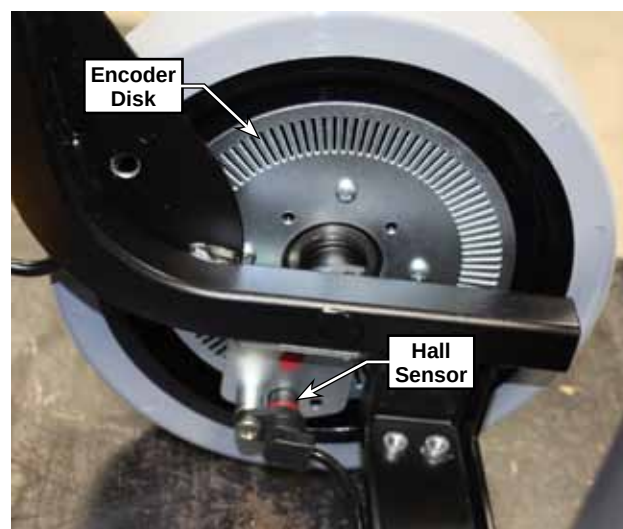
Wheel Encoders

The rear, non-traction wheels each have quadrature (2-channel) encoders for determining both speed and direction of rotation. This information is used by the Autonomous system to verify machine travel. The difference between the left and right wheel speeds can be used to determine a rate of turn, and the average of the their speed can be used to determine total speed.

The encoder sensor is a quadrature hall effect sensor. Internal to the sensor body, are two hall effect elements with an offset, which produces two square wave outputs with a slight phase shift between them. It is this phase shift that permits the sensor to identify direction of travel, as opposed to only speed from a single-channel encoder.

The graph to the right shows a simplified representation of the encoder signals relative to the encoder tooth position (*not the time domain, which would be negative in this diagram*). As the encoder tooth advances past the sensor, Channel A will detect the tooth slightly before Channel B. If the encoder tooth were moving in the opposite direction, Channel B would detect the tooth before Channel A.

This leading and lagging relationship allows the sensor to provide the directional information of the wheel. The frequency of the pulses provides the speed information.

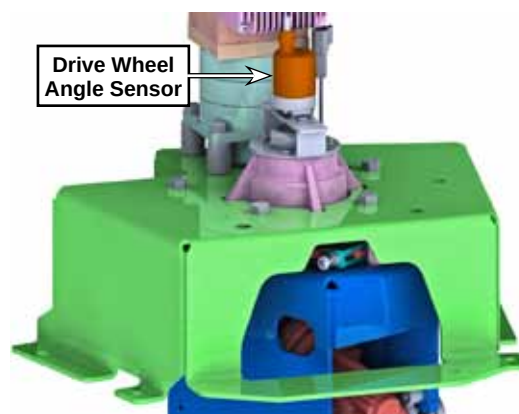


Drive Wheel Angle Sensor

The drive wheel angle sensor is electrically an Autonomous system component, but it is physically part of the steering system. The sensor is mounted to the top of the steering spindle, and provides accurate steering angle information to the Autonomous module without interpretation through the steering module.

The sensor is an intelligent, programmable encoder that provides a varying amperage signal (4-20 mA) to the autonomous module. However, this amperage passes through an input resistor at the Autonomous controller, which then sees the signal as a varying voltage, internally.

Internally, the encoder is similar to the Steering Wheel Position Sensor, and uses Hall Effect sensors for rotational position, and the encoder's internal electronics translate this information into the varying amperage output signal.



3D Vision Sensor

The Multisense 3D Vision Sensor is a stereoscopic camera for imaging and ranging of the machine's environment. Like a standard 2D camera, the 3D Vision Sensor provides an optical picture of what it sees, but it also includes distance data for the objects it identifies.

One of the more complex processes the camera must perform is to identify features or objects seen through one camera lens, and then locate that same feature or object seen by the other camera lens. Once the same feature is identified in both images, its position in each image is compared. The difference in position of the object is then used to calculate the range of the object from the machine.

Consider the very simple example of a ball placed directly in front of the camera shown to the right. The right-hand camera sees the ball slightly toward the left side of the image, and conversely, the left-hand camera sees the ball slightly toward the right side.

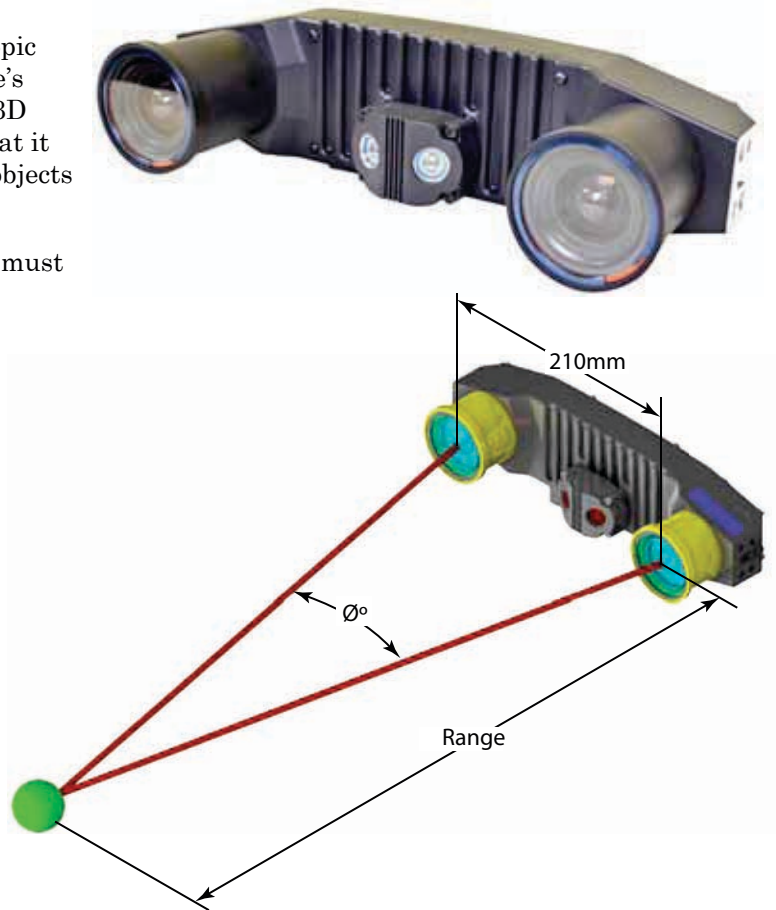
Using trigonometry, the camera is able to calculate the range of the object from the camera. As a form of triangulation, the distance between the two camera lenses is known, the angle of the object relative to each lens is determined from the images, and the distance may then be calculated.

In addition to ranging data, the camera also produces a modified composite image from both lenses. Because the two images are taken from slightly different angles (the distance between lenses), the two images would not normally line up very well. The camera stretches and scales the images according to the various ranges of the objects to produce a relatively clear composite image.

Pattern Projector

As mentioned above, one of the more complex tasks for the camera system to perform is to identify features and edges of objects, as seen from each lens. This can be especially difficult if the object is featureless, such as a flat wall.

To overcome this, the camera includes an infrared pattern projector, which produces easily identifiable marks on the objects in the room. These “artificial features” are easily detected by the camera, and used for the triangulation process to determine object ranges. This also permits the camera to identify objects in the dark, although lighting is required for reading location tags.



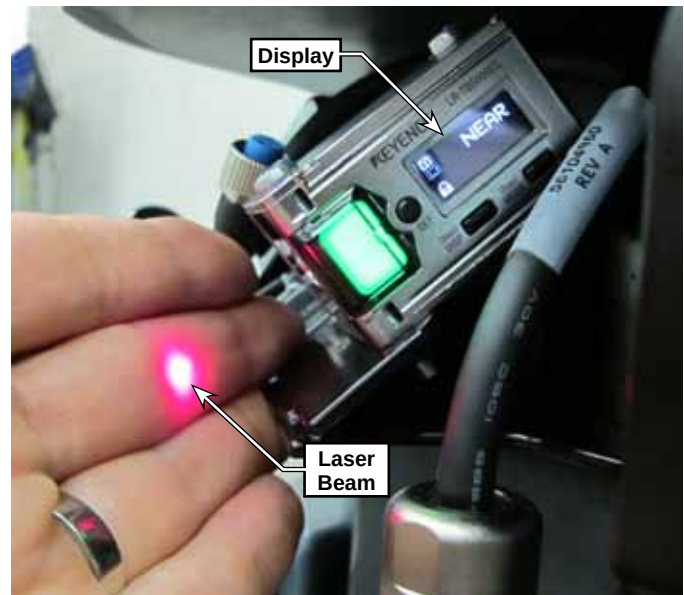
Drop-Off Sensors

There are 4 drop off sensors at the front corners of the machine. These sensors are laser distance sensors, and detect drop-offs in floor elevation as the distance increases.

A pulsed laser beam is emitted from the sensor, which reflects off the object to be measured (the floor), and returns back to the sensor's receiver. The distance to the object is calculated based on the time of flight the light beam took to travel out and back.

Even though the beam appears to be steady-on, it is being pulsed very rapidly. These on/off pulses are what permits the sensor to determine how long the beam took to travel the distance.

The output to the Autonomy controller is a 4-20mA signal.



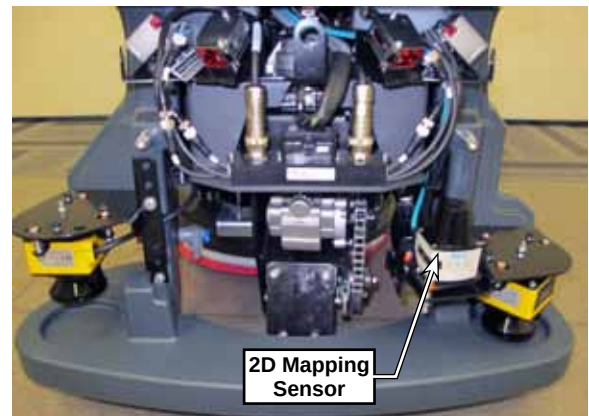
2D Mapping Sensor (Laser)

The 2D mapping sensor is located at the front lower left corner of the machine, and detects and maps out objects to the front of the machine. It detects objects approximately 10½ inches (27mm) off the ground in a horizontal plane, and returns that information in the form of polar coordinates from its current position.

The sensor works on the principle of LiDAR, which stands for Light Detection and Ranging. In a basic 1-dimensional LiDAR system, a pulsed laser beam is sent out to an object, and the reflected beam is detected. The time-of-flight of the beam is used to calculate the total distance the light traveled, which is twice the distance to the target (distance out and back).

A 2-dimensional laser works the same, except a rotating mirror is added so the laser beam sweeps out a circle, or part of a circle, as it scans a space. Each time a beam is sent out, the mirror has rotated slightly so the beam is pointing in a different direction.

How this functions is described in the section below.



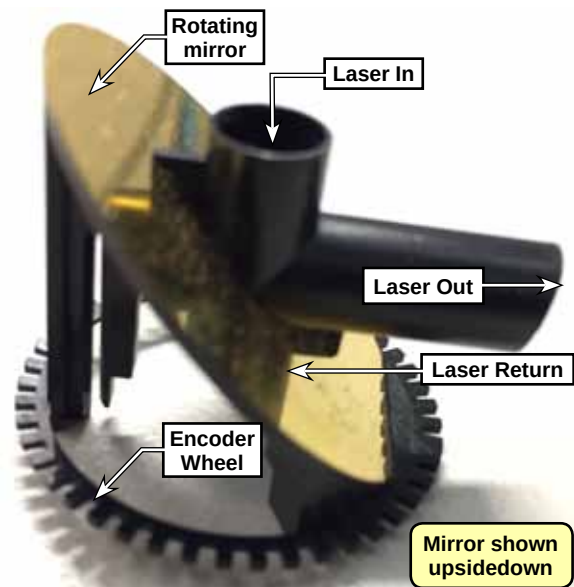
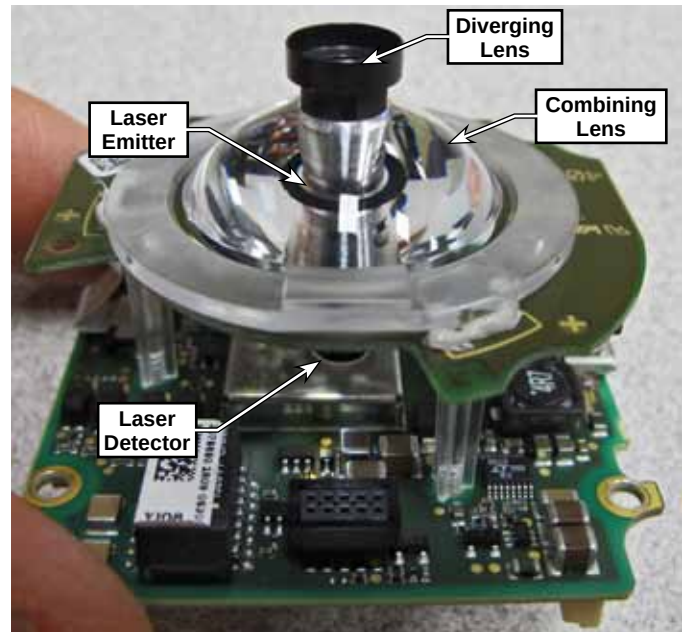
Components and Functions of the Mapping Sensor

At the core of the sensor is a semiconductor laser emitter. This produces a focused beam of infrared laser light at a wavelength of 850 nanometers. This beam passes through a semiconductor “shutter,” which blocks and unblocks the beam to create pulses of light, and also through a diverging lens to expand the beam so it is not so tightly focused. *(Part of the reason for this diverging lens is for eye safety, so the beam isn’t concentrated enough to harm the human eye.)*

The laser beam then strikes the rotating mirror. This mirror is tilted to 45 degrees to direct the laser sideways, and rotates 15 times per second, resulting in a scan frequency of 15Hz. (One scan represents one revolution of the mirror, but each scan contains hundreds of distance measurements.)

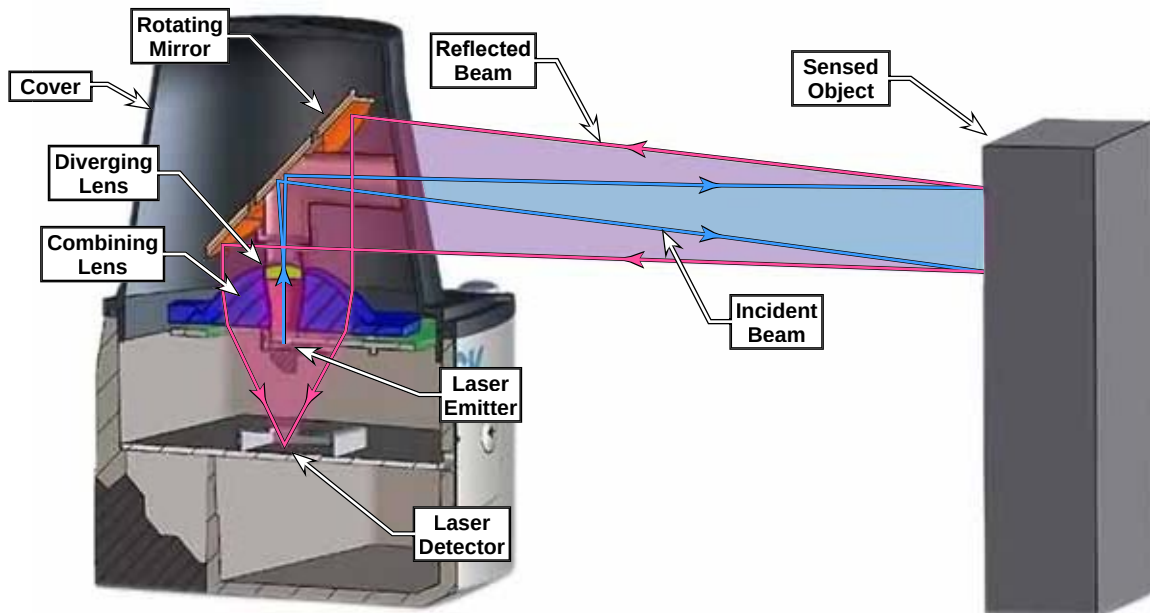
Attached to this rotating mirror assembly is an encoder wheel with a home-position indicator. The sensor electronics uses this encoder to determine the precise direction that the laser beam is pointed as it scans the room. Each of these scan sectors is 0.33 degrees wide. However, the laser is pulsed even faster than this, and each of these 0.33 degree data sectors is actually made up from the average of 84 sub-sector measurements. In other words, each rotation of the mirror is made up of nearly 70,000 individual laser pulses.

The moving components inside the sensor are protected by an opaque cover. That is, it is opaque to the human eye, but it is crystal clear to 850 nanometer light waves. This is the blackish cone on top of the sensor.



After the laser beam leaves the sensor, it bounces off objects in its path. This reflected light passes back through the protective cover and strikes the face of the rotating mirror. Because the speed of light is so fast (2.99×10^8 m/s), the mirror has not appreciably moved since the beam left the sensor. Due to scattering at the reflected surface, the reflected beam is much wider than the original emitted beam, and strikes the whole surface of the rotating mirror.

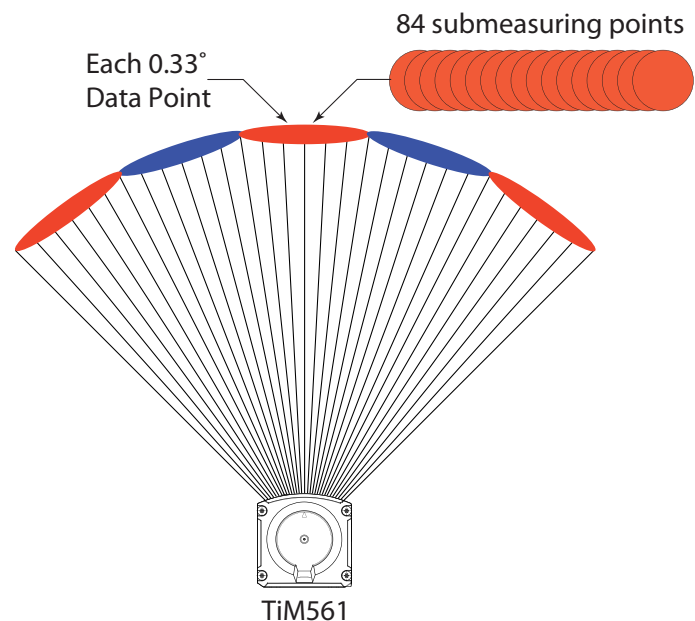
The mirror redirects the beam downward, toward the surface of a combining lens. This lens refocuses the beam to be more concentrated, and making it easier to detect. The beam strikes the light detector (which is tuned to specifically detect 850 nanometer light) and reports this detection back to the electronics.



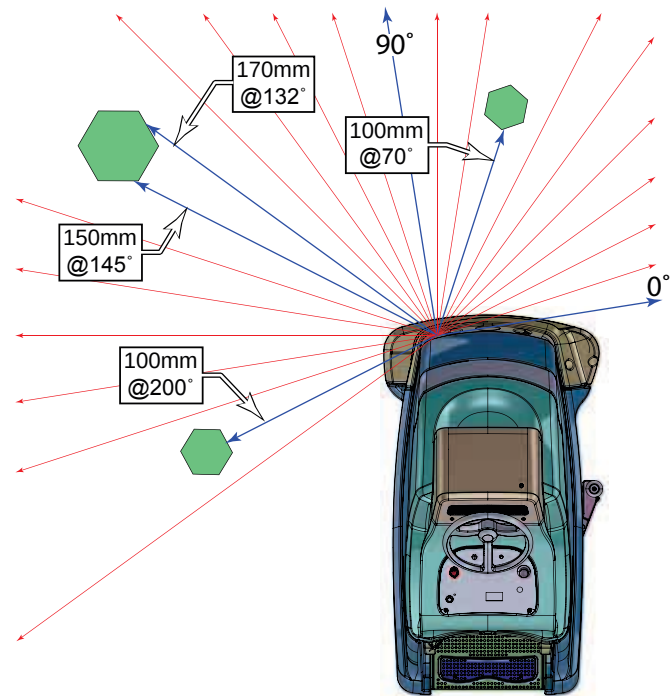
This all happens very fast. Considering a distance sensed of 10 meters, and the light beam travels out and back (20 meters total), the total time of flight for each measurement is $20 \div 2.99 \times 10^8 = 6.7 \times 10^{-8}$ seconds (0.000000067 sec).

The key to determining time of flight is that the laser must turn on and off very rapidly, and the sensor calculates the amount of time between turning the laser on and receiving the beginning of a returned pulse. This is the function of the electronic shutter, which is called a Pockel's Cell or Q-cell. The Q-cell turns on and off very rapidly compared to the speed of the rotating laser (at least 68 kHz for this sensor).

The sensor reports a distance measurement to the Autonomous system every 0.33 degrees of mirror rotation, but the laser is pulsing much, much faster than this. For every one data point the sensor reports, it actually takes 84 distance measurements, and then internally averages the results to provide just the one distance for that sector. This produces a more accurate distance measurement by reducing errors in any individual measurement.



The data reported to the Autonomous system is in the form of polar coordinates up to a 25 meter distance. Each reflected beam is reported as a distance and an angular position. However, the coordinate origin is oriented parallel to the front face of the sensor body, which is approximately 10 degrees counterclockwise to the front of the machine.



Safety Sensors (Lasers)



To reduce the computational load on the main autonomous processor, two safety sensors semi-autonomously monitor obstacles around the machine. Unlike the 2D mapping sensor, which returns a large amount of data to the system requiring processing, the safety sensors function more like a pass/fail system for obstacle detection.

Instead of a large data stream, the safety sensors provide either a warning signal that an object is nearby, or a protection signal that an object is eminently close. However,

the lasers aren’t just blindly monitoring the whole room. Instead, the autonomous system tells the safety sensor where it should be looking for objects, based on where the machine will be traveling and at what speed.

For example, if the machine will be turning to the left, it will instruct the safety sensors to monitor towards the left, to determine if any objects are, or will be, within its path of travel. In short, the autonomous controller tells the safety sensor where to look, and the safety sensor reports whether it sees something in that area or not.

Each sensor is programmed with 32 scan areas, and the autonomous controller simply needs to tell the laser which of those areas should be monitored. The autonomous controller decides which 1 of 32 areas is of interest, based on machine speed and direction of travel. These areas are programmed into each sensor, and the autonomous controller specifies which area number should be active.

Area Selection				
Steering Angle		Area Number for Machine Speed		
Start	End	0.0 - 0.3 m/s	0.3 - 0.5 m/s	0.5 - 1.1 m/s
-90°	-78°	1	16	
-78°	-66°	2		
-66°	-54°	3	17	27
-54°	-42°	4		
-42°	-30°	5	18	
-30°	-18°	6	19	28
-18°	-6°	7	20	29
-6°	6°	8	21	
6°	18°	9	22	
18°	30°	10	23	30
30°	42°	11	24	31
42°	54°	12	25	
54°	66°	13		
66°	78°	14	26	
78°	90°	15		

Area Address Selection

The most common data transmission scheme we encounter in the machine is called serial data. This is where a sequence of data bits are transmitted across a single pair of wires, one after the other. The area number, however, uses parallel data transmission. This means that each bit of the data has its own transmission wire, and are transmitted all at the same time.

The area number is transmitted by the 5 area address lines, and 5 redundant inverse address lines (for error detection). 5 binary digits results in 32 different area numbers ($2^5 = 32$). For each of the 5 address lines, there is an inverse address line. These pairs must be opposites of each other, or the data is not considered valid. The address lines follow a plus-1 binary to decimal coding.

Warning and Protection Zones

Within each area, there are 3 zones of observation. These are actually 3 independent geometric outlines that are grouped together into a single Area designator. Because these outlines are independently defined, it is neither required nor prohibited that these outlines overlap one another, or even point in the same direction. (This is significant, because Warning 2, discussed below, never varies, and is used for a unique purpose.)

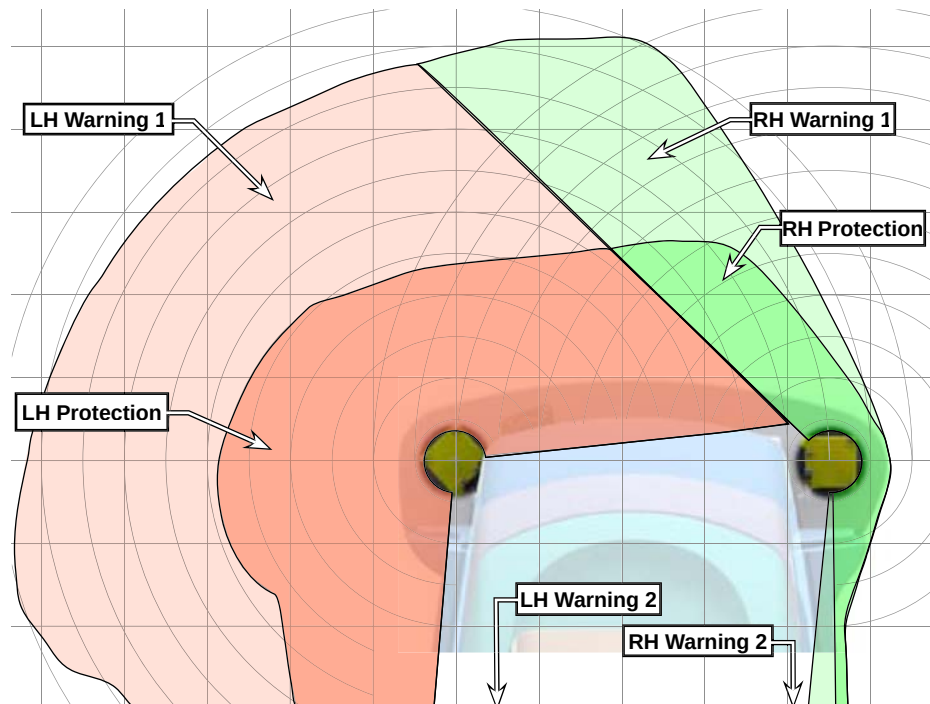
The most critical is the Protection Zone. If an object is detected within the area's protection zone, the Autonomy controller knows that an object is dangerously close, and responds accordingly. The second most important zone of observation is Warning 1. If an object is detected within the Warning 1 zone, the Autonomy controller knows that an object is potentially within its path of travel, and will slow down and formulate a plan of action to avoid that object.

Warning Zone 2 is unique, and is not used to safeguard machine travel, but instead, verifies that the safety sensor is functioning and correctly mounted with respect to the physical machine. Warning Zone 2 for both Left and Right safety sensors looks back toward the respective rear wheel of the machine. If the rear wheel is seen, the Autonomy module knows that the laser is functioning, and is properly mounted. For this reason, Warning 2 should always be active for both lasers.

The example to the right shows a representation of the 25th area for both safety sensors. This is used for a left-hand turn at moderate speed. The darker shaded areas represent the "Protection Zones", and the lighter shaded areas represent the "Warning Zones" (Warning 1, specifically).

One item of note is that not every area has a Warning 1 zone programmed--specifically, the high-speed area maps. So when the machine is traveling at higher speed, you will not see a transition on the Warning 1 LED nor the data signal wire when an object is detected. The protection zone will still trigger, however.

Area Addresses					
Area #	IN A	IN B	IN C	IN D	IN E
1	0	0	0	0	0
2	1	0	0	0	0
3	0	1	0	0	0
4	1	1	0	0	0
5	0	0	1	0	0
6	1	0	1	0	0
7	0	1	1	0	0
8	1	1	1	0	0
9	0	0	0	1	0
10	1	0	0	1	0
11	0	1	0	1	0
12	1	1	0	1	0
13	0	0	1	1	0
14	1	0	1	1	0
15	0	1	1	1	0
16	1	1	1	1	0
17	0	0	0	0	1
18	1	0	0	0	1
19	0	1	0	0	1
20	1	1	0	0	1
21	0	0	1	0	1
22	1	0	1	0	1
23	0	1	1	0	1
24	1	1	1	0	1
25	0	0	0	1	1
26	1	0	0	1	1
27	0	1	0	1	1
28	1	1	0	1	1
29	0	0	1	1	1
30	1	0	1	1	1
31	0	1	1	1	1
32	1	1	1	1	1



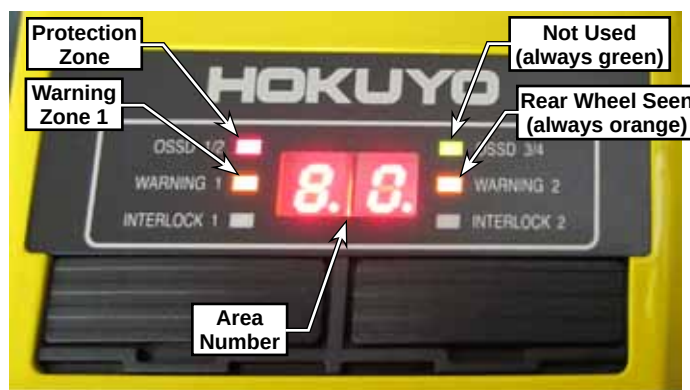
Outputs and LED Indicators

The front of the sensor has several status indicators which may be helpful during diagnostics. These provide visual information related to the electrical outputs from the sensor to the Autonomy module.

The 7-segment LED display shows the currently selected area number. Of the 6 LEDs, 3 of them show the status of the safety sensor output signals to the Autonomy module. These LEDs are summarized in the table below.

There are 4 electrical outputs from each laser to the Autonomy module. However, 2 of these signals are redundant, so there are only 3 functional signals returned to the Autonomy module across 4 wires. These include the Protection Zone, Redundant Protection Zone, Warning 1, and Warning 2.

Because the electrical outputs from the laser can be reassigned to different functions, depending on the programmed configuration, the manufacturer uses the generic designations of OSSD1 through OSSD4 for the 4 electrical outputs. Unfortunately, they also used the same generic designations for the LED labels, and the two do not correlate to one another in the current configuration. The OSSD3/4 LED does not represent the status of the OSSD3 and OSSD4 electrical outputs.



Note: OSSD is just a Hokuyo acronym for their programmable switching output, and stands for Output Signal Switching Device.

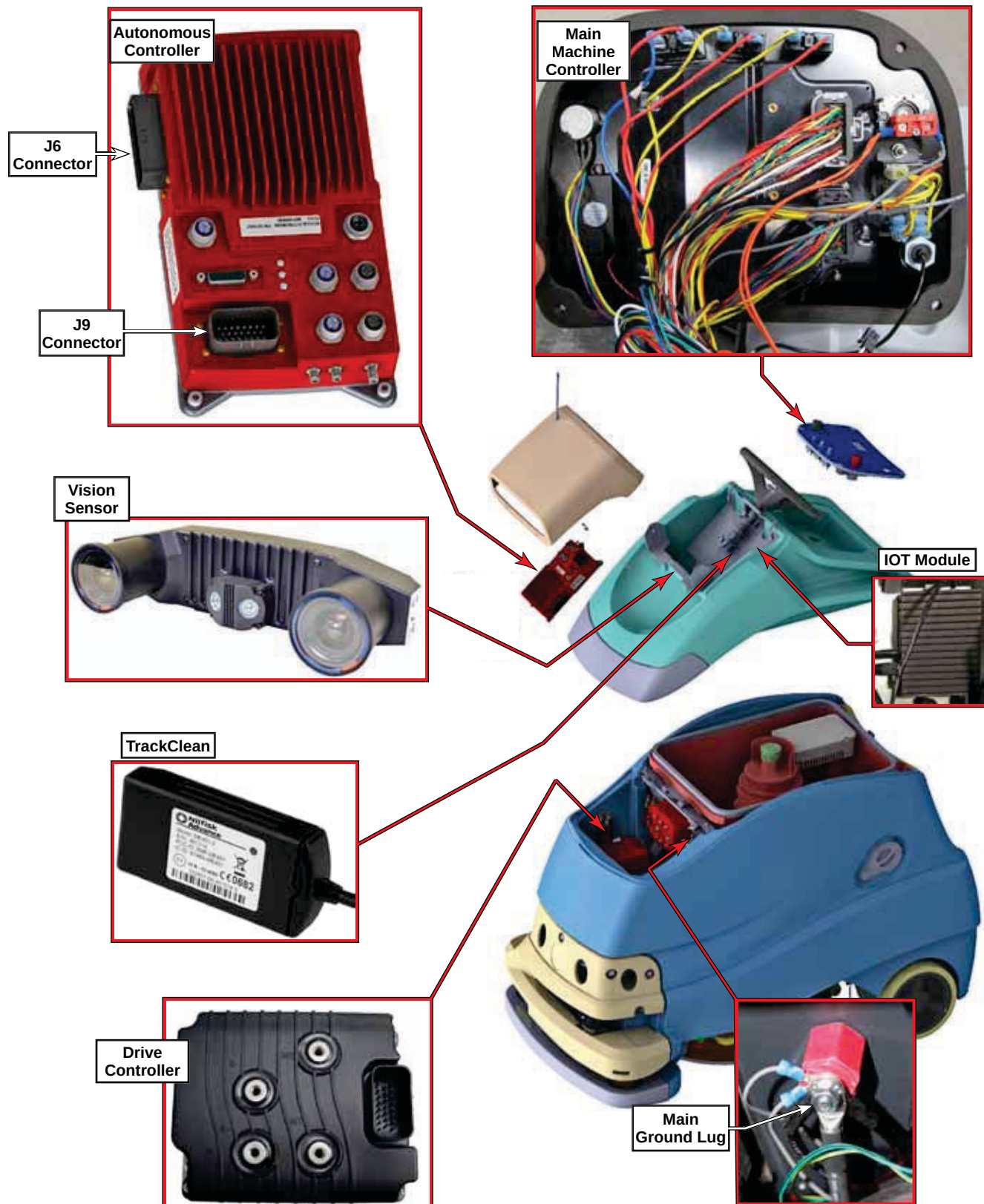
LED	Output	Function	Comment
OSSD1/2	OSSD1	Protection Zone	Green LED and 24 volts on the outputs when the protection zone is clear. Red LED and 0 volts on the outputs when the protection zone is breached. There is only 1 protection zone, but it uses redundant outputs for error detection.
	OSSD2		
OSSD3/4	None	Not used	LED is always green. This isn't used because only 1 protection zone exists. The unused protection zone is replaced by the 2 warning zones described below.
Warning1	OSSD3	Warning 1 (Travel)	LED off and 24 volts on OSSD3 when the warning zone is clear. Orange LED and 0 volts on OSSD3 when the warning zone is breached. This warning zone is looking forward to see where the machine will be traveling.
Warning2	OSSD4	Warning 2 (Wheel)	The LED is always orange and the voltage on OSSD4 is always 0 volts, as long as the laser can see the rear corner of the machine. This zone is the same for all 32 areas.
Interlock1	None	Not used	LED always off. The interlock function is not utilized in this configuration. So these LEDs should never be active.
Interlock2	None	Not used	

Master-Slave Communication

The two safety sensors are semi-independent, but they share area address information. This means that the autonomous controller only has to tell the master sensor (left laser) which area number is of interest, and that laser will subsequently pass that information on to the slave laser (right laser) through a private RS-485 serial connection. This reduces the number of wires required to pass between the autonomous controller and safety sensors.

However, each sensor still reports back to the autonomous controller using its own dedicated “Warning” and “Protection” signal lines.

Component Locations



Maintenance and Adjustment

Wheel Encoder Gap

Use this procedure to troubleshoot wheel encoder errors and dropouts, and to check/adjust the wheel encoder gap.

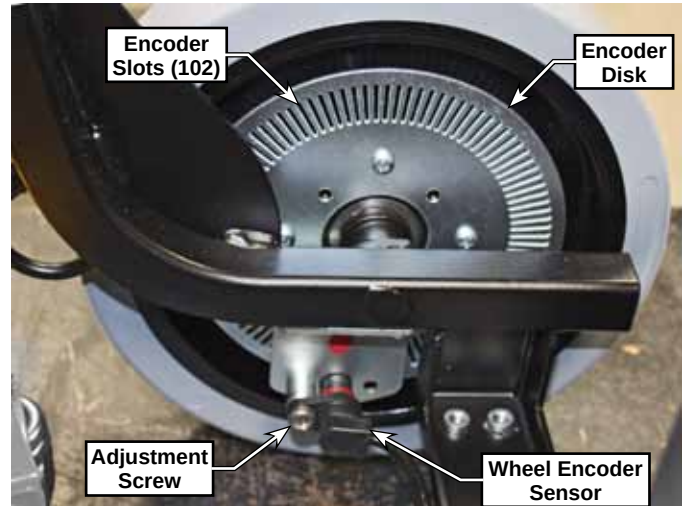
1. Remove the [Operator Platform](#) described on page 261.

2. Slightly raise the rear of the machine, just enough to permit the real wheels to turn freely.

3. While observing a fixed point on the chassis (such as the tip of the encoder) turn the wheel by hand and check for damage, deflection, or bends in the encoder disk.
 - Repair or replace the encoder disk if it is damaged or bent.

4. Check the wheel bearings for lateral slop.
 - Replace the wheels if the bearings are showing signs of wear.

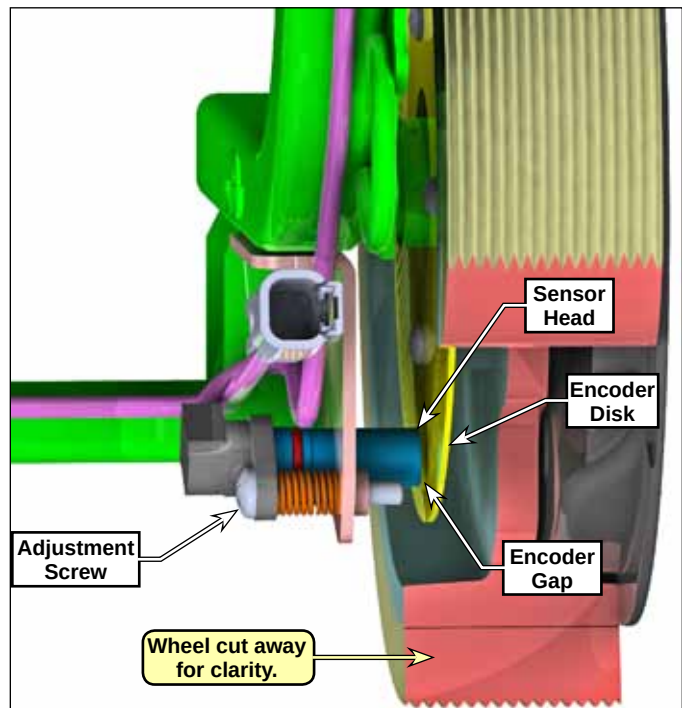
5. Clean and inspect the encoder sensor head and encoder disk for debris, especially metallic debris.



6. Using a feeler gauge or other appropriate gapping tool, measure the gap between the sensor head and the encoder disk.

- a. Repeat the measurement at several locations while rotating the wheel.
 - Make sure that no locations have a gap that exceeds 1.5 mm (0.060").
 - Set the typical gap to 0.25 to 1.5 mm (0.010 to 0.060 inch).
 - If encoder count dropouts are a problem, the gap may be reduced, but make sure the sensor head will not contact the encoder disk at any point.

7. As necessary, adjust the sensor position to achieve the proper gap, as described above.
 - Tighten the adjustment screw to reduce the gap.
 - Loosen the adjustment screw to increase the gap.



8. Lower the machine back to the ground, and confirm the gap measurement with weight on the wheels.

9. Reinstall the operator platform.

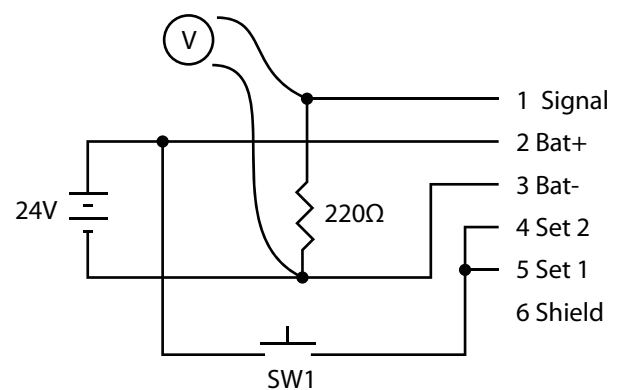
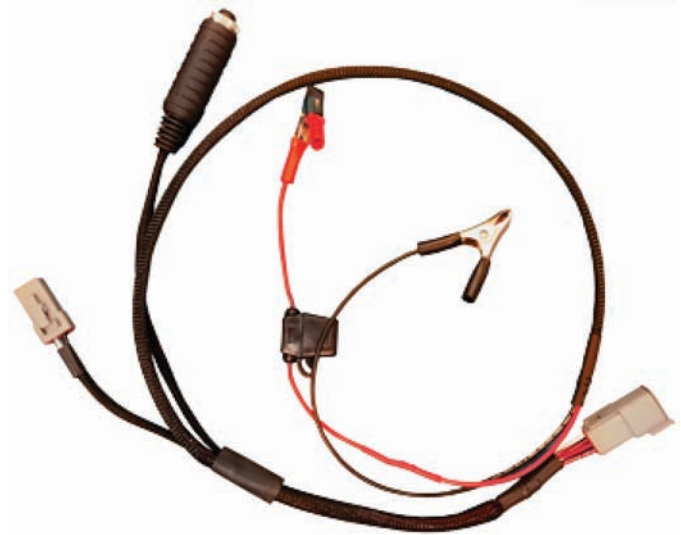
10. For further confirmation, perform the [Wheel Encoder Gap](#) described on page 106.

Drive Wheel Angle Sensor Centering

The steering controller calculates the drive wheel position based on the number of revolutions the motor's rotor has made and the gear ratio between the motor and the drive wheel (including the steering chain). This is sufficient for human/manual control, but is not sufficient for autonomous operation. The drive wheel angle sensor tells the Autonomous controller what the actual front wheel steering angle is, without any calculation required.

It is important for proper operation that these two position determination methods are in agreement. The drive wheel angle sensor is an intelligent-type encoder, and this procedure resets the center-position of the encoder to match the center position of the steering controller.

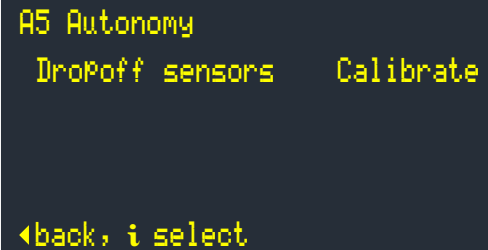
1. Reboot the machine (with service mode access) to force the steering controller to re-home the drive wheel, and detect the home position sensor.
2. Navigate to the A4 Steering Controller menu, and observe the "Position Actual" entry.
3. Turn the steering wheel until the "Position Actual" entry reads 0.
4. Without moving the steering wheel, turn the machine off.
5. Connect the Reset Cable (Part number 56122727) to battery power. For convenience, you can use the main ground lug and K2 relay post in the electrical bay. Otherwise, directly to the machine battery.
6. Unplug the electrical connector to the Drive Wheel Angle Sensor, and connect the Reset Cable to the sensor.
7. If you want confirmation of the reset, connect a voltmeter to the test port of the reset cable.
8. Press and hold the reset button for about 2 seconds.
9. After the reset, the voltage from the test port should be equal (or very close, depending on your meter) to 2.6 volts.
10. Disconnect the Reset Cable, reconnect the sensor, and re-power the machine.



Drop-off Sensor Calibration

Perform whenever a drop-off sensor has been replaced, if the mounting bracket is replaced or has been disturbed or if there is an unexplainable safety system fault code.

1. Move the machine to an area with a flat floor, which remains flat from the rear wheels of the machine and forward to include all 4 laser dots from the dropoff sensors shining on the floor.
2. Go to the Main menu, Service menu, A5 Autonomy menu, and select “Calibrate Dropoff Sensors”.



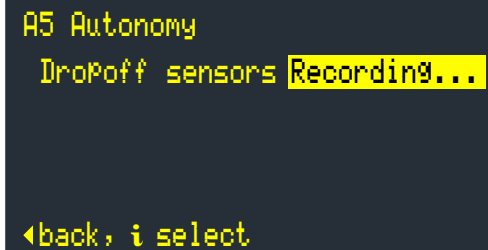
```
A5 Autonomy
DropOff sensors  Calibrate

◀back, i select
```

3. Make sure all four lasers are unobstructed and are striking their typical position on the floor.

4. Press the information button on the display to initiate the calibration.

5. The display will indicate that the Autonomy module is recording the dropoff laser outputs.



```
A5 Autonomy
DropOff sensors Recording...

◀back, i select
```

6. When the “Recording” message clears and returns to the previous display, the calibration is complete.

7. To avoid potential data errors, reboot the machine, as follows:

- a. Power down the machine.
- b. Wait for an additional 15 seconds after the dropoff sensors turn off, to ensure a complete power-down.
- c. Reboot the machine.

8. After the machine is started and the Autonomy module fully booted, check for fault codes:

- a. Navigate to the Service, Fault Codes menu.
- b. Verify that no adverse drop-off sensor fault codes have been set.
- c. Fault code “5-F4A6--Dropoff Calib OK” is acceptable and normal.

3D Vision Sensor (Camera) Calibration

This calibration is an alignment of what the 3D vision sensor sees and what the 2D mapping sensor sees. It must be performed whenever either of the sensors has been replaced or their position has been disturbed.

1. Move the machine to an area with an inside corner at 90 degrees (as shown). The walls should be vertical, unbroken, and at least as tall as the machine. If you cannot find a clear building corner to use, you can construct a corner out of 2 pieces of thick cardboard. Each piece should be approximately 1 meter (3 feet) tall and at least 70 cm (2 feet) wide. Use wide tape to create a hinge joint between the two pieces and stand



the joined pieces up forming a 90 degree inside corner in front of the machine.

2. Park the machine facing directly into the corner, and approximately 7 to 10 feet (2-3 m) from the corner to the front bumper.
3. Go to the Main menu, Service menu, Autonomy menu, and select “Calibrate Camera”.
4. Press the “i” button on the display to initiate the calibration.
5. The display will indicate that the Autonomy module is processing the camera and mapping laser outputs.
6. When the “Processing” message clears and returns to the previous display, the calibration is complete.
 - For additional confirmation, you may check for Autonomy Controller code 5-F4A5....3D Sens Calib OK.

```
A5 Autonomy
Camera           Calibrate
◀back, i select
```

```
A5 Autonomy
Camera           Processing...
◀back, i select
```

2D Mapping (Sensor) Laser Calibration

This item may exist in the menu of some software versions, but it is not used.

2D Mapping Sensor Level Check and Adjust

Checking Laser Level

For proper operation, the laser must be accurately leveled with respect to the machine. This must be checked and adjusted if the sensor or its mounting bracket have been replaced.

The level adjustment is accomplished by placing the machine on a flat floor surface, and measuring the height of the laser beam at 3 positions around the machine.

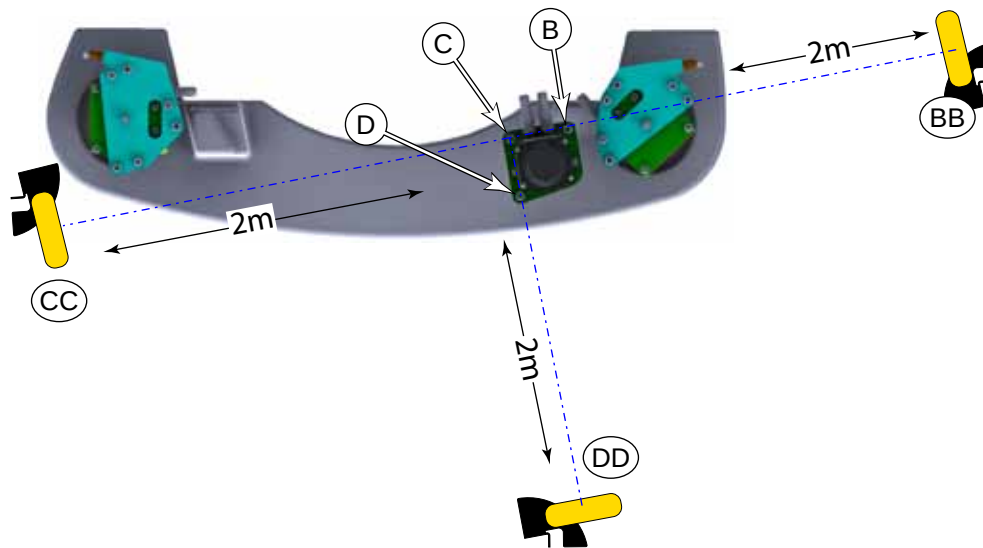
This procedure requires the laser calibration kit (56122718).

1. Park the machine in an open area with a flat, level floor at least 7 feet (2 meters) out from the left, front, and right sides of the machine.
2. Setup the laser detector on the stand, as shown.
3. Adjust the height of the detector on the stand so that the “On-Grade” mark is near, but not exactly at, 11.6” (295 mm) from the floor.
 - To avoid confusion when comparing the 3 different height measurements later in the procedure, you want to intentionally set the on-grade mark 1/2” to 1” (12 to 25 mm) above or below the actual laser height. This way, you won’t have a mix of “above” and “below” grade measurements.
4. Cover the anti-strobe sensor with a piece of tape



5. Press the power button on the detector to turn the detector on. Make sure the detector cannot see any laser beam when first turned on, or it will display an error message.
6. Press the units button as necessary to set the units to “mm” (millimeter).
7. Press the accuracy button as necessary to set the accuracy to the 1-mm range. (3 bars are displayed between the accuracy arrows.)
8. Cover the two safety sensors to avoid interference with the laser detector.

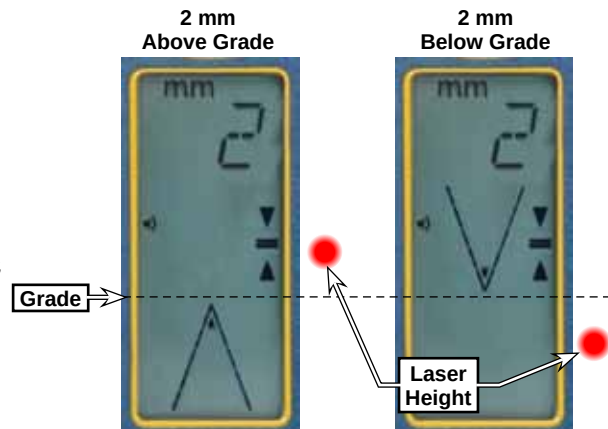
9. To make the adjustments easier, the height measurement locations should be approximately in line with the adjustment screws, as shown below. In this manner, for example, if measurement location **(BB)** is low, then it directly translates to raising adjustment screw **(B)**.



10. Mark the measurement positions **(BB)**, **(CC)**, **(DD)** on the floor, 2 meters from the laser.
11. Move the detector stand to each of the three positions, and record the height of the laser beam from each position. It is recommended that you draw a diagram of the 3 positions and write down the measurements.

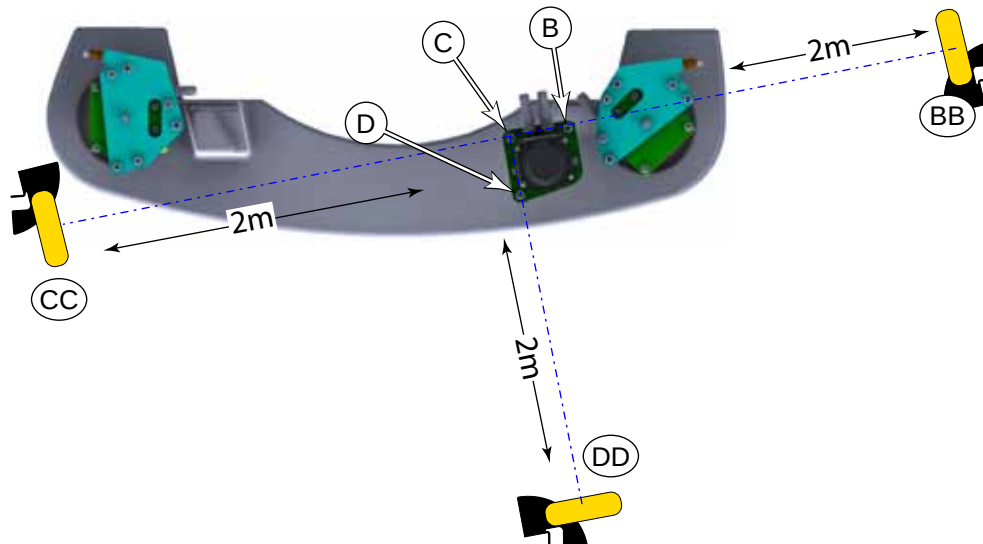
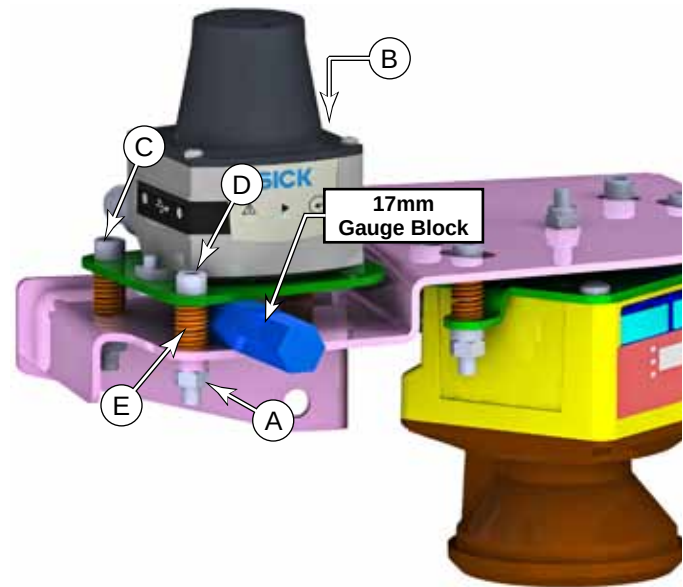
Measurement Interpretation

- The display on the laser detector indicates the distance between where the laser beam was detected and the grade mark on the instrument. It also indicates whether the laser was above the grade mark or below the grade mark.
- For the purpose of leveling Liberty SC50 lasers, the “On-Grade” function of the HL450 laser detector isn’t specifically needed nor desired. To avoid working with a mix of positive and negative measurements, you want to raise or lower the detector so that all of your measurements are either “above grade” or “below grade”.
- The goal of the procedure is to have all 3 measurement heights within $\pm 2\text{mm}$ of each other.
 - If the laser heights at all 3 positions are within $\pm 2\text{mm}$ of each other, then no adjustment is necessary and you may stop.
 - If any height measurement is greater than 2mm away from another height measurement, then adjust the laser level described on the next page.



Adjusting Laser Level

1. Before making adjustments, use the 17mm (11/16") gauge block to verify/set each of the 3 adjustment screws to their neutral position.
 - a. Loosen the 3 jamb nuts **(A)** at the bottom of the laser adjustment screws.
 - b. Loosen the adjustment screw **(B, C, D)** as needed and place the gauge block adjacent to each of the 3 tension springs **(E)**.
 - c. Temporarily tighten the adjustment screw until the gauge block is slightly snug between the brackets.
2. Re-measure the laser height at the three positions.
3. Adjust the **(BB)**-to-**(CC)** level first. Compare the height readings from the **(BB)** and **(CC)** locations of the laser detector.
 - If the **(BB)** position is more than 2mm higher than the **(CC)** position, tighten screw **(B)**
 - If the **(BB)** position is more than 2mm lower than the **(CC)** position, loosen screw **(B)**.
4. Adjust the **(DD)** position to match the **(BB)** and **(CC)** heights.
 - If the **(DD)** position is lower than both the **(BB)** and **(CC)** positions, loosen screw **(D)**.
 - If the **(DD)** position is higher than both the **(BB)** and **(CC)** positions, tighten screw **(D)**.



5. While holding each respective adjustment screw from turning, re-tighten the 3 jamb nuts. This may affect the level adjustment so, recheck the level and adjust as necessary.
6. After the laser has been leveled, perform the [3D Vision Sensor \(Camera\) Calibration](#) described on page 109

Left Safety Sensor Level Check and Adjust

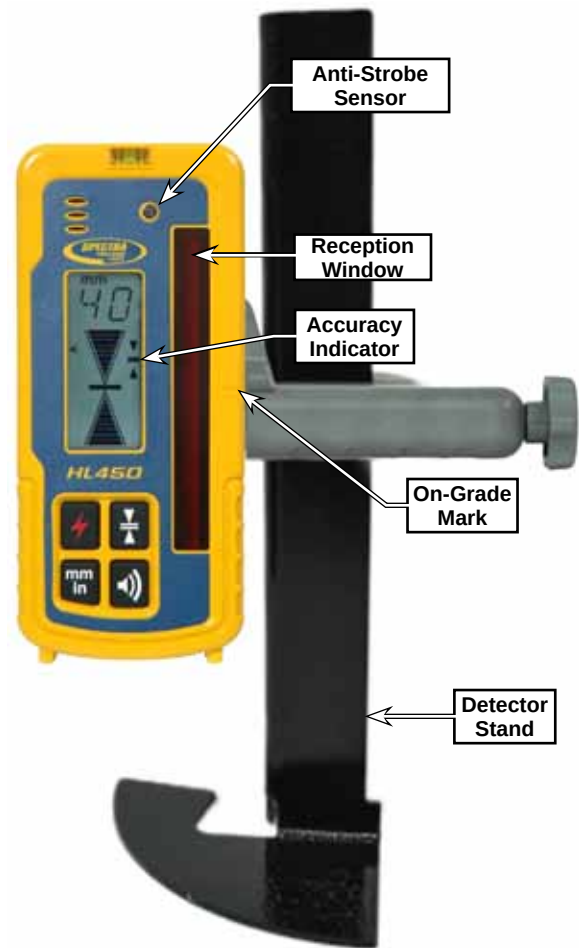
Checking Laser Level

For proper operation, the laser must be accurately leveled with respect to the machine. This is accomplished by placing the machine on a flat floor surface, and measuring the height of the laser beam at 3 positions around the machine.

If the sensor or mounting bracket is replaced, both the level and rotational adjustments must be performed.

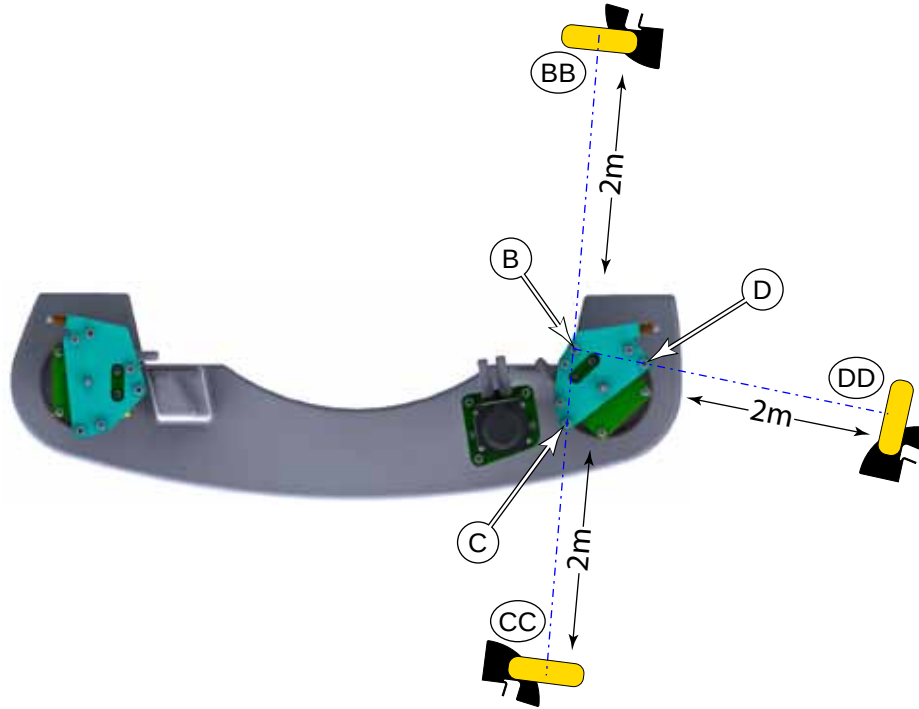
This procedure requires the laser calibration kit (56122718).

1. Perform the [Safety Sensor Rotational Position Check \(Right and Left\)](#) described on page 121 before completing this procedure.
2. Setup the laser detector on the stand, as shown.
3. Adjust the height of the detector on the stand so that the “On-Grade” mark is near, but not exactly at the height of the laser
 - To avoid confusion when comparing the 3 different height measurements later in the procedure, you want to intentionally set the on-grade mark 1/2” to 1” (12 to 25 mm) above or below the actual laser height. This way, you won’t have a mix of “above” and “below” grade measurements.
4. Cover the anti-strobe sensor with a piece of tape



5. Press the power button on the detector to turn the detector on. Make sure the detector cannot see any laser beam when first turned on, or it will display an error message.
6. Press the units button as necessary to set the units to “mm” (millimeter).
7. Press the accuracy button as necessary to set the accuracy to the 1-mm range. (3 bars are displayed between the accuracy arrows.)
8. Cover the right safety sensor and mapping sensor to avoid interference with the laser detector.

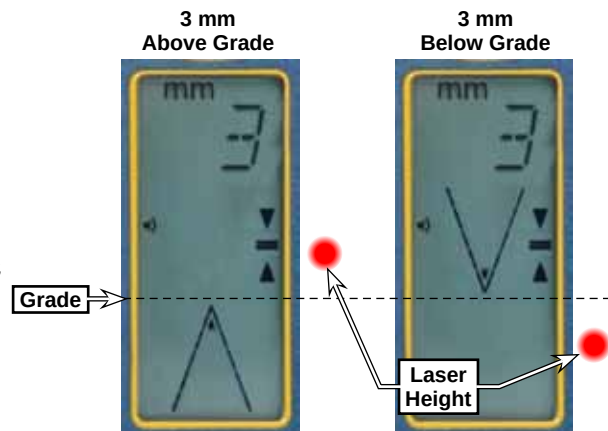
9. Mark the measurement positions **(BB)**, **(CC)**, **(DD)** on the floor at 2 meters from the sensor .
 - To make the adjustments easier, the height measurement locations should be approximately in line with the adjustment screws **(B, C, D)**, as shown below. In this manner, for example, if measurement location **(BB)** is low, then it directly translates to raising adjustment screw **(B)**. Note that position **BB** needs to outboard far enough that the laser is not blocked by the machine body.



10. Move the detector stand to each of the three positions, and record the height of the laser beam from each position. It is recommended that you draw a diagram of the 3 positions and write down the measurements.

Measurement Interpretation

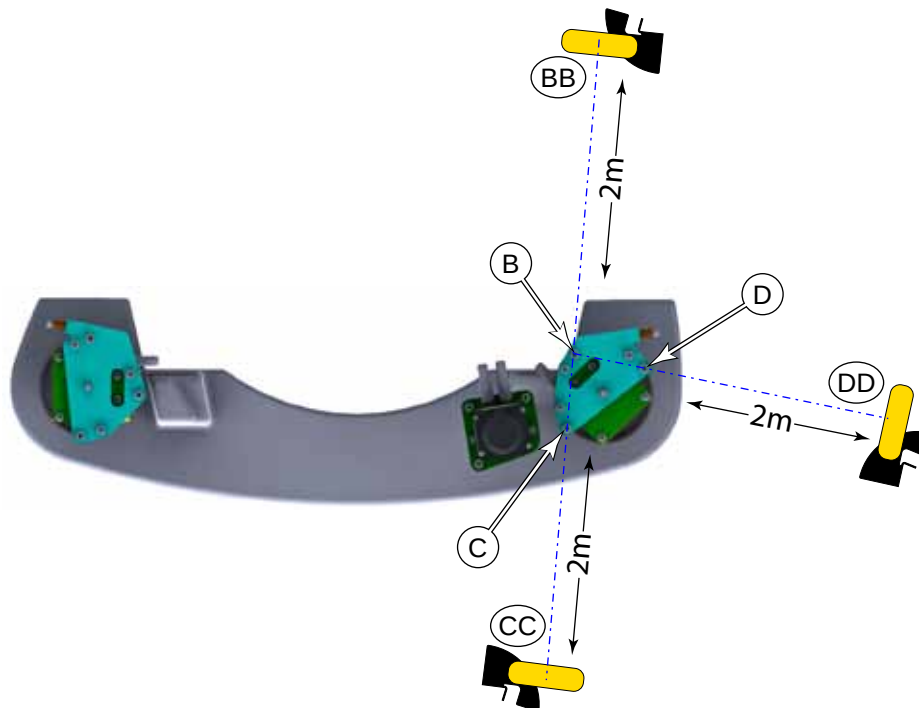
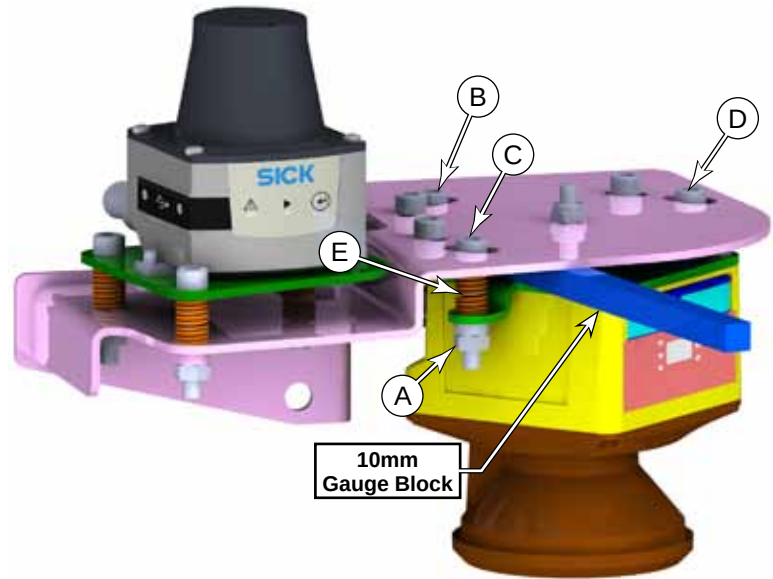
- The display on the laser detector indicates the distance between where the laser beam was detected and the grade mark on the instrument. It also indicates whether the laser was above the grade mark or below the grade mark.
- For the purpose of leveling Liberty SC50 lasers, the “On-Grade” function of the HL450 laser detector isn’t specifically needed nor desired. To avoid working with a mix of positive and negative measurements, you want to raise or lower the detector so that all of your measurements are either “above grade” or “below grade”.



- The goal of the procedure is to have all 3 measurement heights within $\pm 3\text{mm}$ of each other.
 - If the laser heights at all 3 positions are within $\pm 3\text{mm}$ of each other, then no adjustment is necessary and you may stop.
 - If any height measurement is greater than 3mm away from another height measurement, then adjust the laser level described on the next page.

Adjusting Laser Level

1. Before making adjustments, use the 10 mm (3/8") gauge block to verify/set each of the 3 adjustment screws to their neutral position.
 - a. Loosen the 3 jamb nuts (**A**) at the bottom of the laser adjustment screws.
 - b. Loosen the adjustment screw (**B**, **C**, **D**) as needed, and place the gauge block adjacent to each of the 3 tension springs (**E**).
 - c. Temporarily tighten the adjustment screw until the gauge block is slightly snug between the brackets.
2. Adjust the (**BB**)-to-(**CC**) level first. Compare the height readings from the (**BB**) and (**CC**) locations of the laser detector.
 - If the (**BB**) position is more than 3mm higher than the (**CC**) position, tighten screw (**B**).
 - If the (**BB**) position is more than 3mm lower than the (**CC**) position, loosen screw (**B**).
3. Adjust the (**DD**) position to match the (**BB**) and (**CC**) heights.
 - If the (**DD**) position is lower than both the (**BB/CC**) positions, loosen screw (**D**).
 - If the (**DD**) position is higher than both the (**BB/CC**) positions, tighten screw (**D**).



4. While holding each respective adjustment screw from turning, re-tighten the 3 jamb nuts. This may affect the level adjustment so, recheck the level and adjust as necessary.

Right Safety Sensor Level Check and Adjustment

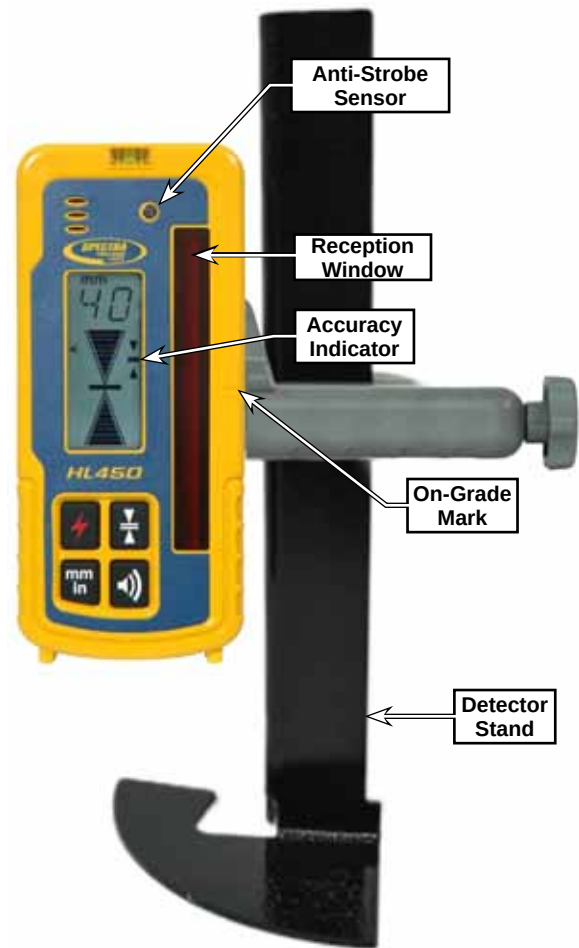
Checking Laser Level

For proper operation, the laser must be accurately leveled with respect to the machine. This is accomplished by placing the machine on a flat floor surface, and measuring the height of the laser beam at 3 positions around the machine.

If the sensor or mounting bracket is replaced, both the level and rotational adjustment must be performed.

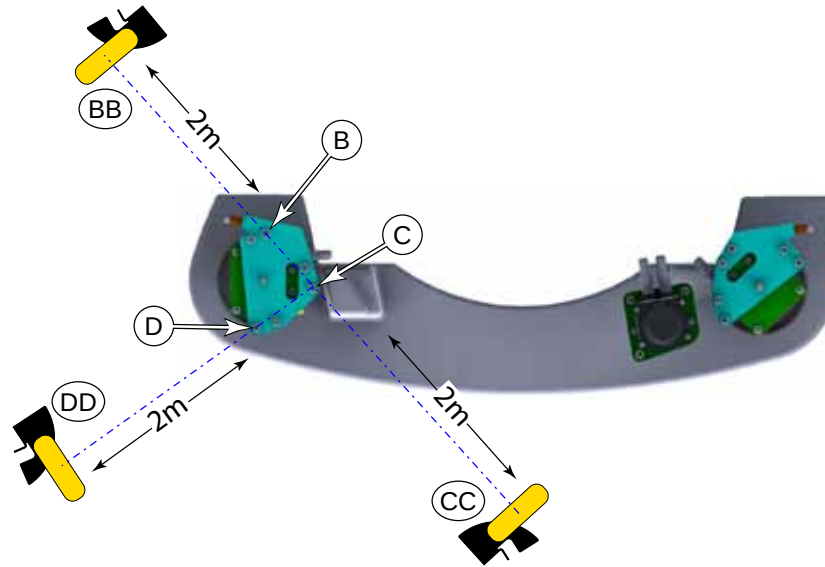
This procedure requires the laser calibration kit (56122718).

1. Perform the [Safety Sensor Rotational Position Check \(Right and Left\)](#) described on page 121 before completing this procedure.
2. Setup the laser detector on the stand, as shown.
3. Adjust the height of the detector on the stand so that the “On-Grade” mark is near, but not exactly at the height of the laser
 - To avoid confusion when comparing the 3 different height measurements later in the procedure, you want to intentionally set the on-grade mark 1/2” to 1” (12 to 25 mm) above or below the actual laser height. This way, you won’t have a mix of “above” and “below” grade measurements.
4. Cover the anti-strobe sensor with a piece of tape



5. Press the power button on the detector to turn the detector on. Make sure the detector cannot see any laser beam when first turned on, or it will display an error message.
6. Press the units button as necessary to set the units to “mm” (millimeter).
7. Press the accuracy button as necessary to set the accuracy to the 1-mm range. (3 bars are displayed between the accuracy arrows.)
8. Cover the left safety sensor and mapping sensor to avoid interference with the laser detector.

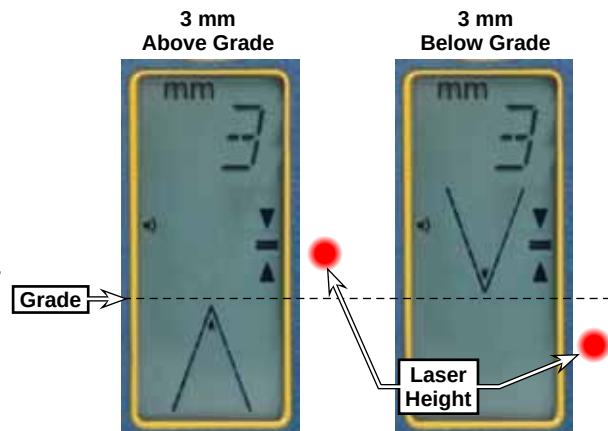
9. Mark the measurement positions **(BB)**, **(CC)**, **(DD)** on the floor at 2 meters from the sensor.
 - To make the adjustments easier, the height measurement locations should be approximately in line with the adjustment screws **(B, C, D)**, as shown below. In this manner, for example, if measurement location **(BB)** is low, then it directly translates to raising adjustment screw **(B)**.



10. Move the detector stand to each of the three positions, and record the height of the laser beam from each position. It is recommended that you draw a diagram of the 3 positions and write down the measurements.

Measurement Interpretation

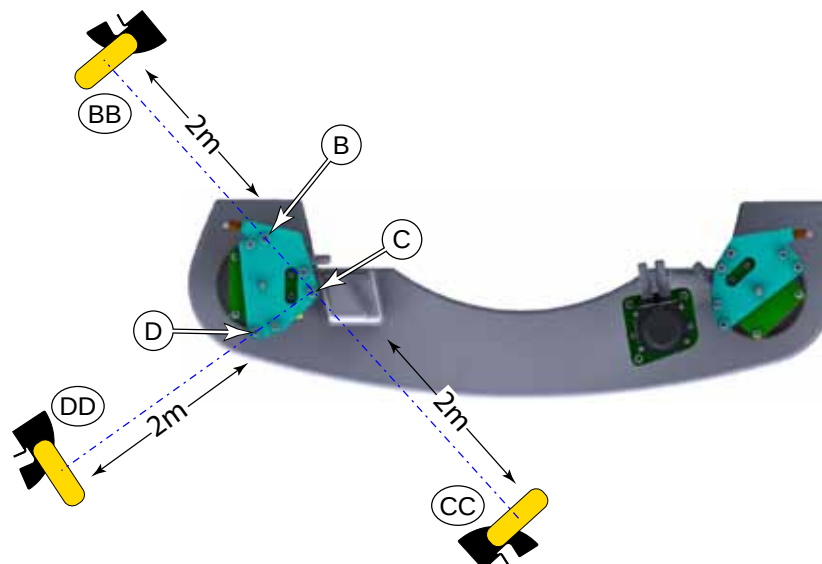
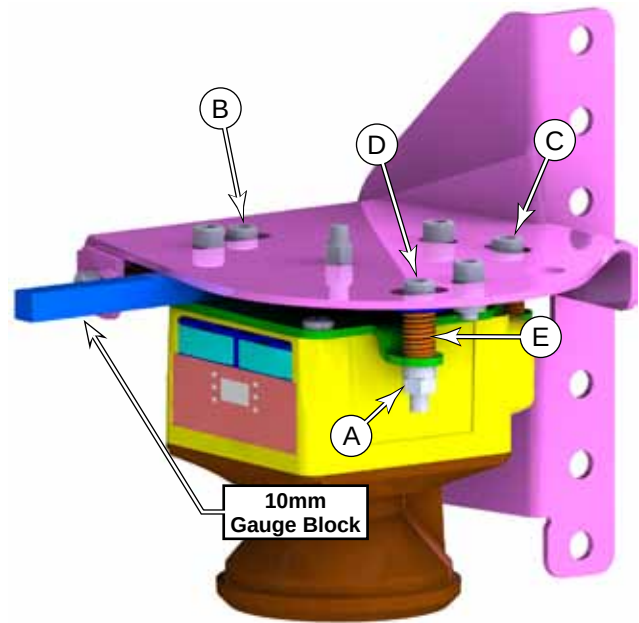
- The display on the laser detector indicates the distance between where the laser beam was detected and the grade mark on the instrument. It also indicates whether the laser was above the grade mark or below the grade mark.
- For the purpose of leveling Liberty SC50 lasers, the “On-Grade” function of the HL450 laser detector isn’t specifically needed nor desired. To avoid working with a mix of positive and negative measurements, you want to raise or lower the detector so that all of your measurements are either “above grade” or “below grade”.



- The goal of the procedure is to have all 3 measurement heights within $\pm 3\text{mm}$ of each other.
 - If the laser heights at all 3 positions are within $\pm 3\text{mm}$ of each other, then no adjustment is necessary and you may stop.
 - If any height measurement is greater than 3mm away from another height measurement, then adjust the laser level described on the next page.

Adjusting Laser Level

1. Before making adjustments, use the 10 mm (3/8") gauge block to verify/set each of the 3 adjustment screws to their neutral position.
 - a. Loosen the 3 jamb nuts **(A)** at the bottom of the laser adjustment screws.
 - b. Loosen the adjustment screw **(B, C, D)** as needed, and place the gauge block adjacent to each of the 3 tension springs **(E)**.
 - c. Temporarily tighten the adjustment screw until the gauge block is slightly snug between the brackets.
2. Adjust the **(BB)-to-(CC)** level first. Compare the height readings from the **(BB)** and **(CC)** locations of the laser detector.
 - If the **(BB)** position is more than 3mm higher than the **(CC)** position, tighten screw **(B)**.
 - If the **(BB)** position is more than 3mm lower than the **(CC)** position, loosen screw **(B)**.
3. Adjust the **(DD)** position to match the **(BB)** and **(CC)** heights.
 - If the **(DD)** position is lower than both the **(BB/CC)** positions, loosen screw **(D)**.
 - If the **(DD)** position is higher than both the **(BB/CC)** positions, tighten screw **(D)**.



4. While holding each respective adjustment screw from turning, re-tighten the 3 jamb nuts. This may affect the level adjustment so, recheck the level and adjust as necessary.

Right Safety Sensor - Check Maximum Laser Height

The right safety sensor laser beam height must be no higher than 190 mm when measured at the center line of the rear wheel axle. If the beam is too high, the sensor bracket must be moved to a lower position on the solution tank. This procedure explains how to check the laser beam height.

1. Setup the laser detector on the stand next to the right rear wheel in line with the axle.
2. Adjust detector height so that it reads 0

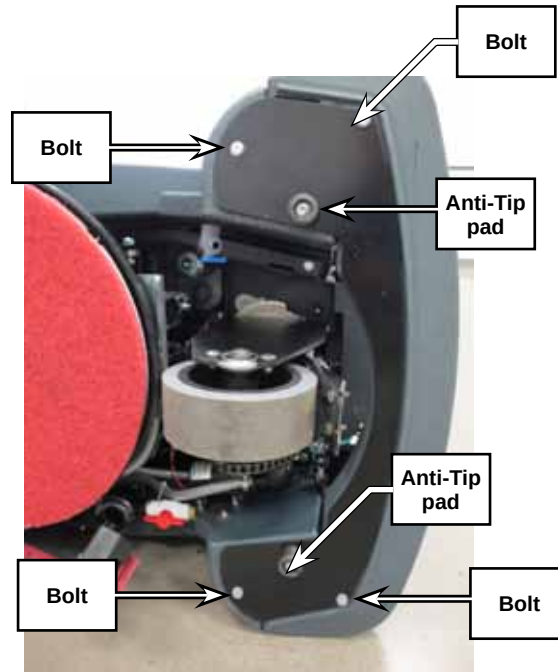


3. Measure distance from floor to on grade mark on the detector.
 - a. If it is <190 mm (7.48 inches) the minimum height is okay.
 - b. If it is >190 mm (7.48 inches), the height is too high. Go to the next step to adjust the height.
4. Mark the current position of the right safety sensor mounting bracket on the machine.
5. If the front bumper interferes with the removal of the front lower mounting bolt, you will have to loosen the front bumper from the machine using the following steps. If not, skip to removing the bracket attaching bolts.
6. Drain the solution and recovery tanks.
7. Remove the batteries.
8. Tip the machine on its left side to gain access to the front lower bumper fasteners.



Note: Use cardboard or a suitable material between the machine and the floor to prevent scratching the machine.

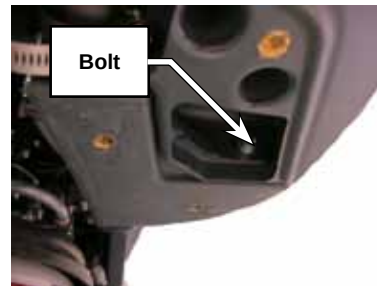
9. Remove the two anti-tip pads and 4 bolts which secure the metal plate under the front bumper, then remove the plate.



10. Remove the two bolts which attach the front bumper to the solution tank. There is one on each side.



Right Side



Left Side

11. Remove the right safety sensor bracket attaching bolts and remove the bracket with the sensor attached.



Note: Tip the front bumper down a bit with hand pressure to provide clearance to remove the front lower bracket attaching bolt

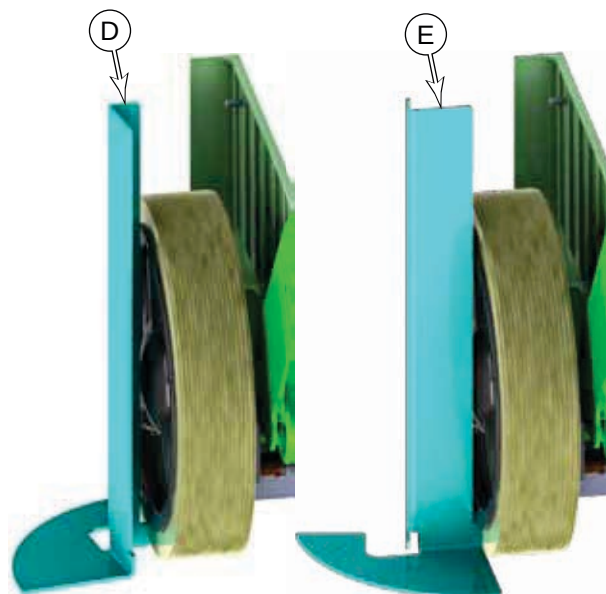
12. Move the bracket down one set of holes, reinstall and tighten attaching bolts.
13. Reassemble in reverse order.
14. When finished **recheck the right safety sensor laser beam height, rotational position and level adjustments**. Adjust as required.



Note: After adjustments you must perform the Dynamic Safety System Test Of Safety Sensors.

Safety Sensor Rotational Position Check (Right and Left)

1. Turn the steering wheel toward the straight ahead position.
2. Place the laser detector stand (from laser kit 56122718) against the applicable rear wheel with the stand in the **narrow** direction **(D)** at the center line of the axle. Note the warning 1 LED status.
3. Place the stand in the **wide** direction **(E)** at the center line of the axle. Note the warning 1 LED status.
4. The warning 1 LED should be off and the OSSD 1/2 illuminated green with the stand in the narrow direction (D). The warning 1 LED should be illuminated orange and the OSSD 1/2 illuminated red with the stand in the wide direction (E). If this is true, the rotational position is correct and does not require adjustment. If not true, proceed to the safety sensor rotation position adjustment.



Condition	Expected LED States
Stand in narrow position (Or no stand) 	 Warning 1 = Off OSSD 1/2 = Green
Stand in wide position 	 Warning 1 = Orange OSSD 1/2 = Red

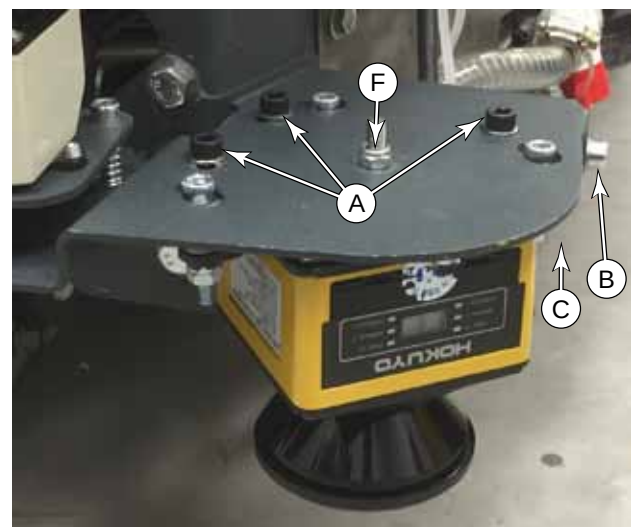
Safety Sensor Rotational Position Adjustment

Because the safety sensors utilize pre-programmed zones to determine where they should be scanning as the machine travels, it is important that they be oriented correctly with respect to the machine. To ensure that the zones are pointing in the right direction, each zone looks back toward the rear corner of the machine. If the rear wheel of the machine is seen in the area of warning zone 2, Warning 2 is triggered as a confirmation for the Autonomous controller to see and the warning 2 LED on the sensor is illuminated orange.

This adjustment is accomplished by using the laser detector stand as a gauge and monitoring the LED states on the sensor. It must be done if the sensor or its mounting bracket is replaced.



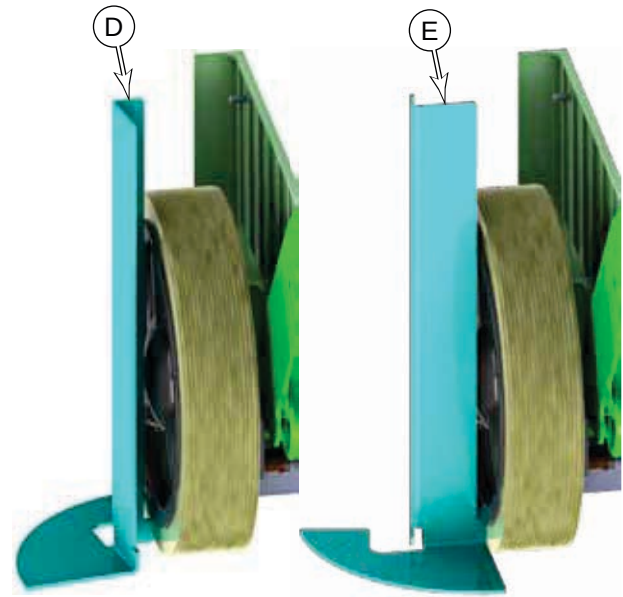
1. Remove the 4 screws and washers that secure the front nose to the recovery tank, and remove the front nose.
2. Power the machine and make sure the safety sensors are active.
3. Turn the steering wheel toward the straight ahead position. Area address 08 should be displayed on each safety sensor.
4. For each sensor, slightly loosen the 3 mounting screws (**A**), the center pivot nut (**F**) and the adjustment lock nut (**C**).



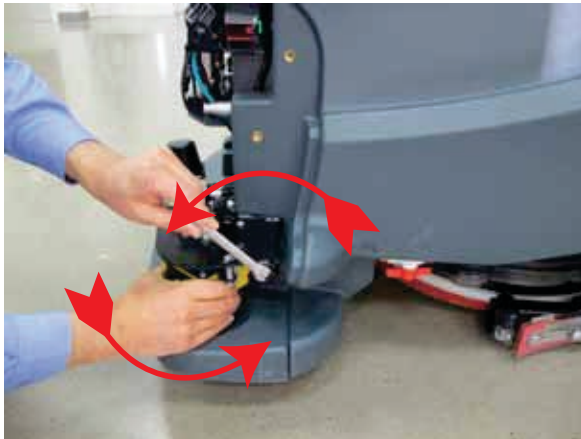
5. Place the laser detector stand (from laser kit 56122718) against the applicable rear wheel with the stand in the narrow direction **(D)** at the center line of the axle.



Note: For these next steps, keep your body and tools away from the sensor laser when observing the LED status to prevent false triggering of the LEDs.



6. Turn the adjustment screw **(B)** counterclockwise until the Warning 1 LED illuminates orange and the OSSD 1/2 LED illuminates red. (You may have to help the sensor rotate using hand pressure.) Give the screw at least 1-full turn more so it's past the transition.



Left Side



Right Side



7. Slowly turn the adjustment screw **(B)** clockwise until the Warning 1 LED turns off and the OSSD 1/2 LED illuminates green, and then another 1/2-turn.



Left Side



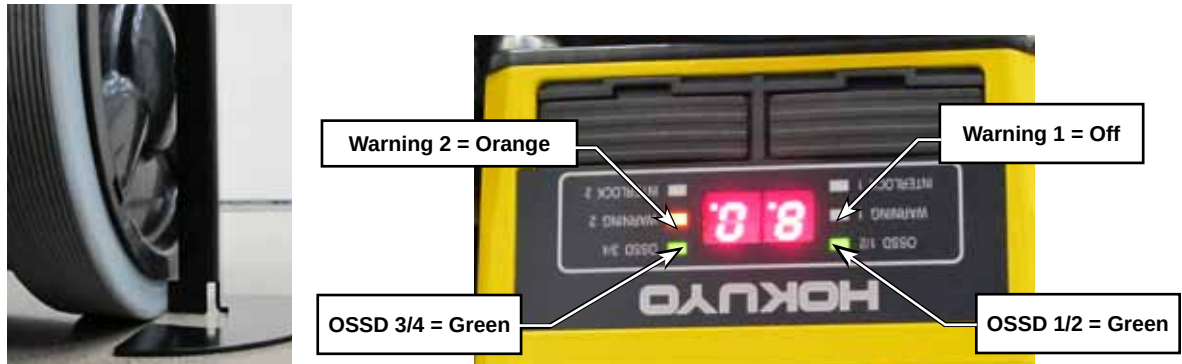
Right Side



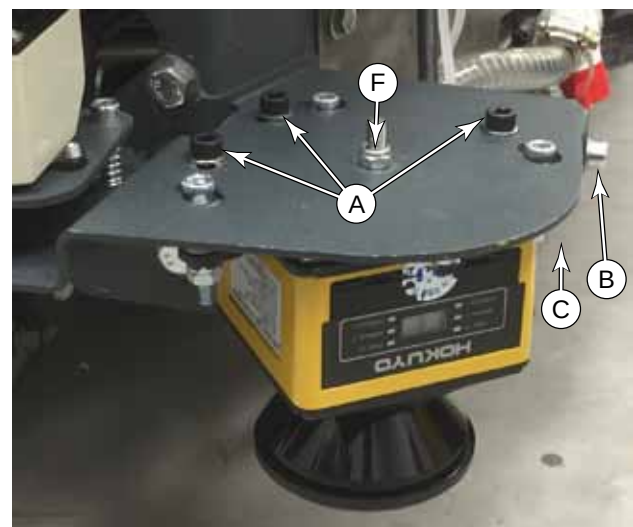
8. Rotate the laser detector stand to the wide position **(E)**, and verify that the Warning 1 LED illuminates orange and the OSSD 1/2 illuminates red.



9. Remove the laser detector stand, and verify that the Warning 2 LED illuminates orange, Warning 1 LED is off. (both OSSD 1/2 and 3/4 LEDs illuminate green).
 - That is, Warning 1 sees the stand in the wide position, but not the narrow position, and Warning 2 always detects the rear wheel.



10. Retighten the 3 mounting screws (A), the center pivot nut (F) and the adjustment lock nut (C).



Autonomous Controller and Main Machine Controller Software Update

Because the Autonomous controller and main machine controller interact with one another their software (also known as firmware) must be compatible with one another. Consequently, when updating the autonomous controller, firmware for the main controller is also downloaded to the machine. After updating the autonomous controller, at the next power on cycle, in user or supervisor access mode, if the main machine controller requires an update it will automatically initiate the update of the MMC.

The update process is done in two steps. First, you download the files. Second you install the update. The download normally takes through the IOT module cellular network connection. If that is unable to work, it is possible to use the “Connect to WiFi” feature to download the files, but that will require one on one assistance from a Nilfisk representative.

SOFTWARE UPDATE

```
Connect to WiFi
Download Update
Install Update
```

```
◀back, i select
```

Downloading and Installing software updates

1. Power on the machine into the supervisor mode using the yellow key or into the service mode.
2. Make sure the machine has Internet access.
3. Press the information button to access the main menu. Select “Software Update.”
4. Press the up or down arrow to select Download Update. Press the information button to select.
5. Press the up or down arrow to select Yes, and then press the information button to start the download.
6. Wait for the download to complete. (Typically this may take approximately 15 minutes). When finished you should see the message “Ready to Install.”
7. After the download is complete, back up and navigate to Install Update. Press the information button to select.
8. Press the up or down arrow to select Yes, and then press the information button to start the installation. When finished you should be prompted to turn the machine off and back on to finish the installation process.
9. After installation is complete, perform a sequence of rebooting processes to ensure proper application of the updates:
 - a. Power down the machine in a normal manner, and wait 15 seconds after the drop-off sensors have turned off.
 - b. Re-boot the machine in a normal manner without Service Mode access.
 - c. Allow the Autonomous controller to full boot up. If necessary, press the Autonomy Help button to view the progress.
 - d. Repeat this same boot-up sequence one more time. On the second reboot, the boot process may hesitate for about 10 seconds during the process.
10. After the 2 reboots are complete, both the Autonomy and Main Machine controllers will be up to date

```
SOFTWARE UPDATE
Connect to WiFi
Download Update
Install Update
◀back, i select
```

```
SOFTWARE UPDATE
Connect to WiFi
Download Update
Install Update
◀cancel, ↕edit, i save
```

Yes



Connect to Wifi

This option can provide an alternative method for downloading autonomous controller updates if needed and can support advanced diagnostics by Nilfisk Engineering when needed. If you need to use this feature, you will need assistance from Nilfisk Technical Support. .

Autonomous System Safety Testing

Testing the autonomous safety system validates that the safety sensors and drop-off sensors are functioning and that the autonomous controller responds to their inputs correctly. Perform these tests whenever a drop-off sensor is replaced or a safety sensor is replaced or adjusted.

Locking machine out of Autonomous Operation

If the machine fails a safety system test, contact your local Nilfisk Technical Support center for assistance. If the issue cannot be resolved, you must lock the machine out of autonomous operation. To do that, remove the front cover and disconnect one of the drop-off sensor connectors. Then reinstall the cover. This will prevent the machine from playing back a plan (It will also set a fault code if play back is attempted).

Static Test of Drop-off Sensors

This test confirms that the drop-off sensors are properly detecting a simulated drop-off condition, and also that they are properly connected to the Autonomy Controller.



Note: If the machine fails any portion of the test, it fails the whole test and must be locked out of autonomous operation. Contact your local Nilfisk Technical Support center for assistance.

1. Power the machine with Service Mode access, and wait for the Autonomy system to boot up.
2. If not already completed, perform the [Drop-off Sensor Calibration](#) described on page 108.
3. Navigate to the Service, A5 Autonomy, Dropoff Sensors menu, and refresh the data.
 - All 4 sensors should be displaying similar values, and be within the range of 650 to 750.

4. Place a mirror over the right side drop-off sensor laser dot projected on the floor.



5. Confirm that the right side dropoff sensor is reporting a high value, and the remaining sensors are reporting normal values to the floor.

```
A5 Autonomy
DropOff Side Left      708
DropOff Front Left     714
DropOff Front Right    710
DropOff Side Right     5013
◀back, i refresh
```

6. Move the mirror to the Right Front position.



7. Confirm that the Right Front sensor is reporting a high value.

```
A5 Autonomy
DropOff Side Left      708
DropOff Front Left     714
DropOff Front Right    5013
DropOff Side Right     697
◀back, i refresh
```

8. Move the mirror to the Left Front position.
9. Confirm that the Left Front sensor is reporting a high value.



```
A5 Autonomy
DropOff Side Left      708
DropOff Front Left     5013
DropOff Front Right    710
DropOff Side Right     697
◀back, i refresh
```

10. Move the mirror to the Left Side position.
11. Confirm that the Left Side sensor is reporting a high value.



```
A5 Autonomy
DropOff Side Left      5013
DropOff Front Left     714
DropOff Front Right    710
DropOff Side Right     697
◀back, i refresh
```

Dynamic Floor Drop-off Simulation

This procedure confirms that all 4 of the drop-off sensors will trigger the machine to stop when a simulated drop-off condition exists. It also confirms that the machine will stop within a prescribed distance when travelling at speed.

A drop-off condition is simulated with a mirror placed on the floor. When a drop-off sensor's laser beam shines on a mirror placed on the floor, the laser beam is no longer reflected back to the sensor (or reflects off the ceiling, which is beyond the sensor's range). The sensor perceives this as an infinite drop-off of the floor surface.

This procedure should be completed any time one or more of the conditions below have occurred:

- One or more drop-off sensors are replaced, or their mounting bracket is removed.
- The Breakout Box is replaced or disconnected.
- An unexplained Safety System fault has occurred.

Test Setup

- You will need an open space of at least 15 meters in length, with at least 1 meter of clearance to either side of the machine. The floor should be level, smooth, and conducive for autonomous travel.
 - You will need a flat mirror that is at least 30 cm long (11 inches), and at least wide enough to reliably have the drop-off sensor laser beam pass over the mirror during autonomous playback.
 - It will be helpful to have some masking tape to mark locations on the floor.
1. Power the machine with Service Mode access.
 2. If not already completed, perform the [Drop-off Sensor Calibration](#) described on page 108.
 3. Move the machine to the beginning of a 15 meter long, clear area, and record a transport-only copycat plan in a straight line that you can reference during playback.
 - You will need to replay this plan several times, so it may be helpful to place some masking tape on the floor identifying one of the wheel locations at the starting point
 4. Move the machine back to the beginning of the path you recorded above.



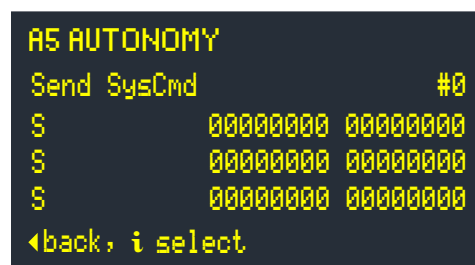
CAUTION: This section of the procedure requires disabling a portion of the Autonomous System Obstacle Avoidance Function. The 3D Vision and 2D Mapping sensors will not be used for obstacle avoidance and the “feel around function” will also be disabled. The machine will halt only if an obstacle is detected by the Left or Right Safety Lasers or a dropoff condition is detected. Objects above or below the safety lasers will not be detected.

5. Navigate to the Service, A5 Autonomy, “Send Any System Command” menu.



Note: Use care when using this menu screen. Sending the wrong command number to the Autonomy Controller can have adverse affect on the system, including deleting customer data, deleting all memory, deleting all paths, etc.

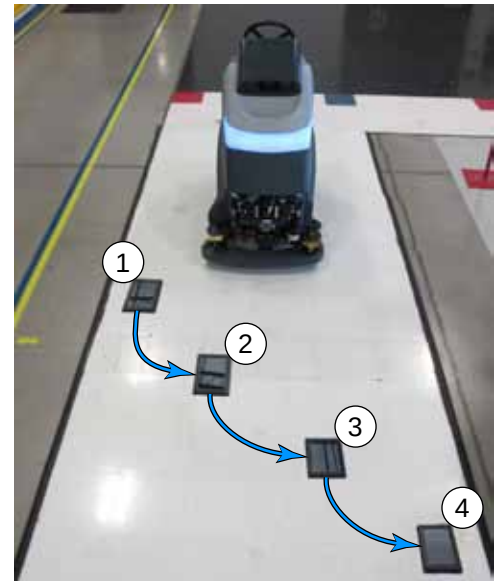
6. Press the down-arrow until command number 60 (#60) is displayed.



7. Double check that “#60” is displayed, and then press the “i” button to select the command.
 - The only feedback that Command 60 has been executed is that the “#60” highlights briefly, as shown.
 - Command 60 means: Disable mapping laser, 3D vision sensor obstacle detection and “feel around function” to test just the safety system.
 - This command is automatically reset if the machine is rebooted. If the machine is powered down during this procedure, you will have to re-send command #60.

Individual Test of Drop-off Sensors

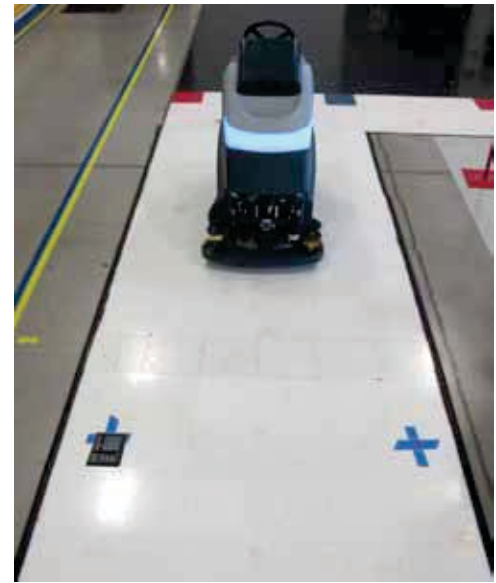
8. Place a mirror ahead of the right side drop-off laser dot on the floor. (As shown by position **(1)** in the image to the right, approximately 1/2 meter ahead of the machine.)
9. Play back the recorded plan, and confirm that the machine stops when it reaches the mirror.
 - The machine may move past the mirror before coming to a complete stop. This is acceptable as long as the machine comes to a complete stop.
10. Before the machine exits auto playback, move the mirror approximately 1/2 meter ahead of the Right Front laser dot on the floor (shown by position **(2)** in the image).
 - If the machine exits auto playback, simply press the play button to resume the plan.
 - After playback resumes, the machine should again come to a stop when the mirror is reached.
11. Repeat for the Left Front laser dot (position **(3)**) and Left Side laser dot (position **(4)**).
12. Leave the machine in its current position to help you set up for the “Stopping Distance” portion of the test. (Continued below).



Stopping Distance Performance Test

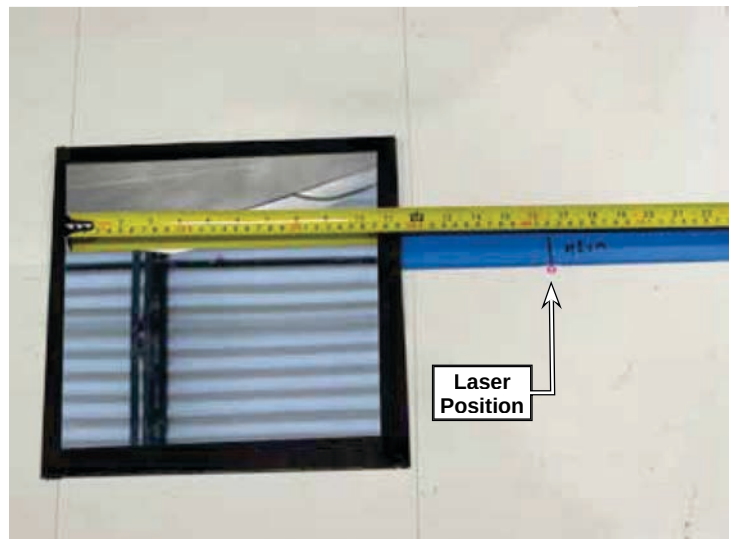
This portion of the test is a continuation of the previous, and confirms that the machine comes to a complete stop within a specified distance when travelling at full speed.

13. **Setup:** After completing the previous section, allow the machine to continue on its path until it reaches at least 7 meters (22 feet) from the original starting position.
 - a. Stop the machine, and mark the location of either the left or right drop-off laser dots on the floor.
 - b. Move the machine out of the way, and place a mirror where the laser dot was marked.
 - During later playback, this position should be far enough away from the starting point that the machine is able to reach full speed.
14. Move the machine back to the beginning of the path.
15. Navigate to Service, A3 Drive Controller menu so that you can monitor the machine speed during play back.
16. Remove the key before pressing the play button. (If you fail to do this, you will not be able to monitor the machine speed.)
17. Play back the plan while walking behind the machine so that you can monitor the machine speed.
 - Make sure the machine speed exceeds 1.8 mph (2.9 kph) before reaching the mirror.
18. If the machine stops with the dropoff laser beam past the mirror, you can block one of the safety sensors with an object to prevent the machine from resuming motion.
19. Measure the distance from the “leading edge” of the mirror to the stopped laser position.
 - The stopping distance should be less than 1.32 meters (52 inches).
 - If the stopping distance is greater than 1.32 meters, the machine fails the test **and it must be locked out of autonomous operation. Contact your local Nilfisk Technical Support center for assistance.**



```

A3 Drive
SPEED      3.1 kph 1.9 mph
THROTTLE           1
J4-13 GO PEDAL      5.0
J4-14 SPEED POT     1.8
◀back, ▶scroll
  
```



Safety (Laser) Sensor Performance Tests

Whenever a safety sensor is replaced and/or adjusted, it is necessary to verify that the sensors are working properly and that the machine stops when a safety sensor reports an obstacle to the Autonomy Controller. This is done by placing the machine in a special operational mode along with using cylinder shaped “obstacles” of a specific size and material which are placed in the path of the machine during playback. The machine should stop before contacting the obstacle.

The obstacles are called “Target-Cylinders.” They are shaped like a cylinder and covered with a black felt-like cloth. There are two sizes. The large cylinder is 60 cm long and 20 cm wide. The small cylinder is 40 cm long and 7 cm wide. When in use, the small target cylinder is placed so that it stands up vertically, while the large target cylinder is laid down on its side horizontally.

Most of the tests are to ensure that the machine stops without contacting the obstacle when the obstacle is placed in several different positions and orientations, however there are also tests to ensure that the autonomous system will quit playback mode (kick out) within 20 seconds when the obstacle remains in place and tests to make sure that the machine will refuse to move when playback is started if the object is directly in front of the machine.



Note: All of the procedures in the following sections must be completed in order.



Straight-line Test Setup

This straight-line setup procedure is used for multiple tests listed below that use a straight line copycat plan. If you are able to record a long straight-line plan, you can perform all of these tests consecutively. However, if you are limited in floor space, you may need to replay a shorter plan for each phase of the tests.

The limiting factor in how short the plan can be is the High Speed Stop test, where the machine must reach a speed of 2.9 kph (1.8 mph). This typically takes about 7 meters (22 feet) to reach required speed. If you have the space available, a plan of about 15 meters in length will permit you to complete all of the tests consecutively.

- You will need an open space of at least 7 meters in length (as described above), with at least 1 meter of clearance to either side of the machine. The floor should be level, smooth, and conducive for autonomous travel.
 - It will be helpful to have some masking tape to mark locations on the floor.
1. For recording the plan and the first test, power the machine without Service Mode access (normal mode)
 2. Move the machine to the beginning of the test area, and record a transport-only copycat plan in a straight line that you can reference during playback.
 - You may need to replay this plan several times, so it may be helpful to place some masking tape on the floor identifying a wheel location at the starting point.



Stay-Put Test

This first test is completed in normal autonomous mode, and confirms that the machine will not move when its forward path is blocked at the start of autonomous playback.

1. Return the machine to the beginning of the path you recorded above.
2. Make sure the machine is in normal operating mode. If you are unsure, reboot the machine.
3. Place the large target cylinder in front of the machine, touching the front bumper.
4. Press the play button to command the machine to replay the plan.
 - The machine should not move. If the machine moves, it fails the test.
 - The machine should exit playback within 60 seconds.
5. Place the small cylinder standing in front of the machine and against the bumper.
6. Press the play button to command the machine to replay the plan.
 - The machine should not move. If the machine moves, it fails the test.
 - The machine should exit playback within 60 seconds.



High Speed Stop

1. Reboot the machine with service mode access.
2. If the machine is not still at the start of the recorded plan, move it to the start.
3. Navigate to Service, A3 Drive Controller menu so that you can monitor the machine speed during play back.
4. Remove the key before pressing the play button. (If you fail to do this, you will not be able to monitor the machine speed.)
5. Play back the plan while walking behind the machine so that you can monitor the machine speed.
6. Place a tape mark on the floor slightly ahead of where the machine speed exceeds 2.9 kph, 1.8 mph.

```
A3 Drive
SPEED      3.1 kph 1.9 mph
THROTTLE           1
J4-13 GO PEDAL      5.0
J4-14 SPEED POT     1.8
◀back, ▶scroll
```

CAUTION: This section of the procedure requires disabling a portion of the Autonomous System Obstacle Avoidance Function. The 3D Vision and 2D Mapping sensors will not be used for obstacle avoidance and the “feel around function” will also be disabled. The machine will halt only if an obstacle is detected by the Left or Right Safety Lasers or a dropoff condition is detected. Objects above or below the safety lasers will not be detected.

7. Navigate to the Service, A5 Autonomy, “Send Any System Command” menu.

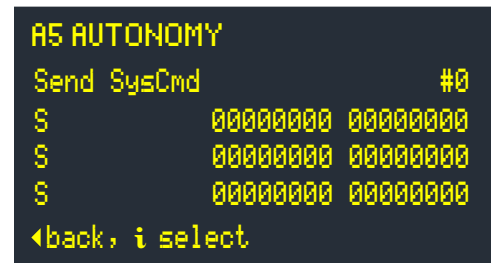


Note: Use care when using this menu screen. Sending the wrong command number to the Autonomy Controller can have adverse affect on the system, including deleting customer data, deleting all memory, deleting all paths, etc.

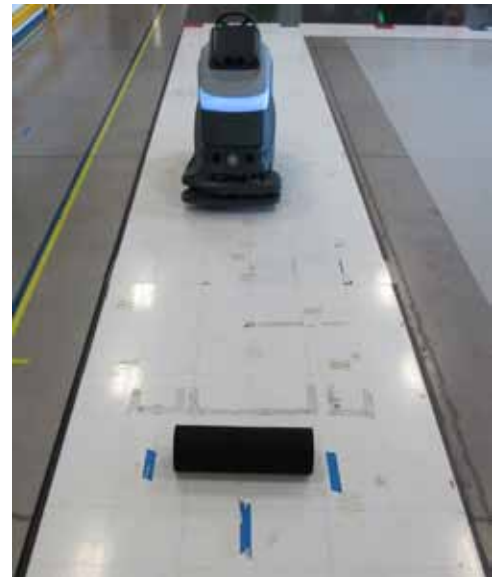
8. Press the down-arrow until command number 60 (#60) is displayed.

9. Double check that “#60” is displayed, and then press the “i” button to select the command.

- The only feedback that Command 60 has been executed is that the “#60” highlights briefly, as shown.
- Command 60 means: Disable mapping laser, 3D vision sensor obstacle detection and “feel around function” to test just the safety system.
- This command is automatically reset if the machine is rebooted. If the machine is powered down during this procedure, you will have to re-send command #60.

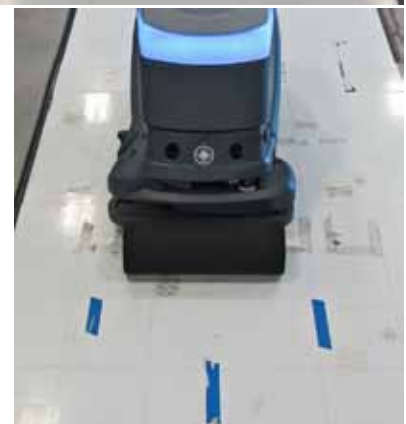


10. Place the large cylinder at the location where the machine speed exceeded 1.8 mph (2.9 kph).
11. Move the machine to the start area.
12. Navigate to Service, A3 Drive Controller menu so that you can monitor the machine speed during play back.
13. Remove the key before pressing the play button.
14. Play back the plan and monitor the machine speed to make sure it exceeds 1.8 mph (2.9 kph) before reaching the target cylinder area.
15. The machine should stop before contacting the cylinder. If it touches the cylinder it fails the test.



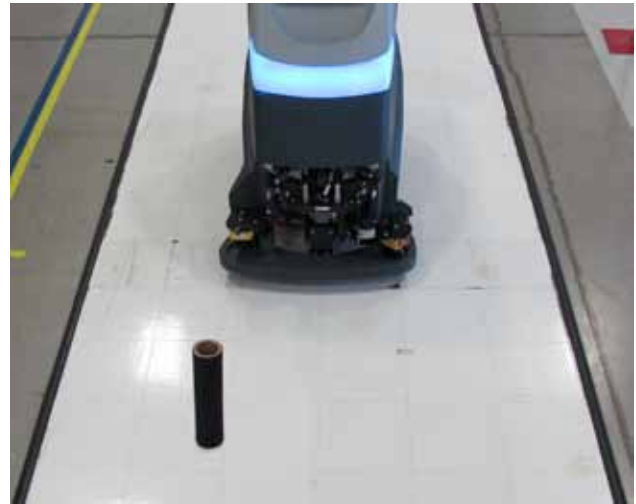
16. Measure the time until the playback “kicks out” (quits playback).

- a. Move the cylinder into the protection zone of the safety laser by placing it directly against the bumper.
- b. Playback should quit within 60 seconds of the protection zone being blocked.
- c. If the machine does not exit playback within 60 seconds, it fails the test.

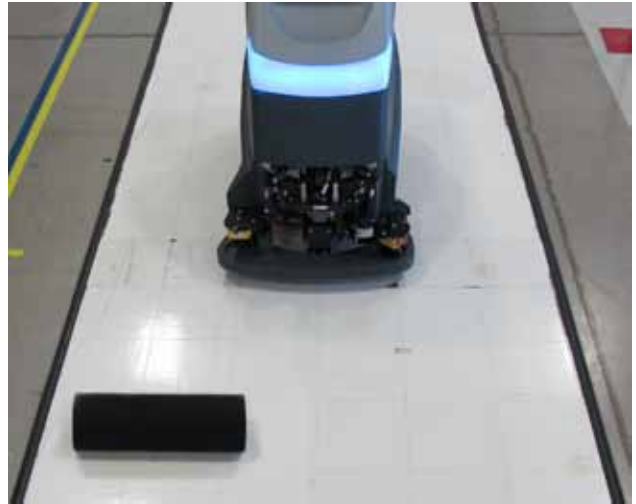


Forward Low Speed Stop

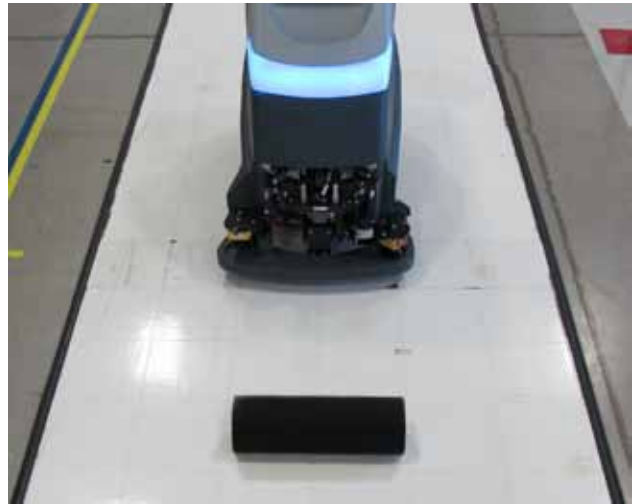
- Use the same copycat plan you recorded for the high speed stop test.
 - You will need the small target cylinder.
 - Make sure Command 60 is still active. (Refer to the high speed test).
1. Move the machine back to the beginning of the path you recorded above.
 - If your recorded plan is long enough, you can just continue from where you left off previously.
 2. Stand the small target cylinder approximately 1 meter (3 feet) in front of the machine and toward the right edge of the machine, such that the machine will strike the cylinder if it fails to stop.
 3. Press the play button.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.
 4. Move the target cylinder another meter forward and in front of the center of the machine.
 5. Press the play button to resume the plan.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.
 6. Move the target cylinder another meter forward and in front of the left edge of the machine.
 7. Press the play button to resume the plan.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



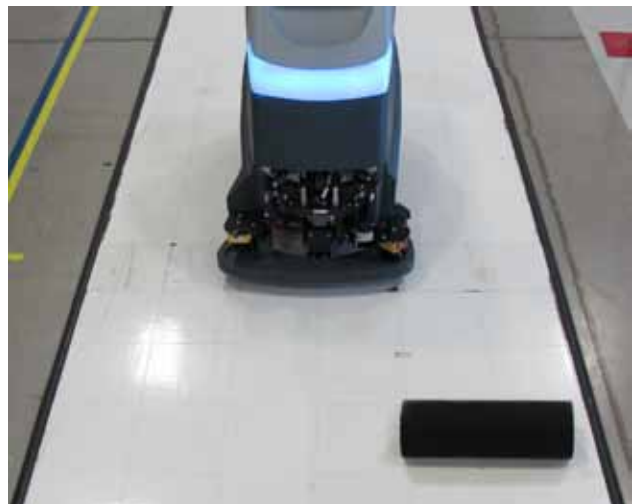
8. If there is room, continue with the path. Otherwise move the machine back to the beginning of the path and restart.
9. Place the large target cylinder approximately 1 meter (3 feet) in front of the machine, perpendicular to, and toward the right edge of the machine.
10. Press the play button.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



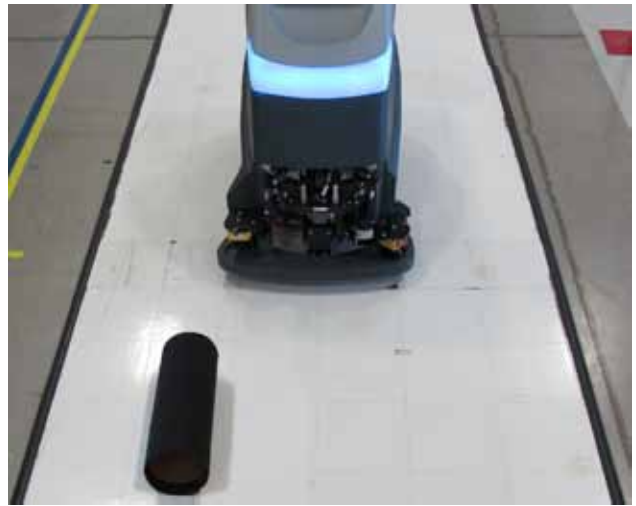
11. Move the target cylinder another meter forward and in front of the center of the machine.
12. Press the play button to resume the plan.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



13. Move the target cylinder another meter forward and in front of the left edge of the machine.
14. Press the play button to resume the plan.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



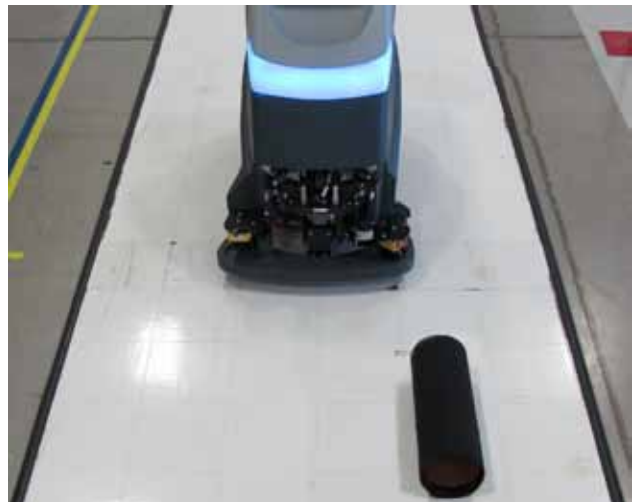
15. If there is room, continue with the path. Otherwise move the machine back to the beginning of the path and restart.
16. Place the large target cylinder approximately 1 meter (3 feet) in front of the machine, parallel to, and toward the right edge of the machine.
17. Press the play button.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



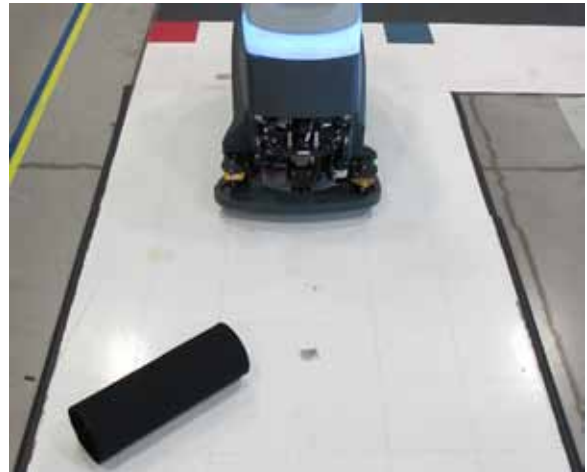
18. Move the target cylinder another meter forward and in front of the center of the machine.
19. Press the play button to resume the plan.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



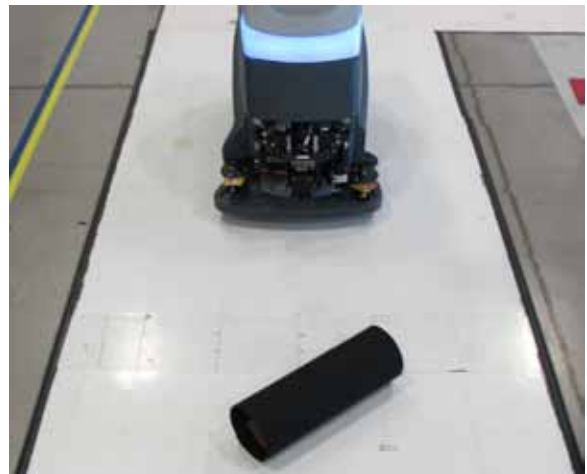
20. Move the target cylinder another meter forward and in front of the left edge of the machine.
21. Press the play button to resume the plan.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



22. Move the machine back to the beginning of the path.
23. Place the large target cylinder approximately 1 meter (3 feet) in front of the machine, oblique to, and toward the right edge of the machine.
24. Press the play button.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



25. Move the target cylinder another meter forward and in front of the center of the machine.
26. Press the play button to resume the plan.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



27. Move the target cylinder another meter forward and in front of the left edge of the machine.
28. Press the play button to resume the plan.
 - The machine should move forward, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



29. Move the machine back to the beginning of the path and use the autonomous help menu to Delete the plan when finished.

Right Turning Low Speed Stop

This tests confirms that the machine will stop when turning into an object along the right side the machine.

- You will need an open space with at least 1 meter in front of the machine, and at least 2 meters to either side of the machine.
 - You will need the large target cylinder.
 - Make sure Command 60 is still active. (Refer to the high speed test).
1. Record a transport-only copycat plan for a 180 degree turn to the right.
 - Mark the position of the machine start location using tape on the floor which will be easy to remove. This will allow you to return the machine to the exact start location for the test.
 - Turn the steering wheel all the way to the right until it reaches the mechanical stop, and record a complete 90-degree turn.
 2. Position the machine at the exact start location.
 3. Make sure the squeegee is in the “center” position (as shown). This represents the worst-case for contact with a side object.
 4. Place the large target cylinder to the right side of the machine where the front bumper will be when the machine begins the turn.
 5. Press the play button.
 - The machine should turn to the right, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.
 6. Move the large target cylinder to the right side of the machine where the squeegee roller will be when the machine continues its turn.
 7. If the machine doesn’t automatically resume playback, press the play button to resume.
 - The machine should continue its turn to the right, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



8. Move the large target cylinder to the right side of the machine where the rear of the squeegee will be when the machine continues its turn.
9. If the machine doesn't automatically resume playback, press the play button to resume.
 - The machine should turn to the right, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.
10. Reposition the machine at the start location.
11. Use the autonomous help menu to Delete the plan when finished.



Left Turning Low Speed Stop

This tests confirms that the machine will stop when turning into an object along the left side the machine.

- You will need an open space with at least 1 meter in front of the machine, and at least 2 meters to either side of the machine.
 - You will need the large target cylinder.
 - Make sure Command 60 is still active. (Refer to the high speed test).
1. Record a transport-only copycat plan for a 180 degree turn to the left.
 - Mark the position of the machine start location using tape on the floor which will be easy to remove. This will allow you to return the machine to the exact start location for the test.
 - Turn the steering wheel all the way to the left until it reaches the mechanical stop, and record a complete 90-degree turn.
 2. Position the machine at the exact start location.
 3. Make sure the squeegee is in the “center” position (as shown). This represents the worst-case for contact with a side object.
 4. Place the large target cylinder to the left side of the machine where the front bumper will be when the machine begins the turn.
 5. Press the play button.
 - The machine should turn to the left, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



6. Move the large target cylinder to the left side of the machine where the squeegee roller will be when the machine continues its turn.
7. If the machine doesn't automatically resume playback, press the play button to resume.
 - The machine should turn to the right, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



8. Move the large target cylinder to the left side of the machine where the rear of the squeegee will be when the machine continues its turn.
9. If the machine doesn't automatically resume playback, press the play button to resume.
 - The machine should turn to the left, and then stop before it contacts the target cylinder.
 - If it touches the cylinder it fails the test.



10. Reposition the machine at the start location.
11. Use the autonomous help menu to Delete the plan when finished.

Sensor Input Validation Testing

During the course of routine troubleshooting, it may be necessary to confirm that various sensors are operating correctly, and/or providing valid results to the Autonomous Controller. The following validation procedures are intended to be quick-checks of the sensor systems, without the need to perform complete diagnostic or calibration procedures.

- [“Drive Wheel Angle Sensor”](#) on page 143
- [“Safety Sensors \(Left and Right\)”](#) on page 144
- [“3D Vision Sensor \(Camera\)”](#) on page 145
- [“2D Mapping Sensor”](#) on page 145
- [“Drop-Off Sensors”](#) on page 146
- [“Rear Wheel Encoders”](#) on page 147

Drive Wheel Angle Sensor

The drive angle sensor informs the Autonomous Controller of the actual direction that the drive wheel is pointing. As long as the Safety Sensors (lasers) are communicating, the easiest validation check is to observe that the Safety Sensor Area Numbers change as the drive wheel is turned left and right.

If the Safety Sensors are not functioning, or suspected non-functional, then you will need to use Method B.



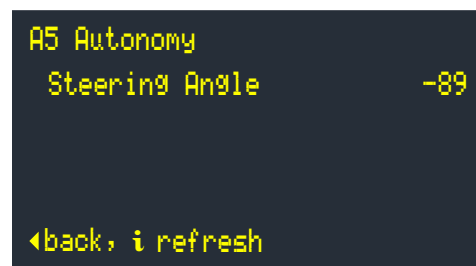
Method A: Using the Safety Sensors

1. Power on the machine and wait for the autonomous system to boot up.
2. Observe the Area Number display of one of the safety sensors while turning the steering wheel from full right to full left.
 - The area number should begin at 01 at full right, and increment up to 15 at full left.
 - If the area numbers respond as expected, it proves that the drive angle sensor (and safety laser) is working and communicating with the autonomous controller.
 - If the area numbers do not update as expected, continue to Method B to directly check the angle sensor input values.



Method B: Using the Service Menu

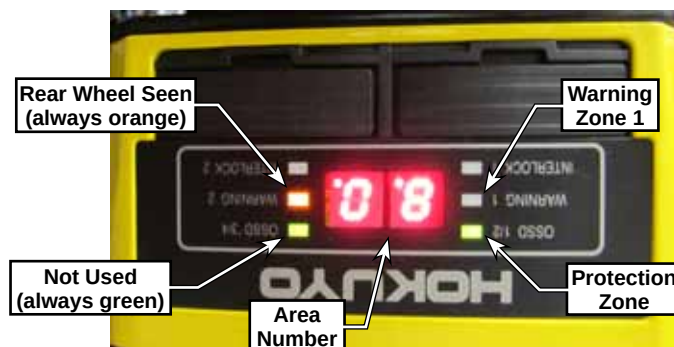
1. Power on the machine with service mode access, and wait for the autonomous system to boot up.
2. Enter the service menu and navigate to A5 Autonomy, “Check Steering Angle.”
3. Turn the steering wheel to the right stop, and refresh the display data.
 - The steering angle should be as close to -90 as the machine permits.
4. Turn the steering wheel to the left stop, and refresh the display data.
 - The steering angle should be as close to 90 as the machine permits.



Safety Sensors (Left and Right)

The LED display on the front of each Safety Sensor provides status information for that laser. This display information can be used to determine whether the sensor itself is functioning, but not necessarily whether the sensor is communicating with the Autonomy Controller.

However, note that there are enough redundancy error checks in the Autonomy Controller communications, that machine error codes should be present if communication with the safety sensors fails.



1. Power on the machine and wait for the autonomous system to boot up.
2. Check the 7-segment number display. Any number other than 01 through 15 represents an error code. See [“Safety Sensor Error Codes”](#) on page 148.
3. Turn the steering wheel as necessary, until the drive wheel is pointing straight ahead.
4. Without stepping into the observation zones of the laser (at least 1 meter away), observe the area number and the status LEDs for each laser:
 - The area address number should be 08
 - Warning 1 LED should be off (if orange, step back to verify it clears).
 - Warning 2 LED should be orange (always sees the rear wheel)
 - OSSD 1/2 LED should be green (protection zone is clear)
 - OSSD 3/4 LED should always be green (function not used)
5. Begin moving closer to the sensor and observe the status LED changes.
 - a. Warning 1 LED should change from off to orange as you enter the outermost observation zone (the warning zone).
 - b. OSSD 1/2 should change from green to red as you enter the protection zone (very close to the sensor).
 - c. The remaining LEDs should remain unchanged.
6. Repeat the observations for the other safety sensor.

3D Vision Sensor (Camera)

Because there is no outward interface, validating the 3D vision sensor is limited to confirming that the Autonomy Controller is receiving valid data. In it's simplest form, reading a location tag will validate the communication to the Autonomy Controller. However, this does not validate complete stereoscopic vision, as only one lens is required for that function.

The best method for validating the 3D vision system is to put the machine into a situation of obstacle avoidance where the 3D camera should see the object, but the mapping laser should not see the object. If the machine veers to avoid the object, then the vision system is known to be functional.

1. Record a fill in plan for an area.
2. Playback the plan.
3. During playback, hold out a horizontal object in front of the 3D vision sensor, but high enough above the floor that the 2D Mapping Sensor cannot see the object.
4. If the machine attempts to deviate from it's planned path to go around the object, it indicates that the camera is able to see and report information properly to the autonomous controller.

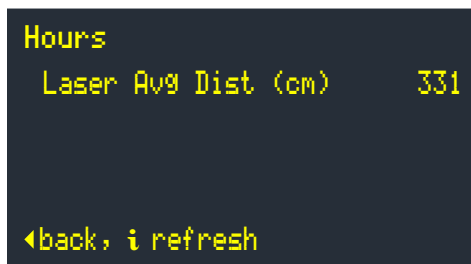


2D Mapping Sensor

The mapping laser transmits a data stream of scan coordinates to the Autonomy Controller. Even though this data stream and resulting map is not directly accessible, it can be validated by observing a change in the “open space” in front of the machine. Each coordinate contains a distance to a scanned object. If the machine is parked in an open space, the average distance of all of these scan coordinates will be a large number. If the machine is moved to a confined space, the average distance of the scan coordinates will be smaller.

To aid in diagnostics, the Autonomy Controller calculates a variable called “Laser Average Distance”. Observing a significant change in this value as the machine's scannable space is altered will validate proper operation of the 2D Mapping Sensor.

1. Park the machine in a relatively open area, where there are no walls closer than 1 meter to the front of the machine.
2. Enter the service menu and navigate to A5 Autonomy, “Laser Average Distance” screen.
3. Refresh the data and note the value.
4. Block the mapping laser with an object, such as a large piece of cardboard resting against the front of the machine.
5. Refresh the on-screen data.
6. If the Laser Average Distance value decreases significantly, then the mapping laser is known to be functioning and communicating with the Autonomy Controller.



```
Hours
Laser Avg Dist (cm)    331
◀back, i refresh
```

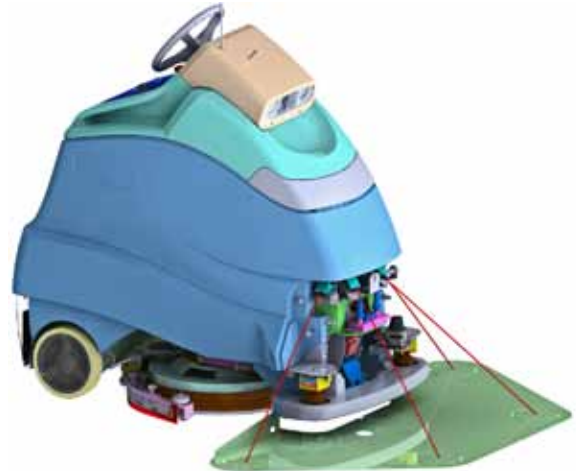
Drop-Off Sensors

Each of the drop-off sensors provides a data stream to the Autonomy Controller of measured distances from the floor. This data is also present on the LCD display of each sensor. For this reason, it is possible to validate both the sensor's function, and the communication to the Autonomy Controller.

1. Power on the machine with Service Mode access, and wait for the autonomous system to boot up.
2. Move the machine to an open area where all 4 beams are unobstructed to the floor.
3. Enter the service menu and navigate to A5 Autonomy, "Dropoff Sensors" screen.
4. Refresh the data and record the value for each sensor. They should be close to the same value. (Typical values range from 650-750)
5. Place an object (such as a block of wood or a mirror) under one of the sensor's laser beam at the floor.
6. Refresh the data. The input value for that sensor should change.
7. Repeat for each sensor.

If all 4 sensors respond correctly, you can stop. If one or more sensors is not responding as expected, continue with the next step to examine the sensor(s) directly.

8. Remove the front cover from the machine to expose the drop-off sensors.
9. Repeat the examination described above, except observe the distance measurements shown directly on the sensor's LCD display.
 - If the sensor's LCD display responds as expected, the sensor is detecting properly, but the communication to the Autonomous Controller is suspect.
 - If the sensor's LCD display does not respond as expected, the sensor is suspect.



Rear Wheel Encoders



Note: Make sure the rear wheels are cleaned daily. Debris adhering to the outside of the wheel can affect the rolling circumference of the wheel and cause encoder errors.

Use the service menu data to validate that the rear wheel encoder input counts are equivalent when traveling in a straight line. When driving in a straight line, the right and left encoder counts should remain close to being equal, but minor variations in tire diameter can result in a small difference in the counts. This is expected behavior.

There are 102 encoder slots in the disk, but the wheel encoder count will be 4-times that amount (408) per revolution. This is because the encoder count includes both A-phase and B-phase counts, and also both rising-edge and falling-edge counts.

1. Power on the machine and wait for the autonomous system to boot up.
2. Navigate to the Service menu, A5 Autonomy Menu, Wheel Counts screen.
3. Zero the count of both encoders. Refresh the data to ensure that both counts are near zero.
4. Drive the machine in a straight line for 10 meters if possible or as far as practical.

```
A5 Autonomy
Left wheel count      5142
Right wheel count     5114
▲ to re-zero left count
▼ to re-zero right count
◀back, i refresh
```



Service Tip: If you wish to track wheel rotation, use masking tape to place a mark on the wheel and a matching mark on the solution tank. There should be 408 encoder counts per rotation.

5. Refresh the data. Record the count of both encoders. They should be within 1% of one another.
6. If the counts are not in reasonable agreement, inspect the machine for the causes listed below.

Causes for Encoder count variation

- Incorrect sensor to encoder wheel gap. (See [Wheel Encoder Gap](#) described on page 106.)
- Metallic debris on sensor or encoder wheel.
- Loose sensor or encoder wheel.
- Bent encoder wheel.
- Worn wheel bearings.
- Debris on the outside of the wheel.

Rebooting

Many troubleshooting procedures are initiated with a machine reboot. However, this may not fully reset all controllers, as they have direct battery power supplied to them, as opposed to only KSI power. This includes the MMC, Steering controller, and Autonomy controller. If a “hard reboot” or “power cycle reboot” is called for, shut down the machine, wait for the Autonomy module to shut down (i.e. Safety Sensors turn off), disconnect the main battery connector for 30 seconds, and then re-power the machine.

Safety Sensor Error Codes

The safety sensors cannot report errors back to either the Autonomous Controller nor the Main Machine Controller. Instead, the error codes are displayed on the 7-segment display in the form of hexadecimal numbers. Even though many of the possible error codes are not applicable to the configuration of the sensor in the machine, they are all listed in the table below. If an unused function is reporting an error, it typically means that the configuration file is corrupted, and the sensor needs to be replaced.



Service Tip: If the number displayed on the safety sensor is 1-31, it is a valid area address. If a valid **area address is flashing**, it means the lens is getting dirty and needs to be cleaned. Any other value is an error code.

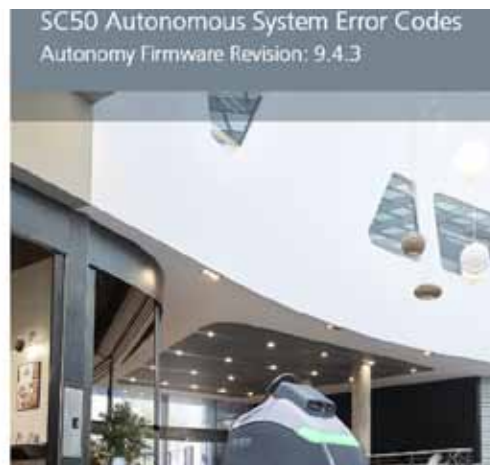
Safety Sensor LED Error Codes		
Code	Description	Diagnostics
45	Setting error/Incomplete setting	Reboot the machine. If the error persists, replace the laser.
56	Invalid area error	Check the area address voltages on J11-3 through J11-12. Make sure each address line and its compliment are opposite one another. (See Sample Shop Voltage Measurements on page 161)
57	Area input connection error	
5E	Invalid area error	
59	Area sequence error	Function not used. If error persists, replace the laser.
5b	Encoder speed error	Reboot the machine. If the error persists, replace the laser.
5C	Encoder error	
5d	Encoder speed error	
5F	Encoder speed error	
60-63	Motor error	Make sure the laser mounting/suspension springs are in the middle of their adjustment travel. If the error persists, replace the laser.
64	Master-Slave communication	Make sure both lasers are powered, and their electrical connectors are secure.
70	Optical interference/High reflective background	
72	Operating temperature	If the machine is operating in a hot environment, allow the machine to cool.
74-79	Power supply error	Make sure the voltage between J13-A and J13-V is 24 volts.
7C	OSSD excess current error	Check all 4 OSSD lines for short circuit to any other conductors.
7d	Slave unit 1 error	Check the right laser for an error code.
7E	Slave unit 2 error	Not used
7F	Slave unit 3 error	Not used
80	Master unit error	Check the Left laser for an error code
84	Object in limited detection zone or contamination on the optical window.	Clean the outer lens with a soft, clean cloth.
85		
86	Mutual interference error	Make sure the front bumper is installed on the machine. It contains a block between the lasers.
8F	SD card detection error	An SD card is only used for reprogramming the lasers, which is not a currently supported function.

Safety Sensor LED Error Codes		
Code	Description	Diagnostics
95-9A	OSSD diagnostic error	Check all 4 OSSD lines for either short circuit or open circuit.
AB-AC		
A6	EDM1 input connection error	Functions not used. If the error persists, replace the laser.
A7	EDM2 input connection error	
A9	Reset input error	
AA	Reference monitor error	
b1-C0	Optical window is contaminated	Clean the outer lens with a soft, clean cloth.
C1	Optical window is removed or contaminated	
CE	Adjustment of the optical window is incomplete after replacement.	
CF	Laser is not configured	An SD card is only used for reprogramming the lasers, which is not a currently supported function.
d3-EE	Configuration is incomplete	
F0	SD card initialization error	
F1	SD card file content error	
41-F5	Device Error	Make sure the voltage between J13-A and J13-V is 24 volts. If the error persists, replace the laser.

Autonomous System Error Code Reference

To ensure that the autonomy error code information remains up to date, it has been located in the EzParts database, along with the parts lists and manuals.

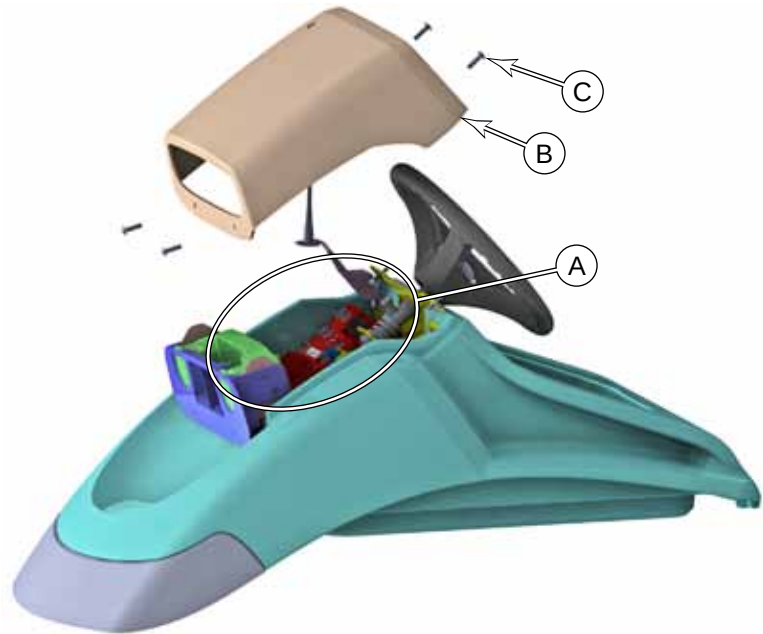
OM56091250 - Liberty SC50 (MMC 4.1)
 OM56091250 - Liberty SC50 (MMC 5.1)
 OM56091253 - UVGI Accessory
 OM56091256 - Liberty SC50 Lithium I
 PL36042654 - Liberty SC30
SC50 Autonomy System Error Code
 SM56043177 - Liberty SC50
 SM56043177_DE - Liberty SC50 (Deu
 SM56043177_FR - Liberty SC50 (Fran
 SM56043180_DE Lithium Ion Battery
 SM56043180_EN Lithium Ion Battery
 SM56043180_ES Lithium Ion Battery
 SM56043180_FR Lithium Ion Battery I
 SM56043180_IT Lithium Ion Battery I
 SM56043180_PT Lithium Ion Battery I
 Liberty SC30 X20R-Model 56104503-PL5
 Liberty SC30 X20R-Model 56104506-PL5
 Liberty SC30 X20R-Model 56104507-PL5
 Liberty SC30 X20R-Model 56104508-PL5
 Liberty SC30 X20R-Model 56104509-PL5
 ittery Rider
 ittery Stand Up
 ittery Walk-Behind
 eotric Walk-Behind
 eg. Rider
 ialty
 ipers



Removal and Installation

Autonomy Module

1. Disconnect the main battery connector.
2. Remove the 4 screws (C) that secure the autonomy cover (B) over the autonomy bay (A), and remove the cover.

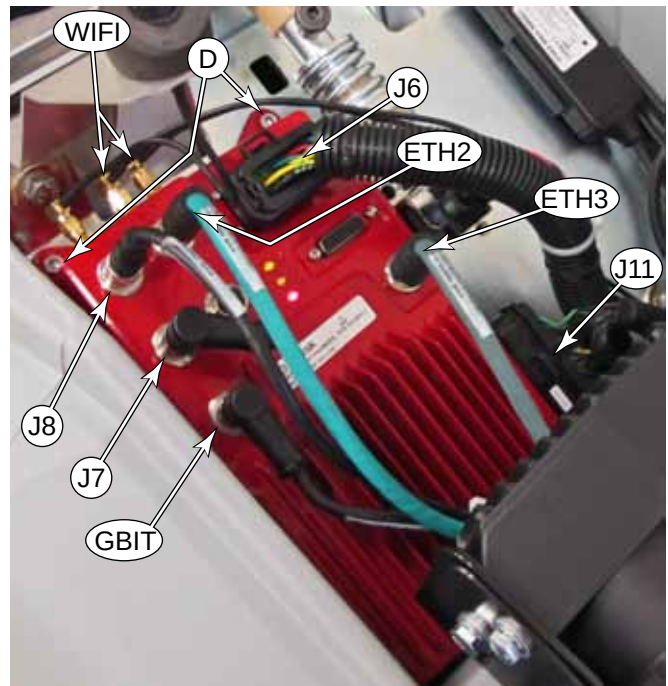


3. Disconnect all electrical connectors from the Autonomy module according to the table and figures (see next page).

Autonomous Module Connectors	
Connector	Description
J6	Main Machine Harness
J7	3D Camera Power
J8	Map Laser Power
J11	Breakout Box
Eth1	Not Used
Eth2	Map Laser Data
Eth3	IOT Connection
Gbit	3D Camera Data
WiFi	Antenna
WiFi	Antenna
RF	Antenna
TP	Engineering Test Port



4. Remove the two screws **(D)** that secure the autonomy module to the autonomy bay platform.
5. Lift the upper end of the autonomy module, and slide the module toward the steering wheel to release it from the lower mounting tabs.
6. Remove the autonomy module from the machine.

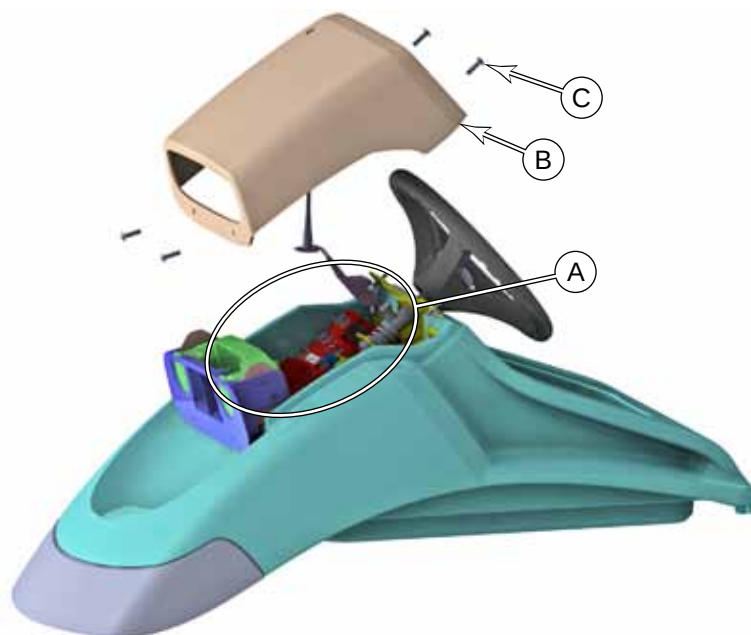


Install the New Autonomy Module

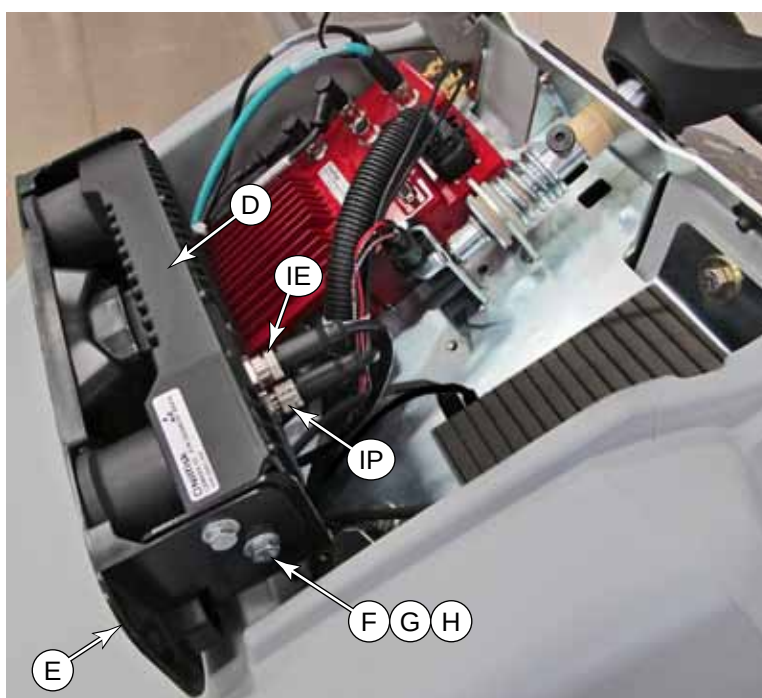
7. Position the new module in position, but tilted forward to aid in the installation of the 2 antenna connectors.
8. Connect the two WiFi antenna connectors.
9. Lay the Autonomy module flat, and secure it into position with the two mounting screws **(D)**.
10. Connect all of the remaining connectors.
11. Re-install the autonomy bay cover.
12. Power the machine with service mode access.
 - Disregard the multiple errors that are related to component calibrations which are described in the subsequent sections.
13. Perform the [3D Vision Sensor \(Camera\) Calibration described on page 109](#).
14. Perform the [Drop-off Sensor Calibration](#) described on page 108.
15. Record a plan and location tag, and replay the plan to confirm machine operation before the job is complete.
16. Inform the customer that the new controller has a “blank memory”, and that all location tags and plans must be re-recorded.

3D Vision Sensor

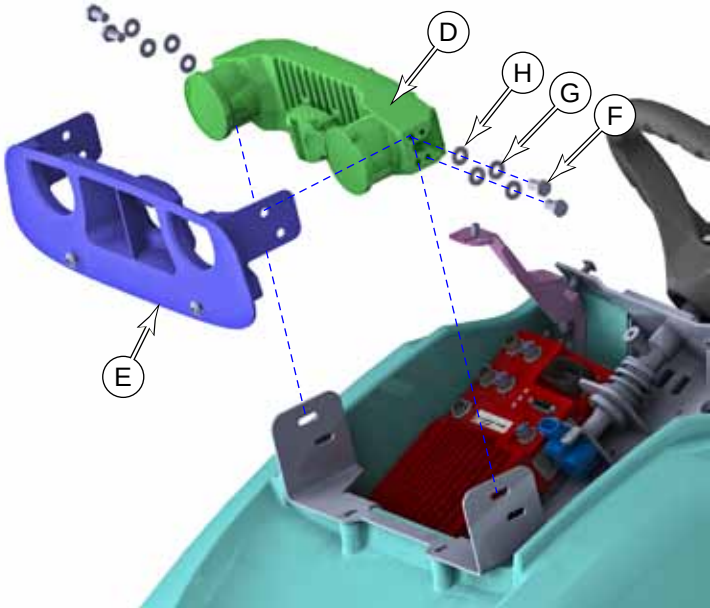
1. Disconnect the main battery connector.
2. Remove the 4 screws (C) that secure the autonomy cover (B) over the autonomy bay (A), and remove the cover.



3. Disconnect the Ethernet electrical connector (IE) and power electrical connector (IP) from the back of the camera (D).
4. Remove the four screws (F), lock washers (G), and flat washers (H) that secure the camera (D) and camera bezel (E) to the mounting bracket.
5. Remove the camera from the machine.

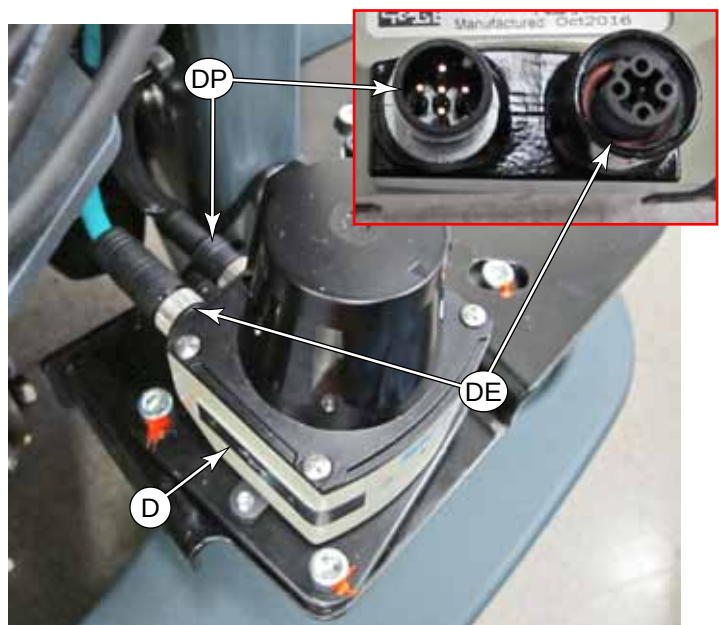
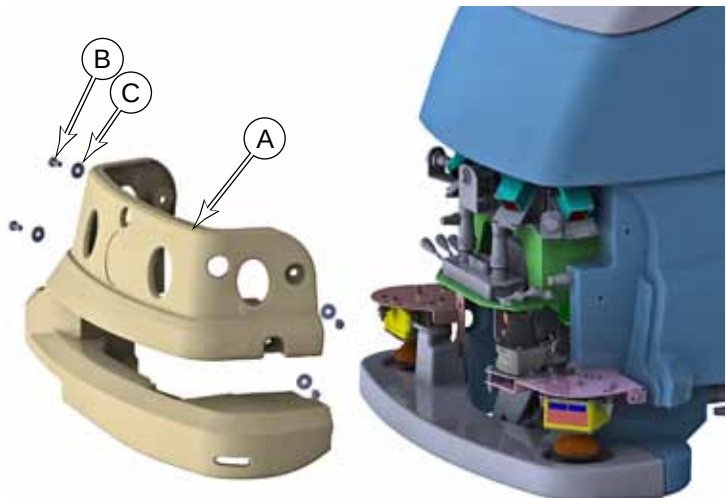


Install the New 3D Vision Sensor

6. Install the camera **(D)** and bezel **(E)**, and loosely secure them with the four screws **(F)**, washers **(G)**, and lock washers **(H)**.
 7. With the camera installed snug enough to hold position, but still loose enough that you can reposition it, temporarily place the autonomy cover **(B)** over the autonomy bay **(A)**, and align the camera bezel with the front face of the autonomy cover.
 8. Carefully remove the autonomy cover, and tighten the four screws securing the camera.
 9. Connect the Ethernet electrical connector **(IE)** and power electrical connector **(IP)** to the back of the camera
 10. Confirm the autonomy cover fits correctly, re-align the camera if necessary, and install the autonomy cover using the original four screws **(C)**.
- 
11. Power the machine with service mode access.
 12. Perform the [3D Vision Sensor \(Camera\) Calibration described on page 109](#)
 13. Verify camera function by performing the validation test of the [3D Vision Sensor \(Camera\)](#) described on page 145

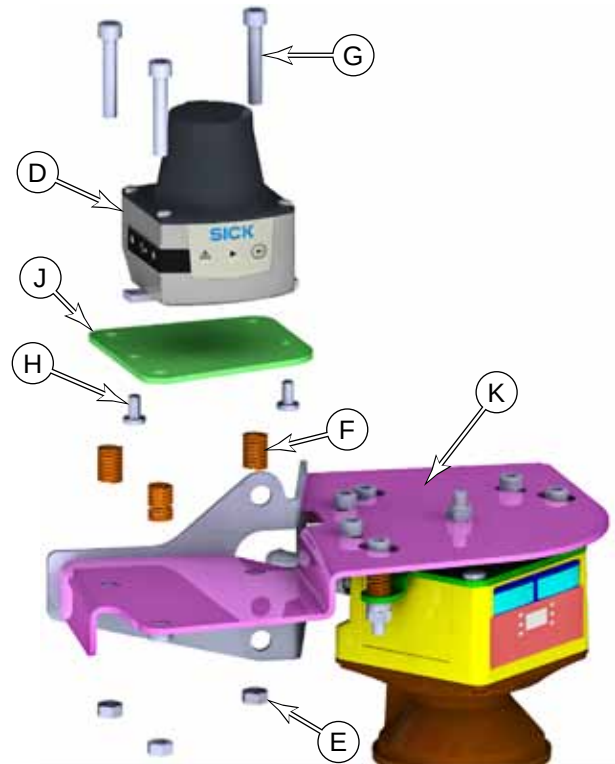
2D Mapping Sensor

1. Disconnect the main battery connector for safety any time you are working near the drive system.
2. Remove the 4 screws **(B)** and washers **(C)** that secure the front nose **(A)** to the recovery tank, and remove the front nose.
3. Disconnect the mapping sensor electrical power connector **(DP)** and Ethernet connector **(DE)** from the back of the mapping laser
4. Remove the sensor **(D)** and leveling plate **(J)** from the machine:
 - Remove the 3 jam nuts **(E)**, adjusting screws **(G)**, and springs **(F)** from the laser platform bracket **(K)**.
5. Remove the 2 mounting screws **(H)** that secure the sensor to the leveling plate **(J)**.



Install the New 2D Mapping Sensor

6. Install the new laser to the leveling plate.
7. Reassemble the leveling plate and laser platform bracket (**K**) using the adjustment screws and compression springs, but leave the jam nuts off at this time.
8. Reconnect the electrical connectors to the sensor.



9. Set the baseline gap between the leveling plate and platform bracket to 17mm:
 - a. Insert the 17mm spacer (p/n 56122724) from the laser alignment kit, between the leveling plate (**J**) and laser platform bracket (**K**).
 - b. With the 17mm spacer positioned near each respective adjustment screw, tighten all 3 adjustment screws (**G**) until the spacer loosely fits between the two plates.
10. Perform the [2D Mapping Sensor Level Check and Adjust](#) described on page 110.
11. Perform the [3D Vision Sensor \(Camera\) Calibration](#) described on page 109.



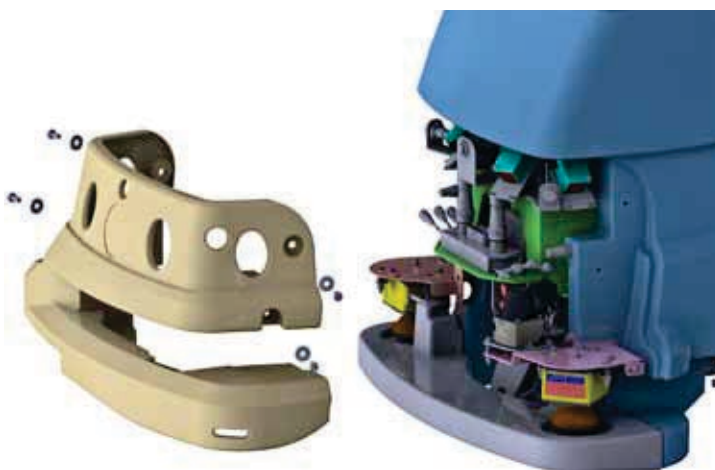
12. Verify sensor function by performing the validation test of the [2D Mapping Sensor](#) described on page 145
13. As a final verification, record and play back a plan.

Left Safety Sensor



Note: After reinstallation, rotation and level adjustments you must perform the *Dynamic Safety System Test Of Safety Sensors*.

1. Remove the 4 screws and washers that secure the front nose to the recovery tank, and remove the front nose.

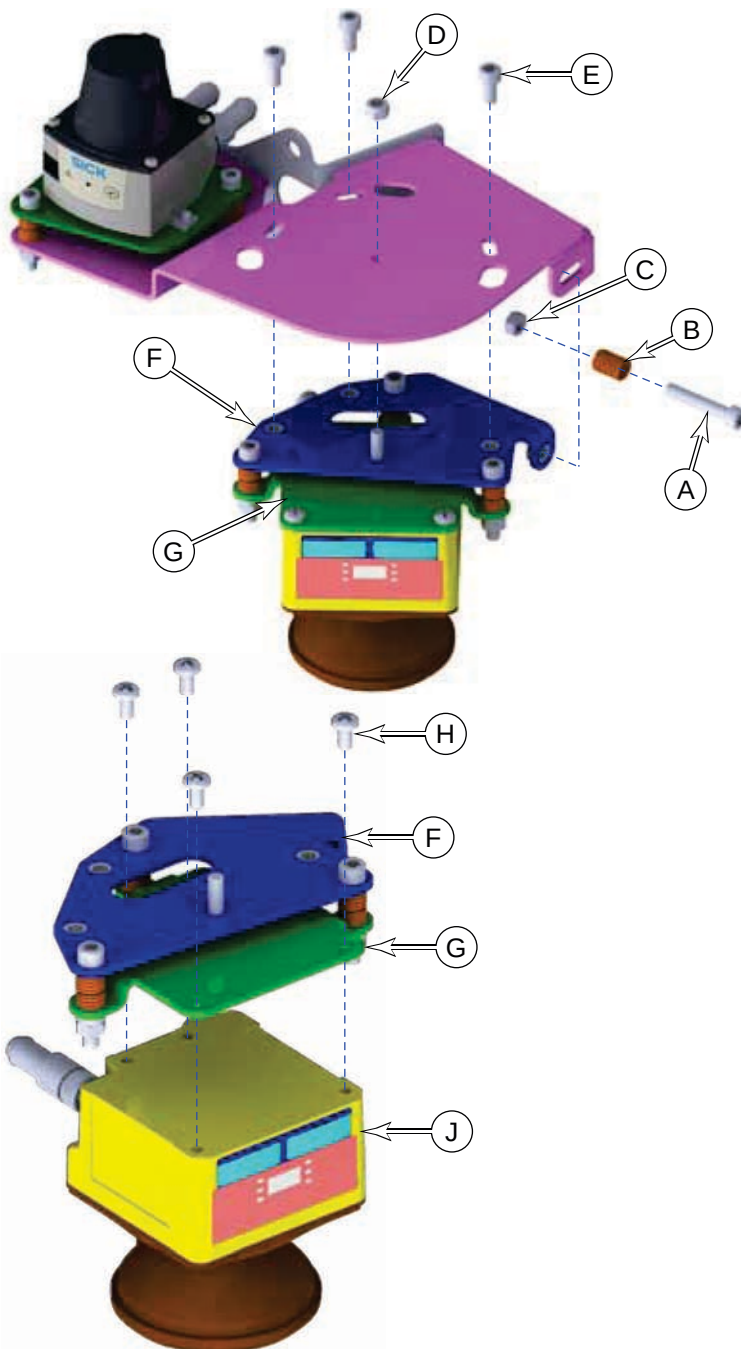


2. Remove the adjusting screw (A), jamb nut (C), and spring (B) from the leveling plate (F).
3. Remove the center pivot nut (D).
4. Remove the 3 mounting screws (E) from the leveling plate (F).



Note: Do not change or remove the 3 leveling screws that connect the leveling plate (F) to the sensor mounting plate (G).

5. Remove the leveling plate and sensor from the machine.
6. Remove the 4 screws (H) that secure the sensor (J) to the mounting plate (G), and remove the sensor.
7. The sensors are pre-configured by the factory. Make sure to replace the sensor with the appropriate left-hand sensor.
8. After reassembly, perform the [Safety Sensor Rotational Position Adjustment](#) described on page 122.
9. Perform the [Left Safety Sensor Level Check and Adjust](#) described on page 113.
10. Perform the [Safety \(Laser\) Sensor Performance Tests](#) described on page 132.



Right Safety Sensor



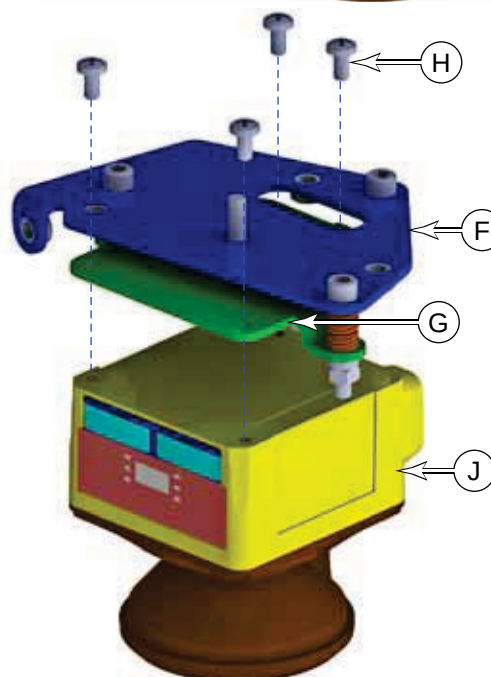
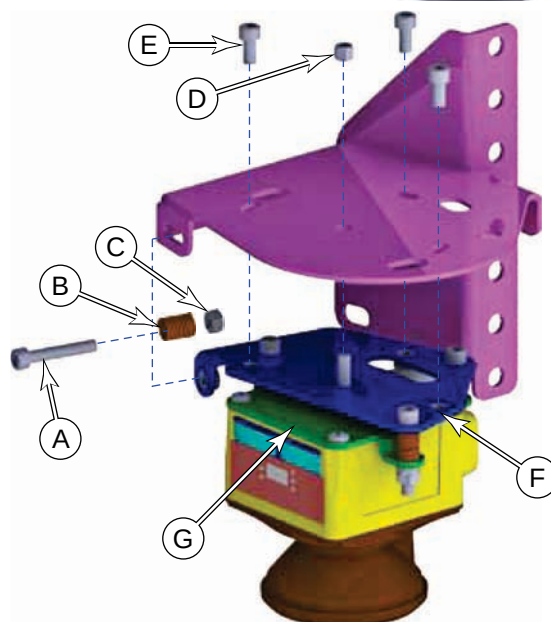
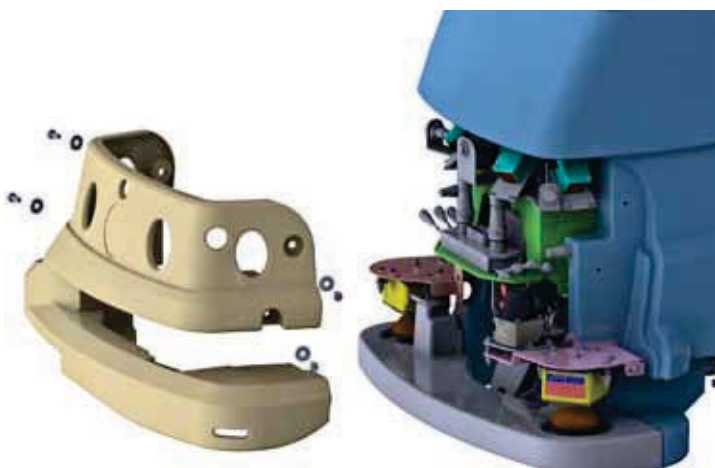
Note: After reinstallation, rotation and level adjustments you must perform the *Dynamic Safety System Test Of Safety Sensors*.

1. Remove the 4 screws and washers that secure the front nose to the recovery tank, and remove the front nose.
2. Remove the adjusting screw (A), jamb nut (C), and spring (B) from the leveling plate (F).
3. Remove the center pivot nut (D).
4. Remove the 3 mounting screws (E) from the leveling plate (F).



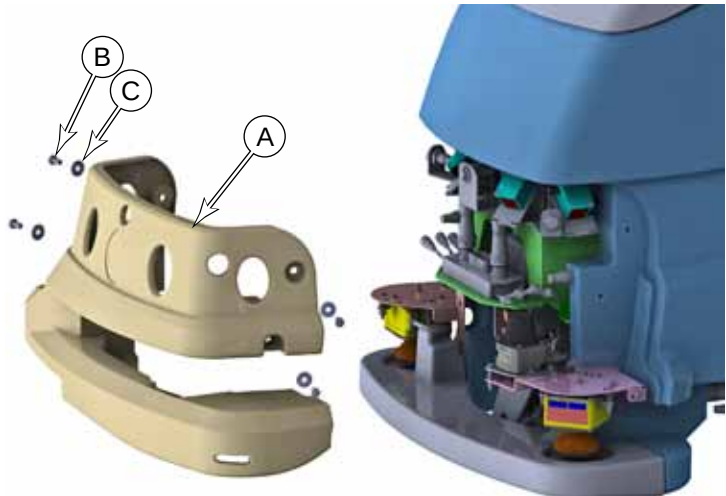
Note: Do not change or remove the 3 leveling screws that connect the leveling plate (F) to the sensor mounting plate (G).

5. Remove the leveling plate and sensor assembly from the machine.
6. Remove the 4 screws (H) that secure the sensor (J) to the mounting plate (G), and remove the sensor.
7. The sensors are pre-configured by the factory. Make sure to replace the sensor with the appropriate right-hand sensor.
8. After reassembly, perform the [Safety Sensor Rotational Position Adjustment](#) described on page 122.
9. Perform the [Left Safety Sensor Level Check and Adjust](#) described on page 113.
10. Perform the [Safety \(Laser\) Sensor Performance Tests](#) described on page 132.



Drop-off Sensors

1. Disconnect the main battery connector for safety any time you are working near the drive system.
2. Remove the 4 screws (B) and washers (C) that secure the front nose (A) to the recovery tank, and remove the front nose.

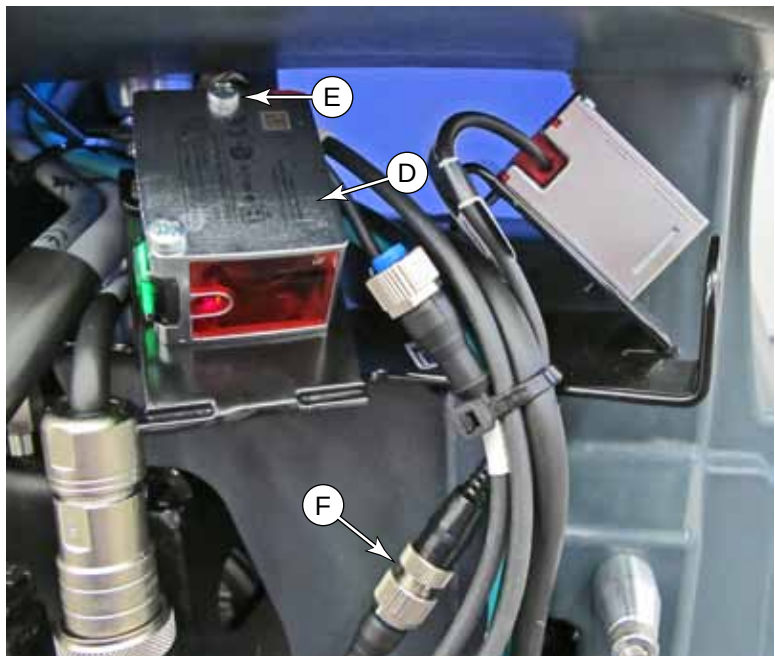


3. Using a right-angle screwdriver, or similar, remove the two screws (E) that secure the faulty sensor (D) to the sensor bracket (G).



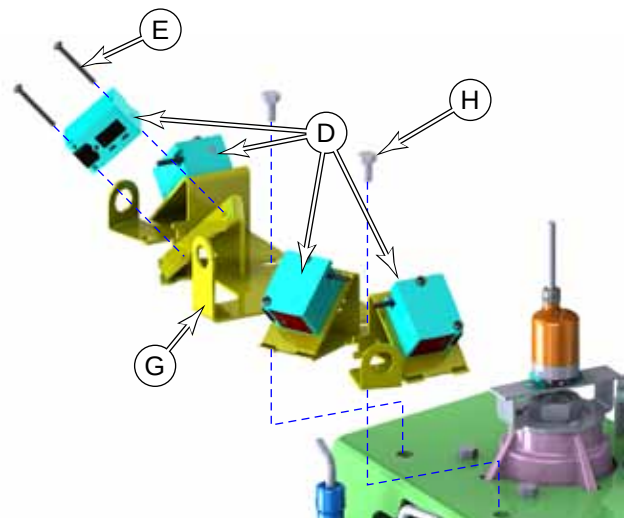
Note: If you do not have a right-angle driver to remove the upper screw, you can loosen or remove the two screws (H) that secure the entire sensor mounting bracket (G) to the machine's chassis, and move the bracket outward far enough to reach the screws.

4. Disconnect the threaded electrical connector (F) for the drop-off sensor, free up the wire as necessary, and remove the sensor from the machine.



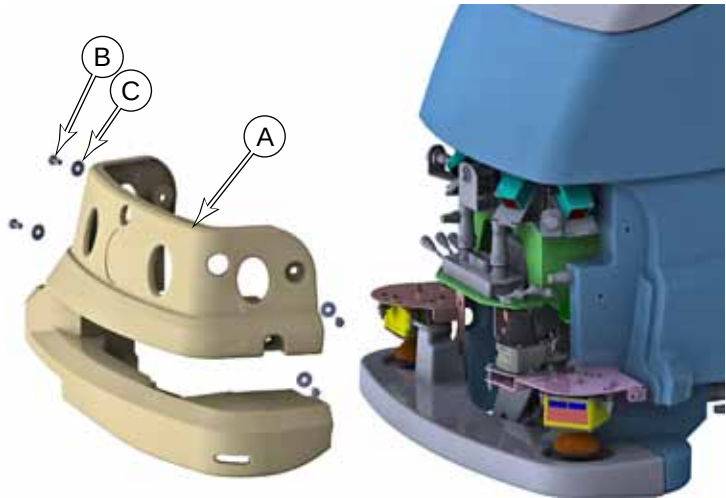
Replacement Notes

- Torque the sensor mounting screws to 25 in-lbs (2.82 Nm).
- Make sure to replace any cable ties cut during disassembly.
- Perform the [Drop-off Sensor Calibration](#) described on page 108.
- Perform the [Dynamic Floor Drop-off Simulation](#) described on page 129.

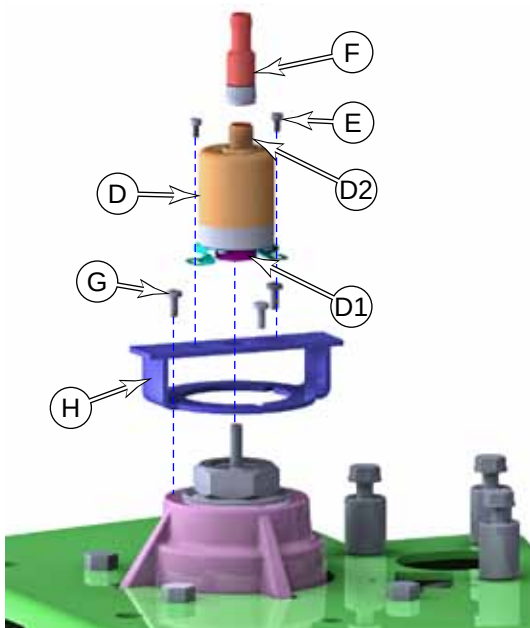


Drive Wheel Angle Sensor

1. Disconnect the main battery connector for safety any time you are working near the drive system.
2. Remove the 4 screws **(B)** and washers **(C)** that secure the front nose **(A)** to the recovery tank, and remove the front nose.

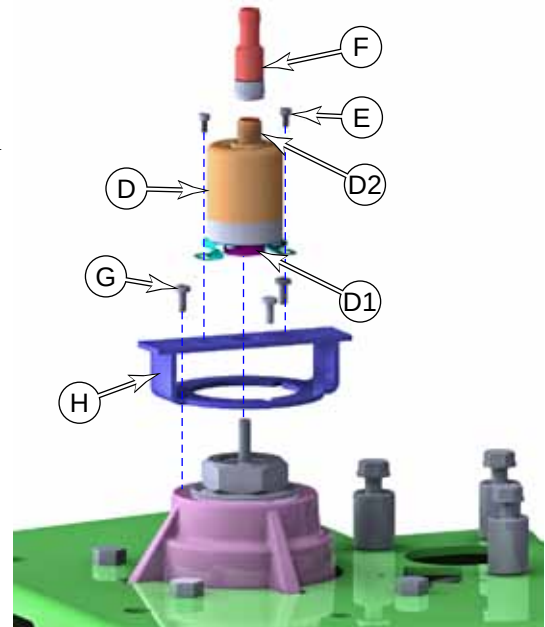


3. From the front of the machine, turn the drive wheel side to side as necessary to locate the clamping collar screw **(D1)**, and loosen the screw. (1.5mm hex key).
4. Disconnect the drive wheel angle sensor electrical connector **(F)**.
5. Depending on the accessibility of the screws, remove the encoder using one of the two steps below:
 - Remove the three screws **(G)**, and lift the mounting bracket **(H)** and sensor **(D)** off the steering spindle.
 - Remove the two screws **(E)** that secure the sensor **(D)** to the mounting bracket **(H)**.



Replacement Procedure

6. At your discretion, you may connect the encoder connector **(F)** to the encoder at any time during the procedure. However, the 6-pin rectangular connector **(X288)** will need to be disconnected during the centering procedure performed below.
7. Make sure the clamping collar screw **(D1)** is slightly loose.
8. Loosely secure the encoder to the mounting bracket **(D)**. Leave the two screws **(E)** loose enough for the encoder to be centered on the steering spindle.
9. If the mounting bracket **(H)** was previously removed, reinstall the bracket (and the encoder) by sliding the encoder hub over the steering spindle. Tighten the 3 screws **(G)** that secure the mounting bracket to the steering spindle hub.
10. With the encoder hub on the steering spindle, tighten the clamping collar screw **(D1)** to 1.55 in-lbs (0.18 Nm).
11. Tighten the 2 encoder mounting screws **(E)**.
12. Perform the [Drive Wheel Angle Sensor Centering](#) described on page 107.



Specifications

Sample Shop Voltage Measurements

The following tables contain some “real world” shop voltage measurements to help you recognize what “normal” looks like.

- Unless otherwise noted, all voltage readings are referenced to the main ground lug in the electrical bay.
- Some pin numbers are listed out of sequence when measurements require pin-to-pin voltage references instead of the main ground lug
- Values of “+Bat” mean the result is direct battery voltage without any resistive device in the circuit.
- Values of “≈24V” represent full battery voltage, regardless of the circuit path.

Autonomous Controller J6 Connector					
Pin#	Wire	Color	Function	Condition	Value
1					
2					
3	W400	GRN	CAN0 L		2.51V
4	W398	YEL	CAN0 H		2.53V
5	W499	RED	Drive Wheel Angle Sensor Power		24.8V
6	W500	BLU	Drive Angle Sensor Input	Full Left	1.33V
				Straight	1.92V
				Full Right	2.51V
7					
8	W519	GRN	Chassis Ground (Bonded to battery ground inside of Autonomy module)	Bond Intact	≈0V
				Bond Broken	8.0V
9	W313	YEL/GRN	Wheel Encoder, Left A1	Open	24.2V
				Closed	0.16V
				Moving	12.2V
10					
11	W318	GRN/YEL	Wheel Encoder, Right A2	Open	24.2V
				Closed	0.16V
				Moving	12.2V
12					
13	W501	WHT	Sensor Ground, Drive Angle		0.087V
14	W505	ORN/GRN	Left Steering Interlock Out	Not active	0.016V
15	W506	ORN/YEL	Right Steering Interlock Out	Not active	0.021V
16	W320	BLK	Sensor Ground, Right Wheel Encoder		0.087V
17	W319	BLU/BRN	Wheel Encoder, Right B2	Open	24.2V
				Closed	0.16V
				Moving	12.2V

Autonomous Controller J6 Connector					
Pin#	Wire	Color	Function	Condition	Value
18	W320	BLK	Wheel Encoder, Left B1	Open	24.2V
				Closed	0.16V
				Moving	12.2V
19	W315	BLK	Sensor Ground, Left Wheel Encoder		0.088V
20	W298	BLU/VIO	AUTO OK	Active, OK	24.2V
				Inactive, Not OK	0.016V
21	W310	GRY	Key Switch Input (KSI)		25.0V
22					
23	W451	YEL/BRN	Main B+ Input		24.8V

Autonomous Controller J11 Connector					
Pin#	Wire	Color	Function	Condition	Value
1			+V (Power for Autonomous Sensors)	Power on	24.43V
2			B- (Power for Autonomous Sensors)	Power on	0.072V
3			Area Address A+	Binary 0	0.43V
				Binary 1	20.28V
4			Area Address A- (Inverse A)	Binary 0	20.28V
				Binary 1	0.43V
5			Area Address B+	See above. Binary Address lines. Some Examples: 7 = 11100 8 = 00010 13 = 10110 22 = 01101	
6			Area Address B-		
7			Area Address C+		
8			Area Address C-		
9			Area Address D+		
10			Area Address D-		
11			Area Address E+		
12			Area Address E-		
13			LH Protection Zone	Clear (Green LED)	23.68V
14			LH Protection Zone, Redundant	Active (Red LED)	0.085V
15			LH Warning 1	Clear (No LED)	23.8V
				Active (Orange LED)	0.089V
16			LH Warning 2	Always Active (Orange LED)	0.098V
17			RH Protection Zone	Clear (Green LED)	23.68V
18			RH Protection Zone, Redundant	Active (Red LED)	0.085V
19			RH Warning 1	Clear (No LED)	23.8V
				Active (Orange LED)	0.089V
20			RH Warning 2	Always Active (Orange LED)	0.098V
21 to 26			Not Used		

Autonomous Controller J11 Connector					
Pin#	Wire	Color	Function	Condition	Value
27			Rear LH Drop-off Sensor signal	Sensing Floor ----- Blocked with hand	1.035V ----- 0.660V
28			Front LH Drop-off Sensor signal		
29			Front RH Drop-off Sensor signal		
30			Rear RH Drop-off Sensor signal		
31 to 34			Not used		
35		GRN	Chassis Ground		0V

Special Tools

Drive Position Encoder Calibration Cable p/n 56122727



Laser Alignment Kit p/n 56122718



Target Cylinders

Small p/n 56122722

Large p/n 56122723



10-Chassis System

Functional Description

The Chassis is a welded steel framework that provides the backbone structure on which the rest of the machine components are mounted.

The chassis itself doesn't require any specific maintenance, but is discussed here simply to describe mounting dependencies.

Due to the concentrated weight, the battery tray mounts directly to the chassis, for stability and support.

The operator platform also mounts directly to the chassis between the rear wheels. Removing the operator platform is required to service the operator foot switches, and also the rear wheel encoders.



The Battery Charger is mounted to the bottom of the Chassis.



The drive and steering assembly bolts to, and forms, the front of the chassis.



The scrub deck hangs below the chassis on a set of parallel link arms to permit up and down movement of the deck.



Removal and Installation

Tipping the Machine

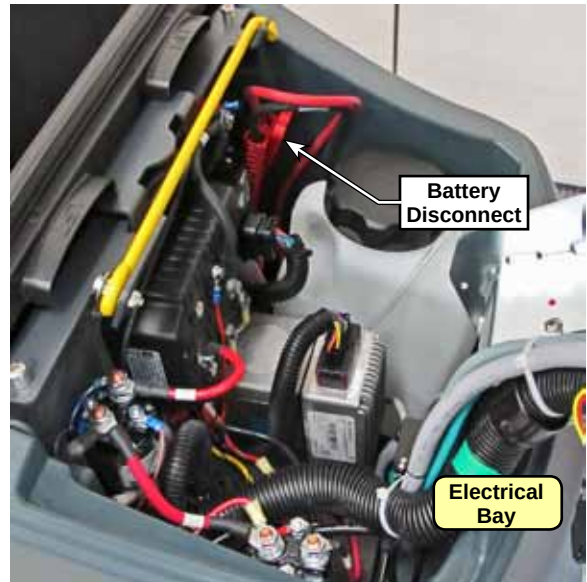
This is a prerequisite procedure for laying the machine on its side in order to better access components on the underside of the machine.

1. Shut down the machine and disconnect the main battery disconnect in the electrical bay.

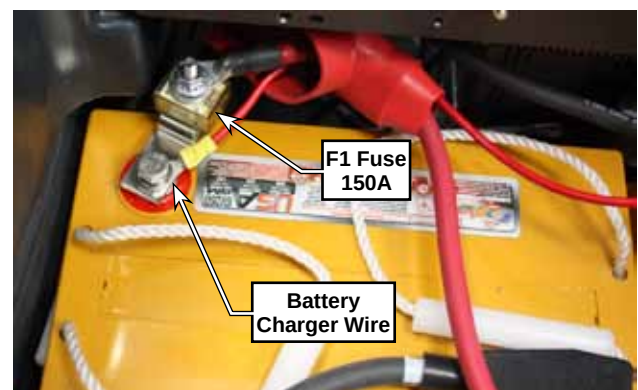
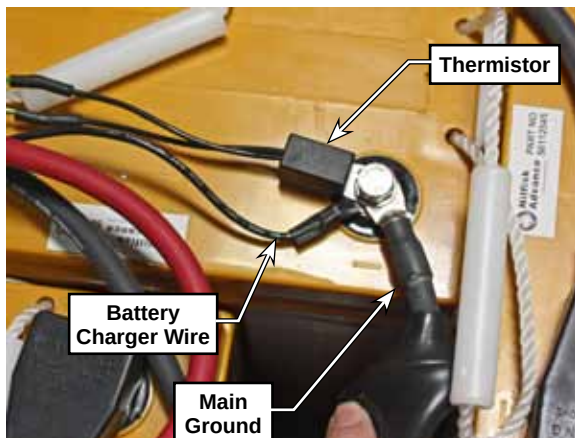
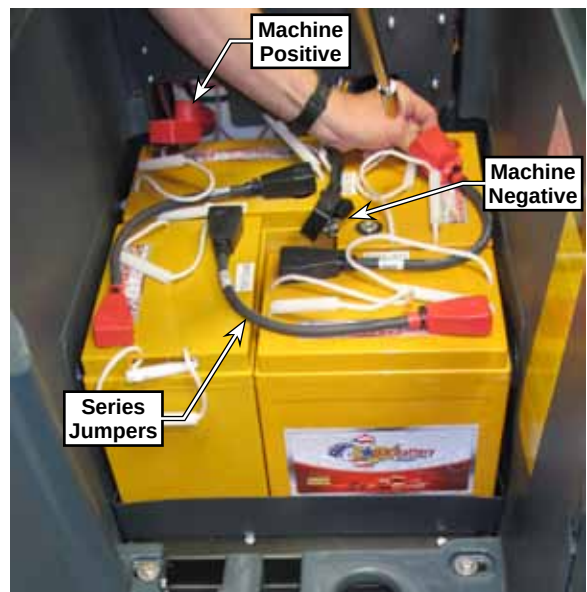


CAUTION: It is important to unplug the main disconnect before removing battery cables to avoid power spikes to the control modules that otherwise are always receiving power.

2. Drain the solution tank and recovery tank, and remove the detergent bottle from the machine.
3. Remove the [Recovery Tank](#) described on page 346.



4. Disconnect the machine negative terminals, including:
 - Main ground
 - Thermistor
 - Battery Charger
5. Disconnect the machine positive terminals, including:
 - F1 Fuse
 - Battery Charger
6. Disconnect the series jumpers from the remaining batteries.



7. Lift the 4 batteries out of the battery bay and set them aside.



8. If the subsequent procedure will require access to any component at the front of the machine, make sure to remove the front nose before tipping the machine.

- Remove the 4 screws and washers that secure the front nose to the recovery tank, and remove the front nose.



CAUTION: Do not remove the front crossbar, as this must protect the safety lasers while the machine is on its side.



9. Close the machine hood. If necessary, secure it with some tape to prevent it from opening while the machine is being tipped.



CAUTION: Do not tip the machine toward the right side, especially if the front nose is removed. The right safety laser could be damaged.

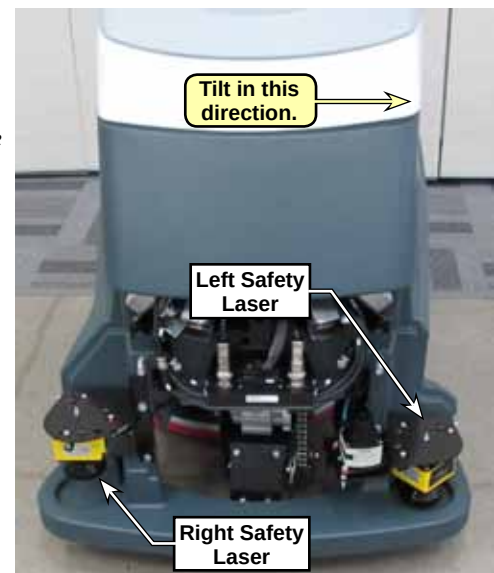


10. Place a protective mat, such as cardboard, on the floor to the left of the machine.

11. Carefully tip the machine toward its left side. Make sure no components will be damaged as the machine lays on its side.



Note: After the batteries are reinstalled, plug the battery charger into facility power for 30 seconds to reset the CANBus communication.



20 - Wheel System - Traction

Functional Description

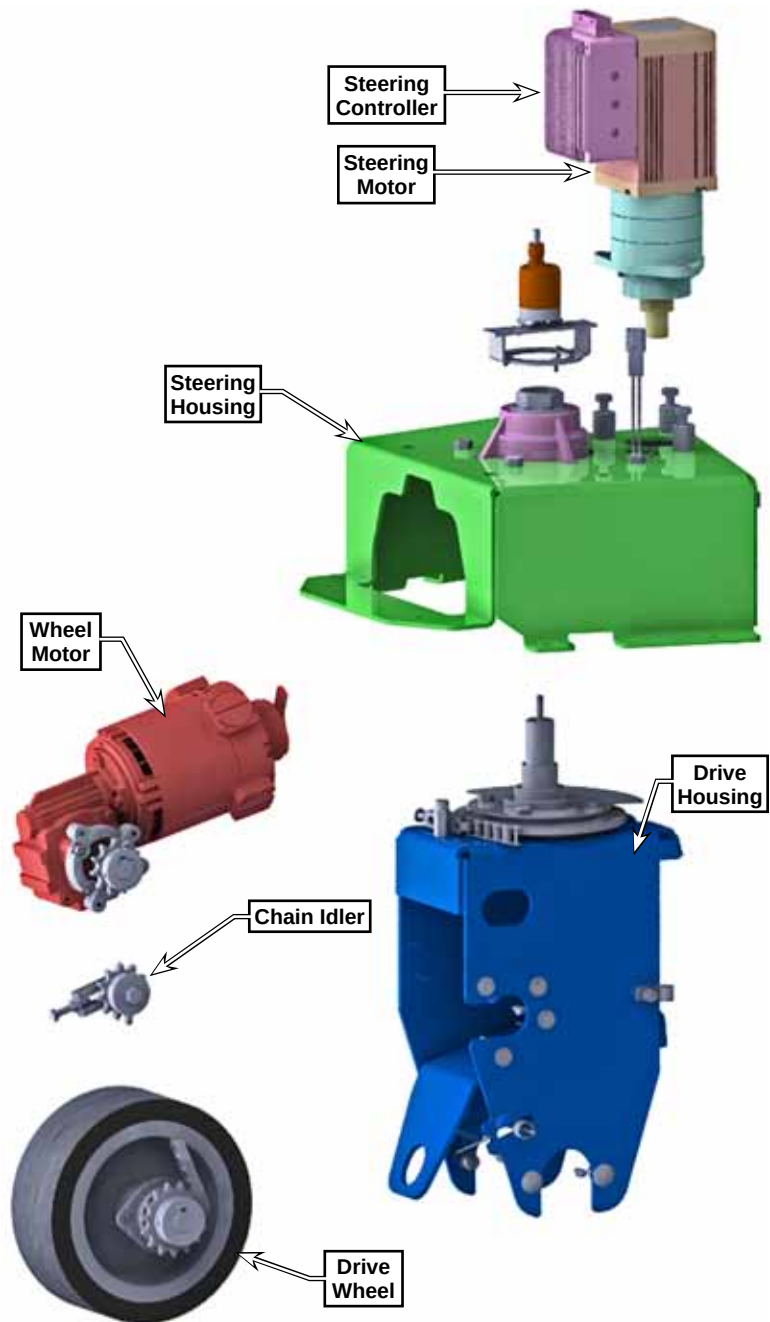
The machine is propelled by the forward drive wheel, which is chain-driven from the drive motor, which contains a right-angle gear box. The drive motor operates at 24 volts, PWM-DC (PWM is Pulse Width Modulated). The wheel drive assembly is attached to the steering assembly, which is controlled by its own motor and controller.

The drive wheel is supported in the lower drive housing with sealed bearings and bolt-in pillow blocks. The drive chain has a minor gear reduction of 11:15, as the upper sprocket has 11 teeth and the lower sprocket has 15 teeth. The majority of the drive's total gear reduction comes from the right-angle worm drive gear box attached to the drive motor. This gear reduction increases motor torque available at the wheel.

Attached to the drive motor's shaft is an electromechanical brake. This brake is active-off, which means that the brake is always apply a braking force to the motor, unless the brake is receiving a power signal, which releases the brake.

A Curtis 1229 motor controller monitors and powers the drive motor. While this setup is fairly typical, what is unique on the Liberty machine is that the drive controller receives speed commands from two different sources, depending on which mode the system is functioning.

In manual mode, the drive controller operates as a typical scrubbing machine, using the go-pedal and speed potentiometer for input. However, in autonomous mode, the drive controller receives its operational commands from the Main Machine Controller via the CANBus system.

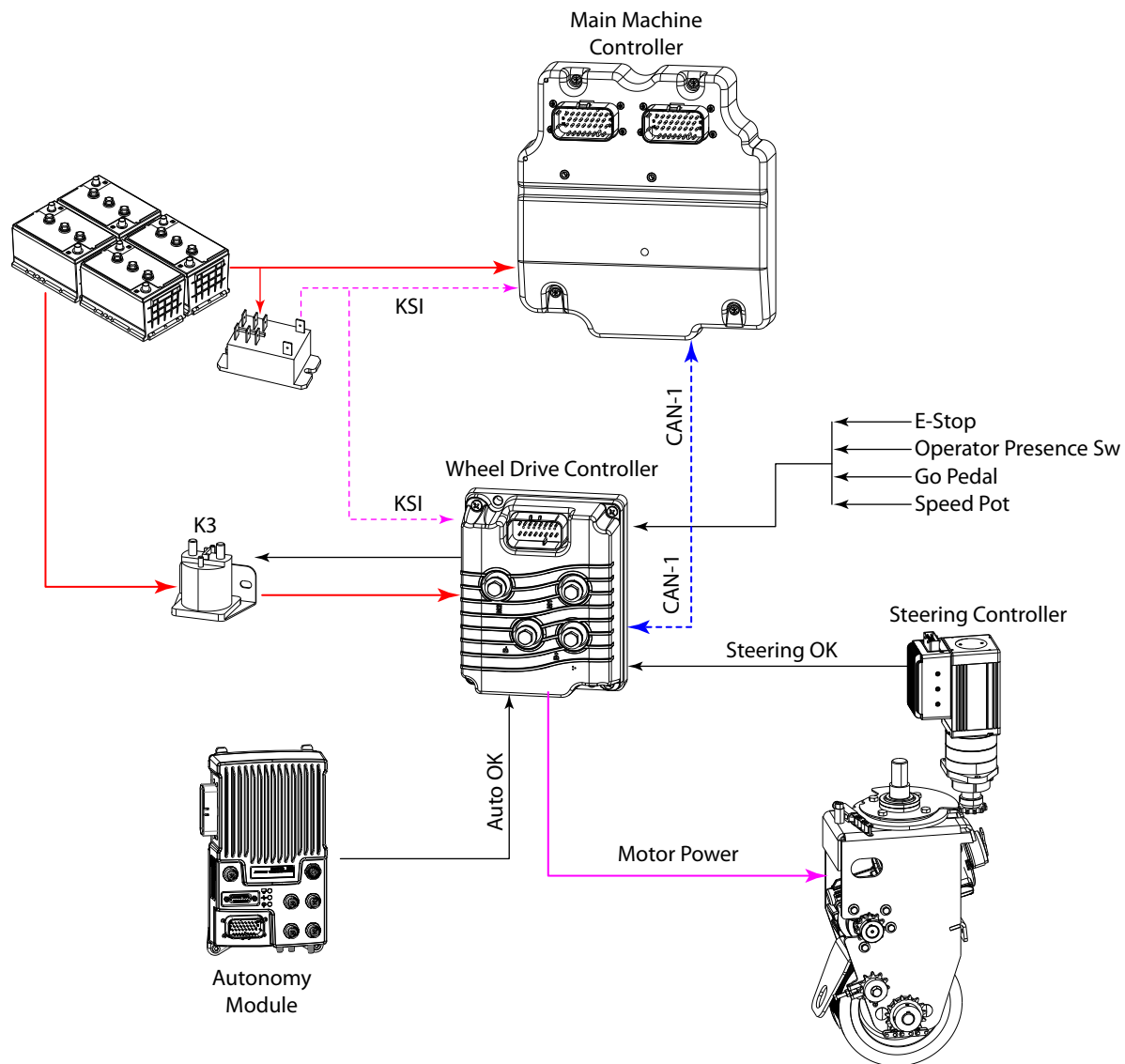


Wheel Drive Controller

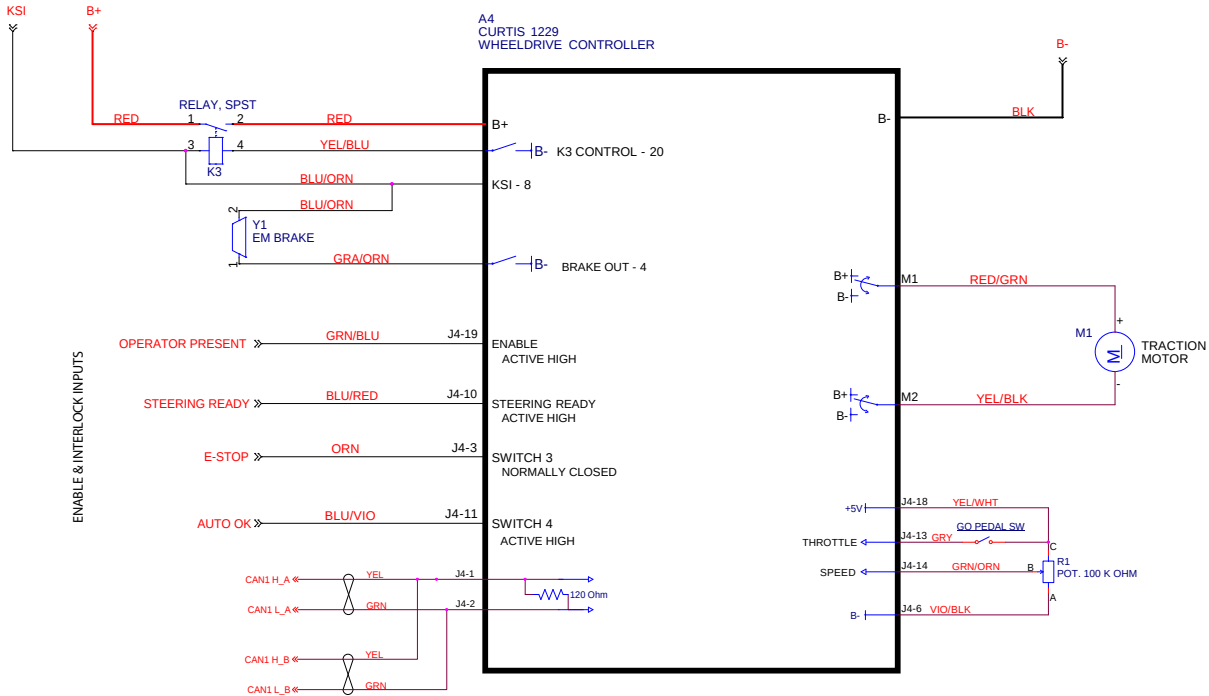
The primary purpose of the wheel drive controller is to control the speed and direction of the wheel motor while monitoring its performance. Control power for the module comes from the KSI relay, which is controlled by the Main Machine Controller. Drive power is controlled from the K3 relay, which is controlled by the drive controller itself.

The controller has several direct and indirect interlock inputs that can disable the drive, depending on its current mode. The direct interlocks will disable the drive while in any mode, and include the Auto-OK, Steering-OK, and E-Stop. The Operator Presence switch is an indirect interlock, and disables the drive (when no operator is present) only when in manual mode. While not considered an interlock, it should be noted that the Main Machine Controller can also disable the drive via CANBus commands.

The Main Machine Controller, through CANBus commands, determines whether the drive controller is functioning in manual mode or autonomous mode. The significant difference is which input is used for speed control.



Drive Control



The incoming (On/Off) control power to the drive module comes from the KSI relay at the Main Machine Controller. This activates the drive module, but the drive module itself has control over its own high-current power, via the K3 relay. The positive side of the K3 relay coil is connected to KSI, and when the drive controller needs output power, it switches the KSI Control line to ground to active the K3 relay.

The drive brake is “Active-Off”, meaning that the brake is engaged when no power is present. Power is required to release the brake. The drive brake operates in a similar manner to control power. Its positive side is connected to the KSI relay, and the drive controller switches the Brake Control Output to ground when it needs the brake released.

Manual Speed Control

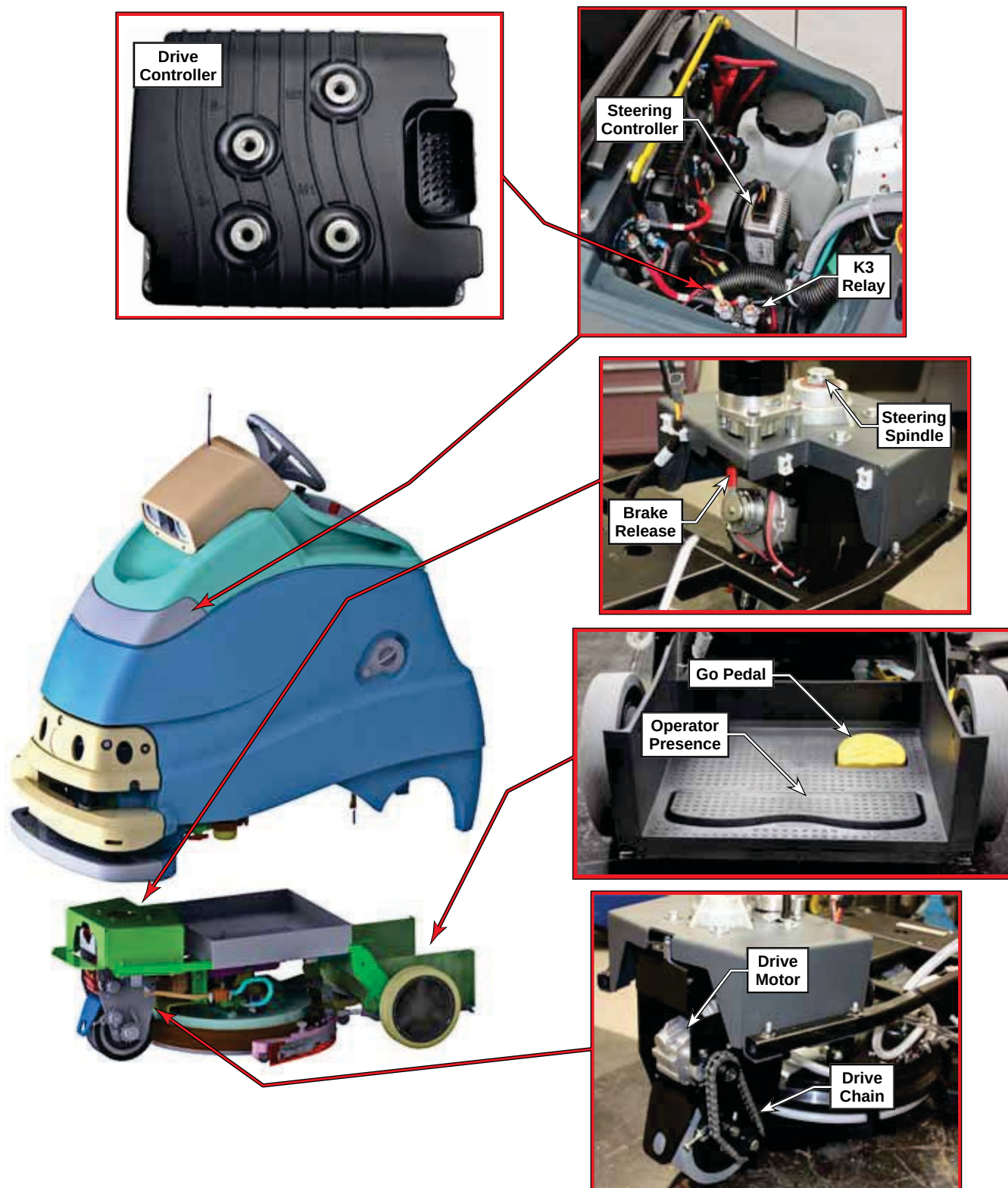
The Main Machine Controller determines whether the drive is in manual mode or autonomous mode. When in autonomous mode, the Main Machine Controller also controls speed and direction commands to the drive controller. However, when in manual mode, the drive controller receives speed commands from the operator’s controls (direction is still controlled by the Main Machine Controller).

Whenever the Go Pedal is depressed, the controller is commanded to full throttle, however the speed is limited by the potentiometer through the speed limit input. When the Go Pedal is depressed, 5 volts is passed into the Throttle input (J1-13), commanding a full throttle response. The speed limit potentiometer is biased with +5V and GND, and the wiper presents a voltage between 0 and 5 volts to the speed limit input (J1-14). The lower this value, the faster the machine speed limit is set.

The Forward/Reverse switches on the operator control panel are connected to the Main Machine Controller. The Main Machine Controller sends this direction command to the drive controller via the CANBus.

Component Locations

The diagram below shows the primary component locations related to the drive system.

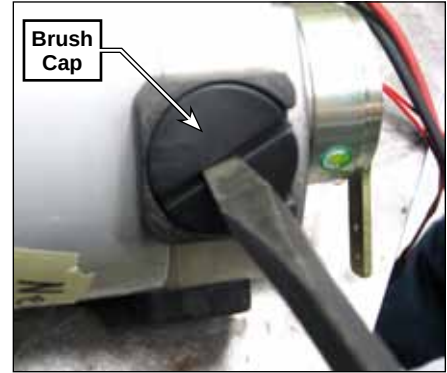


Maintenance and Adjustment

Wheel Motor Brushes

The wheel motor contains four carbon brushes. These make electrical contact to the rotating commutator on the motor's rotor, and will wear with time. All four brushes must be replaced together.

1. Remove the [Drive Wheel Motor](#) described on page 196.
2. Using a wide-blade screw driver, remove the brush cap holding the brush in the motor.



3. Carefully pry out the old brush holder from the motor. It is spring loaded, and may pop out as soon as you remove the cap.
4. Install a new Brush, then reinstall the Cap.
5. Reinstall the Drive Motor into the Drive Wheel Frame.
6. Reinstall the Drive Assembly into the machine.
7. When complete, adjust the drive chain tension as described in the [“Drive Chain Maintenance and Adjustment”](#) on page 173.

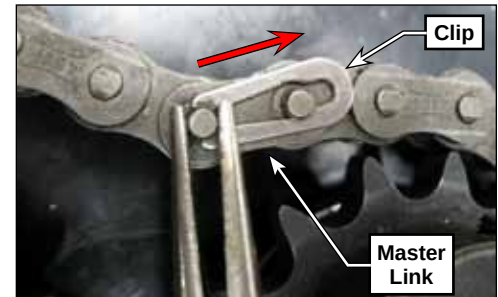


Drive Chain Maintenance and Adjustment

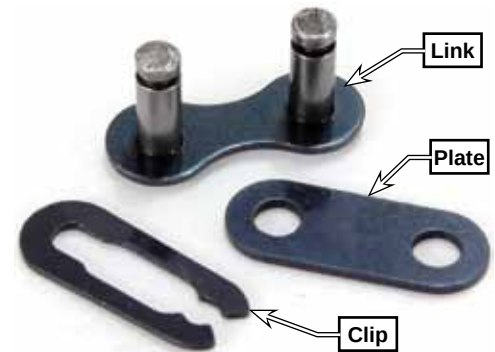
This is a general followup procedure for servicing the chain either independently, or as conclusion to other procedures.

Chain Removal

In most other procedures, the chain is removed when one of the sprockets is removed. If the chain needs to be removed without removing a sprocket, the master link in the chain can be removed and the chain separated. To separate the chain, use a small pliers to push the master clip back, off of the posts, as shown. (Place one jaw on the post, and one jaw on the clip, and squeeze the pliers closed.) Then remove the plate and link.



After the chain is reassembled, the same technique is used for installing the clip across the link posts. Place one jaw of the pliers against the link post, and the other jaw against the back of the clip, and squeeze the pliers closed.



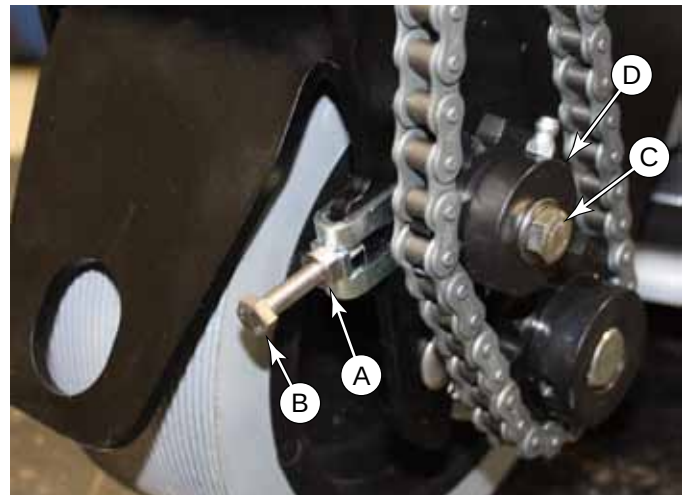
Chain Tension

In procedures where the chain is removed with a sprocket, it typically requires the tension on the chain to be released. Furthermore, the chain tension should be periodically inspected and adjusted as necessary.



Note: *If the chain requires repeated re-tensioning, it is a sign that the chain has worn and needs replacement. Inspect all of the sprockets for wear too. A worn chain can wear the sprockets, and vice versa.*

1. Using two 13mm wrenches, slightly loosen the axle bolt (C) of the idler sprocket (D), enough for the sprocket to slide. (The bolt has a Nylok nut on the back side.)
2. Using a 10mm wrench, loosen the jamb nut (A) from the adjuster screw (B).
3. Begin tightening the adjuster screw (B) to apply tension to the chain. Adjust the Screw so the chain deflects approximately ¼" to ½" when pressed with moderate force.
4. While holding the adjuster screw from turning, retighten the jamb nut.

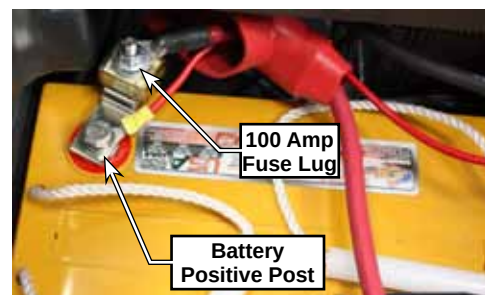
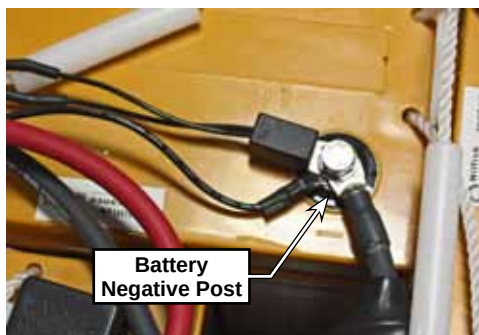
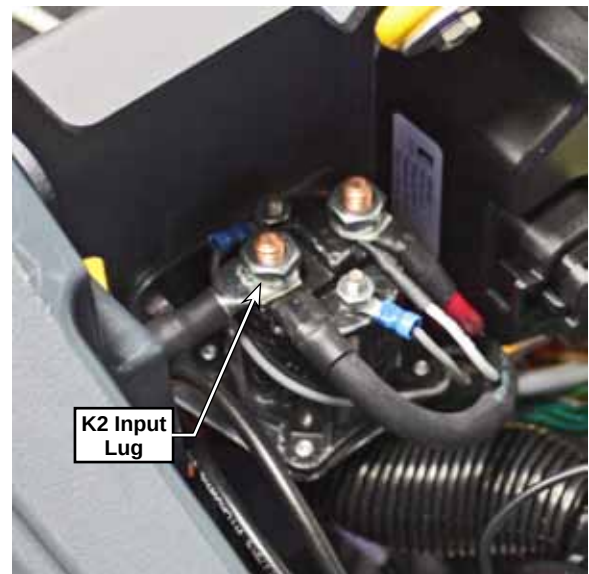
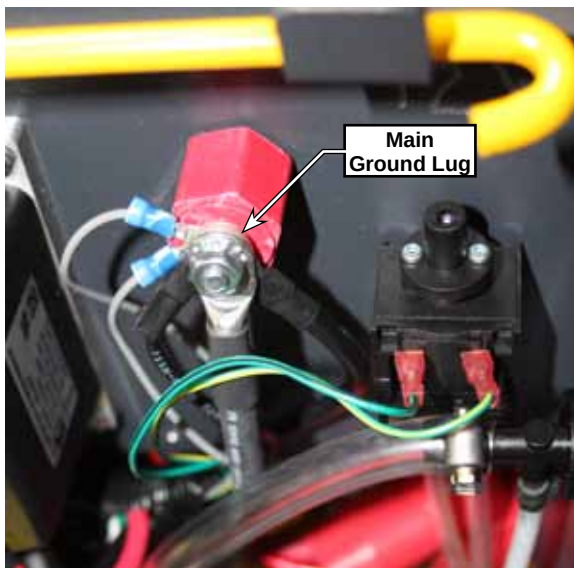


Troubleshooting

Terminology

Voltage measurements are always taken between two points. The first point is the location of interest, and the second point is the reference point. These designations are irrespective of polarity, and the reference point may be at a higher voltage than the test point. Some of the common reference points used in the troubleshooting descriptions are shown below.

- **Main Ground Lug:** This is the main distribution point (node) for all battery negative connections throughout the system.
- **K2 Input Lug:** This is the main distribution point (node) for all battery positive connections throughout the system. (Note that the K2 output lug serves only the Power module.)
- **Battery Posts:** These reference points are generally used only when the two distribution nodes above are suspect.



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Drive Controller Error Codes

3-001 Excess M1 Drv Whl Mtr Current

Description	Hardware failsafe, excessive motor current.	
Setting Conditions	Drive amperage has exceeded 80 amps for 10 seconds.	When Monitored Always
Possible Causes	It is likely that normal overload protection for the drive controller has failed, and the controller's hardware failsafe was activated. While the initial cause may be external, the drive controller itself may have failed.	
Initial Action	Disconnect the main battery connector in the electrical bay.	
Troubleshooting Steps		
1. Inspect the machine wiring for overload damage. • Check the main fuse on the positive battery terminal. • Inspect the high-power wiring between the batteries and the K2 relay, K3 relay, and Main Ground Lug for signs of overheating or damage. • Inspect the wiring between the drive controller and the K3 relay and Main Ground Lug. • Inspect the main machine harness at the J4 connector. 2. Disconnect the motor output wires from the drive controller. a. Check the resistance between the two motor output wires. – With the motor connected the resistance should be approximately 0.3 ohms. – With the motor disconnected, the resistance should be open-circuit. b. Check the resistance between each motor wire and both Bat+ and Bat-. – The resistance should be open-circuit. 3. While being prepared to rapidly disconnect the main battery connector, re-power the machine. • If the condition persists, the drive controller needs replacement. 4. Power down the machine, and reconnect the drive motor. 5. While being prepared to rapidly disconnect the main battery connector, re-power the machine. • If the condition resumes, the drive motor needs replacement. • If the drive controller was not already replaced, and the drive system is non-functional, replace the drive controller.		

3-002 Internal Clock Failure

Description	The controller has detected an error with the internal clock.
--------------------	---

Setting Conditions	When Monitored
	Always

Possible Causes	Faulty drive controller
------------------------	-------------------------

Initial Action	Reboot the machine. If the error persists, replace the drive controller.
-----------------------	--

Troubleshooting Steps

3-009 A3 Calibration Reset

Description

Setting Conditions	When Monitored
	Always

Possible Causes	Faulty drive controller
------------------------	-------------------------

Initial Action	Reboot the machine. If the error persists, replace the drive controller.
-----------------------	--

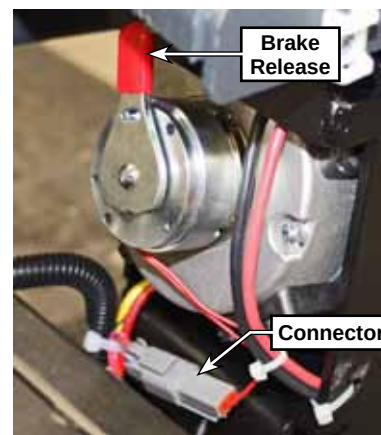
Troubleshooting Steps

3-010 Driver 1or2 Ovrcrnt

Description	The drive controller detected excessive current to the brake solenoid.	
Setting Conditions	Same	When Monitored Always
Possible Causes	• Faulty brake solenoid • Short circuit in wiring	

Initial Action**Troubleshooting Steps**

1. Disconnect the main battery connector for safety.
2. Disconnect the EM brake connector located just below the traction motor.
3. While taking precautions that the machine cannot roll, manually disengage the EM brake by rotating the brake release lever.
4. Set the speed control to minimum, and command the machine to move.
 - If the error persists, repair or replace the orange/green wire between the brake and the J4 connector at the drive controller.
 - If the error clears (changes to open circuit), replace the EM brake solenoid (see parts list for brake solenoid kit part number).
5. Make sure to re-engage the manual brake lever.

**3-011 K3 Cntctr Coil Open**

Description	The drive controller has detected that the K3 contactor coil is open circuit.	
Setting Conditions	Same	When Monitored Always
Possible Causes	• Disconnected/broken wire • Faulty K3 relay	

Initial Action None**Troubleshooting Steps**

1. With the machine powered down, disconnect the Yellow/Blue wire from the K3 relay coil.
2. Check the resistance across the two terminals of the relay coil.
 - If the resistance is high (open circuit), replace the relay.
3. Check the resistance of the Yellow/Blue wire between the relay and J4-20 at the drive controller.
 - If the resistance is high (open circuit), repair or replace the wire.
 - Note that the positive side of the relay is not suspect, because that comes from the KSI circuit, which powers the drive module itself.

3-012 *Emrgcy Reverse Fault*

Description	False Error. This function is not used..	
Setting Conditions	Same	When Monitored
		Always
Possible Causes	Internal error	
Initial Action	Reboot the machine. If the error persists, replace the drive controller.	
Troubleshooting Steps		

3-013 *A3 EEPROM Fault*

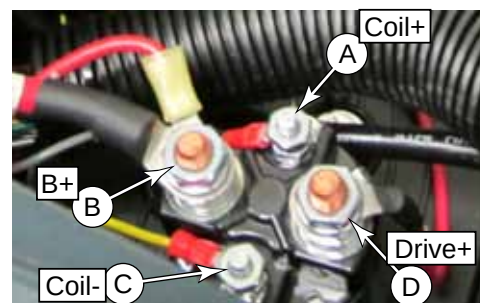
Description	The drive controller could not write to EEPROM.	
Setting Conditions	Same	When Monitored Always
Possible Causes	Internal error	
Initial Action	Reboot the machine. If the error persists, replace the drive controller.	
Troubleshooting Steps		

3-015 K3 Contact Not Closing

Description	K3 relay failed in the open condition.	
Setting Conditions	No voltage detected at the B+ input lug when the K3 relay coil was commanded to close.	When Monitored Always
Possible Causes	- Faulty relay - Loose wire at the relay	
Initial Action	None	

Troubleshooting Steps**Notes:**

- The relay has no mandatory polarity. Wire connections to the coil (**A** and **C**) may be reversed, or contacts (**B** and **D**) may be reversed. (Presumed connections show to the right.)
- Incoming main battery power (**B**) to the K3 relay is not suspect, as the KSI relay would also be dead, and the whole machine would not be powered.
- The Drive controller disables the J4-20 output (**C**) when this error is set. So checking for voltage at the relay coil will be indeterminate.



- Check the function of the relay.
 - Check the voltage from the Gray wire (**A**) to the main ground lug.
 - If the voltage is not 24 volts, repair or replace the gray wire between the K3 relay and the KSI relay.
 - Disconnect the Yellow/Blue control wire (**C**) from the relay (to protect the Drive controller), and jumper that relay post to the main ground lug.
 - If you don't hear the relay click closed, replace the relay.
 - If you do hear the relay click closed, leave the jumper in place and go to [Step 2](#) to check the output of the relay (**D**).
- With the relay closed from the previous step, check the voltage between the relay output contact (**D**) and the main ground lug.
 - If the voltage is not near 24 volts, replace the relay. (Note: Battery+ (**B**) is not suspect, but you may wish to confirm B+ is present at (**B**) before replacing the relay.)
 - If the voltage is at or near 24 volts, leave the jumper connected and continue to [Step 3](#) to check voltage at the Drive controller.
- With the relay closed from the previous step, check the voltage between the Drive controller's B+ lug and the main ground lug.
 - If the voltage is not near 24 volts, repair or replace the wire between the K3 relay and Drive controller.
 - If the voltage is at or near 24 volts, continue to [Step 4](#).
- With the Yellow/Blue wire still disconnected from the relay, check the continuity between J4-20 and the relay connector.
 - If the resistance is not at or near 0 ohms, repair or replace the wire.
 - If the resistance is at or near 0 ohms, reconnect the wire and reboot the machine. If the error persists, replace the Drive controller.

3-016 M1/M2 Outputs Shorted

Description	Drive wheel motor shorted	
Setting Conditions	The drive controller has detected excessive current to the drive wheel motor.	When Monitored Always
Possible Causes	- Faulty drive motor - Short to battery power in the drive wiring.	
Initial Action	None	

Troubleshooting Steps

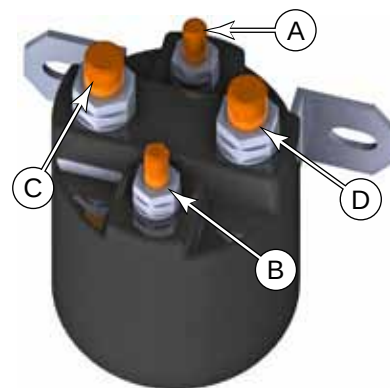
1. Disconnect the traction motor connector at the traction motor.
2. Clear the error and set the speed limit to slow.
3. Command the traction motor to operate.
 - If the error persists, the short is located in the wiring between the drive controller and the motor.
 - If the error clears (changes to open circuit error) the motor is the cause.

3-017 K3 Contactor Closed

Description	K3 relay contacts welded	
Setting Conditions	The drive controller detected power on the B+ input lug when the K3 relay was not commanded to close.	When Monitored Always
Possible Causes	- Faulty K3 relay - Short to ground on relay control wire	
Initial Action	None	

Troubleshooting Steps

1. Check the voltage across the relay coil contacts (A & B).
 - If the voltage is 24 volts, inspect the Yellow/Blue wire between the relay and drive controller for a short to ground.
 - If the voltage is at or near zero volts, the coil is not energized, continue.
2. Disconnect the relay output wire (single red wire) from the K3 relay.
3. Check the voltage between the empty relay post and the main ground post in the electrical bay.
 - If the voltage remains 24 volts, the relay contacts are welded. Replace the relay.
 - If the voltage is not 24 volts, repair or replace the red output wire between the relay and the drive controller.



3-019 *Lost Comm-A1 Mn Cntrlr*

Description	Can message timeout.
--------------------	----------------------

Setting Conditions	No CAN messages received within the timeout period.
---------------------------	---

When Monitored
Always

Possible Causes

Initial Action

Troubleshooting Steps

--

Supervisor Related Error	Note	Pin	Range	Normal
3-020 <i>A3 Supervisor Comm</i>	Note 1			
3-021 <i>A3 Supervisor Watchdog</i>	Note 1			
3-022 <i>Go Pedal (POT 1) Fault</i>	Note 3	J4-13	0 to 5.0 Volts	5.0 V
3-023 <i>Spd Lmt (POT 2) Fault</i>	Note 3	J4-14	0 to 5.0 Volts	0 to 5.0 V
3-024 <i>Supervisor Pot3 Fault</i>	Note 2			
3-025 <i>5V Output Fault</i>	Note 4	J4-18	4.5 to 5.5 Volts	
3-026 <i>S1 Operator Pr Sw Flt</i>	Note 3	J4-19	0 to B+ Volts	0 or B+
3-027 <i>Steer Ready Input Flt</i>	Note 3	J4-10	0 to B+ Volts	6 or 12 V
3-028 <i>S2 E-stop fault</i>	Note 3	J4-3	0 to B+ Volts	0 or B+
3-029 <i>Auto OK Input Fault</i>	Note 3	J4-11	0 to B+ Volts	0 or B+
3-030 <i>Supervisor Sw5 Fault</i>	Note 2			
3-031 <i>KSI Input Fault</i>	Note 5	J4-8	B+	B+
3-032 <i>Motor Speed Fault</i>	Note 1			
3-033 <i>Controller Check Fault</i>	Note 1			

Description Internal disagreement between the drive processor and the safety supervisor processor.

Setting Conditions	When Monitored
	Always

Possible Causes To comply with machine safety directives, the drive controller contains redundant processes to monitor critical functions. These errors are initiated when those processes do not agree with one another. This may be caused by either an anomalous signal, or an internal processor fault.

Initial Action

Troubleshooting Steps

Note 1: For these errors, reboot the machine. If the error persists, replace the drive controller.

Note 2: These inputs are not connected. Verify there are no misplaced connections and reboot the machine. If the error persists, replace the drive controller.

Note 3: Inspect (and repair if necessary) the external circuit function as described below. If the circuit is functioning properly and the error persists, replace the drive controller.

1. Check the voltage at the J4 contact identified in the table above.
 - If the voltage is not normal, as listed in the table, correct the circuit.
 - If the voltage is within the permitted range, as listed in the table, and the error persists, replace the drive controller.

Note 4: Check the output voltage from the J4 contact identified in the table above.

- If the voltage is out of range due to an external fault, correct that fault, and retest.
- If no external fault is found, regardless whether the voltage is in-range or out-of-range, replace the drive controller.

Note 5: Check the KSI voltage. If the voltage is stable and at normal battery voltage, replace the drive controller.

3-034 External Supply Fault

Description	The combined current from the internal 5V and 17V power supplies is out of range.	
Setting Conditions	Same	When Monitored Always
Possible Causes	• Short in the speed limit pot circuit • Unexpected connection on the Curtis Programmer connector.	

Initial Action**Troubleshooting Steps**

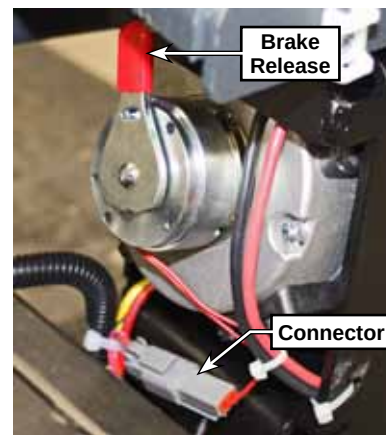
1. Inspect the Curtis programmer connector located below the main machine controller.
2. Disconnect the J4 connector from the drive module.
3. Check the resistance between contacts J4-18 and J4-6.
 - If the resistance is at or near 0 ohms, repair or replace the harness between the drive controller and the speed limit pot.
 - If the resistance is significantly below 100k ohm, but not near 0 ohms, replace the speed limit pot.

3-036 EM Brake Open

Description	The EM brake is open circuit	
Setting Conditions	The drive controller did not detect current draw when the EM brake was commanded to pull in..	When Monitored Always
Possible Causes	• Faulty EM brake solenoid • Disconnected wire	

Initial Action None**Troubleshooting Steps**

1. With the machine powered off, disconnect the EM brake connector located just below the traction motor.
2. Check the resistance between the two contacts of the connector leading to the brake solenoid.
 - If the resistance is high (open circuit), replace the EM Brake (refer to the parts list for the brake solenoid kit).
 - If the resistance is normal (59 ohms), continue to step 3.
3. Check the resistance between the gray wire (KSI) at the brake connector and the gray wire at the K3 relay coil.
 - If the resistance is high (open circuit) the KSI wire is open between the brake and the splice point where it splits off to the drive controller.
4. Check the resistance of the Orange/Green wire at the brake connector and the J4-4 contact at the drive controller.
 - If the resistance is high (open circuit) repair or replace the wire.
 - If the resistance is 0 ohms, replace the drive controller.



3-037 Brake Driver On

Description	The EM brake driver failed to turn off.	
Setting Conditions	Internal error. The drive controller detected the EM brake driver failed to turn off when commanded.	When Monitored Always
Possible Causes	Faulty drive controller	
Initial Action	Reboot the machine. If the error persists, replace the drive controller.	
Troubleshooting Steps		

3-041 Pot 1 Range**3-042 Pot 2 Range**

Description	Pot 1 or pot 2 input is out of range.	
Setting Conditions	The voltage for the Pot input is above 5 volts.	When Monitored Always
Possible Causes	Short to battery positive	
Initial Action	None	
Troubleshooting Steps		
1. Clear the error(s) and observe if/when they get reported. 2. Set the speed limit pot to maximum. a. Observe the error(s) before depressing the Go Pedal. b. Depress the Go Pedal and observe any change in the errors reported. – If the Pot 1 error occurs before the Go Pedal is pressed, the most likely cause is a short to battery power in the gray wire between J4-13 at the drive controller and the Go Pedal. Repair the wire. Stop. – Informational: If the Pot 2 error occurs after the Go Pedal is pressed, this confirms the previous. – If the Pot 2 error occurs before the Go Pedal is pressed, go to step 3 to isolate the cause. – If both Pot errors occur before the Go Pedal is depressed, the cause is indeterminate, and may suggest a failure of the drive controller. 3. Set the speed limit pot to minimum. 4. Clear the error(s) and observe if/when they get reported. a. Observe the error(s) before depressing the Go Pedal. b. Depress the Go Pedal and observe any change in the errors reported. – If the Pot 2 error occurs before the Go Pedal is pressed, the most likely cause is a short to battery power in the Green/Orange wire between J4-14 at the drive controller and the speed pot. Repair the wire. Stop. – If the Pot 2 error no longer is reported, but the Pot 1 error gets reported after the Go Pedal is depressed, the likely cause is a short to battery power in the 5-volt supply wire (Yellow/White and/or Yellow/Blue) between all 3 devices.		

3-043 Pot 3 Fault

Description	False Error. Potentiometer 3 input is not used for this machine.	
Setting Conditions	Unexpected voltage on J4-7	When Monitored Always
Possible Causes		
Initial Action		
Troubleshooting Steps		
Examine the J4 connector for faults. Reboot the machine. If the error persists, replace the drive controller		

3-050 Very Low Voltage

Description	Battery voltage extremely low.	
Setting Conditions	Battery voltage detected below 18 volts.	When Monitored Always
Possible Causes	Loose or corroded connection.	
Initial Action	Make sure the main battery is fully charged before diagnosing any problem.	
Troubleshooting Steps		

3-052 Very Low Cntrlr Temp

Description	Drive controller temperature extremely low.	
Setting Conditions	Temperature below -40	When Monitored Always
Possible Causes	Low temperature Faulty drive module	
Initial Action	If the machine is cold, allow it to warm up. If the machine is warm and the error persists, replace the drive controller.	
Troubleshooting Steps		

3-053 *Very High Cntrlr Temp*

Description	The controller internal temperature has exceeded maximum permitted.	
Setting Conditions	Internal temperature has exceeded 95 °C	When Monitored Always
Possible Causes	• High ambient temperature • Heavy demand on drive system • Loose or poor connections at the high-power lug connections • Faulty drive controller	
Initial Action	Allow the machine to cool. If the error persists replace the drive controller.	
Troubleshooting Steps		

3-054 *Low B+ Power Input*

Description	Precharge fail. The drive controller's DC bus failed to charge to the KSI voltage before timeout. The K3 relay will not be permitted to close.	
Setting Conditions	The DC bus did not charge to within 5 volts of the KSI voltage within 1.5 seconds.	When Monitored Always
Possible Causes	To reduce the amount of arcing inside the K3 relay when it closes, the drive controller pre-charges the DC bus capacitors using KSI power through a current limiting resistor. If the voltage across this resistor remains more than 5 volts, the drive controller knows that the DC bus is not charging properly, and something is bleeding power out of the DC bus. This may be caused by a failed power mosfet	
Initial Action		
Troubleshooting Steps		
Unlike the power module, there are no unswitched loads on the DC bus for the drive controller. Therefore, any drain on the DC bus is caused by a faulty drive controller. • Reboot the machine. If the error persists, replace the drive controller.		

3-070 *K3 Cntr/Y1 Brk Shorted*

Description	One of the output drivers is shorted.	
Setting Conditions		When Monitored Always
Possible Causes	The driver mosfet is shorted	
Initial Action	Reboot the machine. If the error persists, replace the drive controller.	
Troubleshooting Steps		

3-071	<i>Driver3 Fault</i>
3-072	<i>Driver3 Overcurrent</i>
3-073	<i>Driver4 Fault</i>
3-074	<i>Driver4 Overcurrent</i>
3-075	<i>Driver5 Fault</i>
3-076	<i>Driver5 Overcurrent</i>
3-077	<i>Driver6 Fault</i>
3-078	<i>Driver6 Overcurrent</i>
3-079	<i>Correlation Fault</i>

Description	False errors. These errors relate to outputs that are not used by this machine.
--------------------	---

Setting Conditions	When Monitored
	Always

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|--|
| <ol style="list-style-type: none"> 1. Inspect the J4 connector for shorts or damage. 2. If the error persists and no damage was found, replace the drive controller. |
|--|

3-080 *Go Pedal Switch Closed*

Description	The Go Pedal was closed when the drive controller was initiated.
--------------------	--

Setting Conditions	Same	When Monitored
		Always

Possible Causes	• Faulty switch • Broken return spring
------------------------	---

Initial Action	None
-----------------------	------

Troubleshooting Steps

- | |
|--|
| <ol style="list-style-type: none"> 1. Examine the Go Pedal to ensure it is not stuck in the down position. Make sure that when the pedal is released, the spring returns the pedal to the upward position. 2. Disconnect the electrical connector for the operator platform located forward of the platform. 3. Check the resistance between contacts 1 and 2 of the platform connector (X209). <ul style="list-style-type: none"> – If the resistance is at or near 0 ohms, disassemble the operator platform to repair or replace the harness and/or the Go Pedal switch. – If the resistance is not 0 ohms (open circuit), continue. 4. Disconnect the J4 connector from the drive controller. 5. Check the resistance between contacts 1 and 2 of the harness connector at the platform (X208). <ul style="list-style-type: none"> – If the resistance is at or near 0 ohms (short circuit), repair or replace Gray or Yellow/Blue wires between the operator platform and the drive controller. |
|--|

3-081 *Parameter Change*

Description	Drive parameter changed. Restart required.
--------------------	--

Setting Conditions	When Monitored
	Always

Possible Causes

Initial Action	Reboot the machine
-----------------------	--------------------

Troubleshooting Steps

3-082 *A3 NV Memory Fault*

Description	Controller non-volatile Memory Fault
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Setting Conditions	When Monitored
	Always

Possible Causes	Internal error
------------------------	----------------

Initial Action	Reboot the machine. If the error persists, replace the drive controller.
-----------------------	--

Troubleshooting Steps

3-090 *A3 Drive Motor Hot*

Description	False error. This machine does not have a motor temperature sensor.
--------------------	---

Setting Conditions	When Monitored
	Always

Possible Causes	Faulty drive controller
------------------------	-------------------------

Initial Action	Reboot the machine. If the error persists, replace the drive controller.
-----------------------	--

Troubleshooting Steps

3-092 M1 Drive Motor Open

Description	The traction motor circuit is open	
Setting Conditions	The drive controller has detected no current to the traction motor when commanded to operate.	When Monitored Always
Possible Causes	• Worn motor brushes • Faulty motor • Disconnected motor	
Initial Action	None	

Troubleshooting Steps

1. Disconnect the main battery connector for safety.
2. Disconnect the motor connector located just behind the traction motor.
3. Check the resistance of the motor windings between the two contacts of the motor connector.
 - If the resistance is high (more than a few ohms), replace the [Wheel Motor Brushes](#) described on page 172.
 - If the resistance is not high (not open circuit) note the resistance value, and reconnect the motor connector.
4. Check the resistance between M1 and M2 lugs of the drive module.
 - If the resistance is high (not similar to the motor resistance), repair or replace the wires between the drive controller and the traction motor.
 - If the resistance is similar to the motor resistance measured above, reset the machine. If the error persists, replace the drive controller.

3-093 M1 Drive Motor Short

Description	Current to the traction motor has exceeded the programmed threshold.	
Setting Conditions	Same	When Monitored Always
Possible Causes	Short in motor wiring	

Initial Action**Troubleshooting Steps**

1. Disconnect the motor output wires from the drive controller.
 - a. Check the resistance between the two motor output wires.
 - With the motor connected the resistance should be approximately 0.3 ohms.
 - With the motor disconnected, the resistance should be open-circuit.
 - b. Check the resistance between each motor wire and both Bat+ and Bat-.
 - The resistance should be open-circuit.

3-094 High Voltage

Description	Battery voltage too high	
Setting Conditions		When Monitored
		Always
Possible Causes		
Initial Action	Make sure the battery charger is not plugged in.	
Troubleshooting Steps		

3-095 Low Temperature Cutback

Description	Drive controller temperature is low. Output is reduced.	
Setting Conditions	The drive controller is reporting that the temperature is below -40 degrees.	When Monitored Always
Possible Causes		
Initial Action	Allow the machine to warm. If the error persists, replace the drive controller.	
Troubleshooting Steps		

3-096 Stall Detected

Description	False error. This machine does not have motor speed feedback.	
Setting Conditions		When Monitored
		Always
Possible Causes		
Initial Action	Inspect the J4 connector. If no damage found and the error persists, replace the drive controller.	
Troubleshooting Steps		

3-097 A3 Drv Cntrl Temp High

Description	A3 Wheel Drive Controller Temperature Is High	
Setting Conditions		When Monitored Always
Possible Causes	• Temperature above overtemp threshold. • Excessive load on vehicle. • Electromagnetic brake not releasing.	
Initial Action		
Troubleshooting Steps		
1. Diagnose all other motor errors first. 2. Inspect electromagnetic brake.		

3-098 High Voltage

Description	Over-voltage cutback. The DC bus voltage is above permitted level.	
Setting Conditions	Voltage above 28 volts	When Monitored Always
Possible Causes	Abrupt load changes.	
Initial Action	Make sure the battery charger is not plugged in.	
Troubleshooting Steps		
1. Power down the machine and allow the DC bus to self discharge. 2. Check the voltage between the B+ and B- lugs of the drive controller to verify the bus is self discharging. If not, then use a large resistor to jumper between the lugs and force a discharge. 3. After the bus is discharged, reboot the machine. 4. If the error persists, replace the drive controller.		

3-099 Low Voltage

Description	Undervoltage Cutback	
Setting Conditions	Voltage below 18 volts	When Monitored Always
Possible Causes	• Low battery voltage • Poor battery connections	
Initial Action	Make sure batteries are charged	
Troubleshooting Steps		
Inspect all connections from the battery through the K3 relay and to the drive controller.		

3-101 User Fault Estop

Description	Programmed fault condition. Not used.	
Setting Conditions		When Monitored
		Always
Possible Causes		
Initial Action		
Troubleshooting Steps		

3-102 User Fault Severe

Description	Programmed fault condition. Not used.	
Setting Conditions		When Monitored Always
Possible Causes		
Initial Action		
Troubleshooting Steps		

3-103 Go Pedal Always On

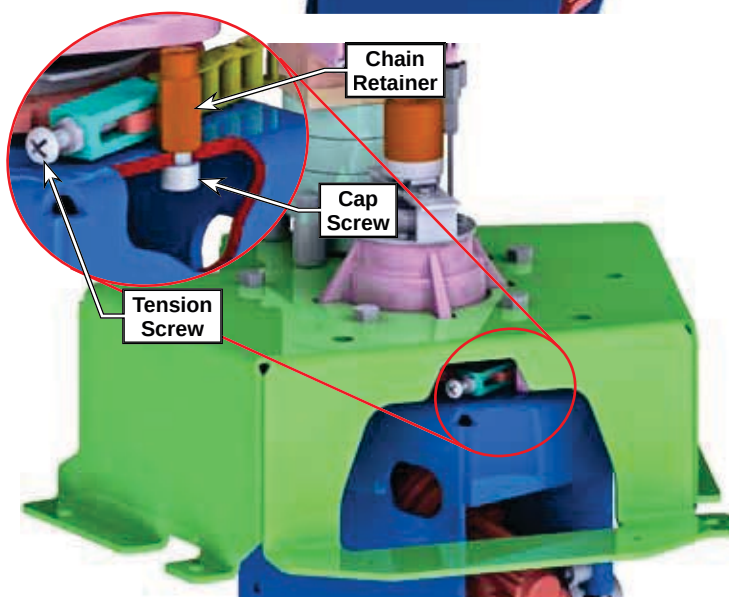
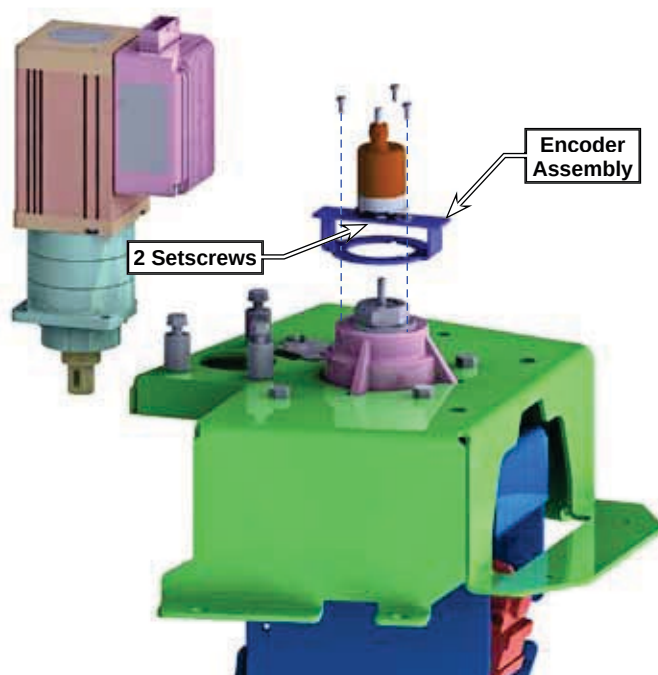
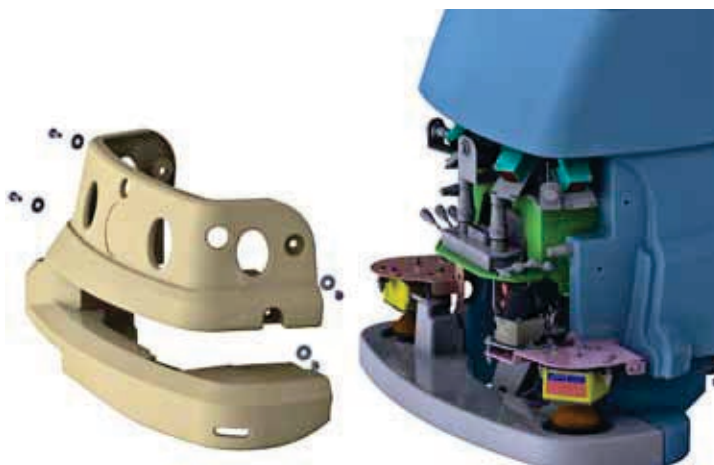
Description	The MMC has detected the Go Pedal switch was closed at startup. (This is a duplicate to the 1-103 message.)	
Setting Conditions	The Drive controller notified the MMC via CANBus message that the Go Pedal was closed during startup. This is not an error to the Drive controller. The MMC sets the error condition.	When Monitored Bootup
Possible Causes	• Short in the Go Pedal wiring. • Operator standing on the switch during startup.	
Initial Action	None	
Troubleshooting Steps		
Inspect the Go Pedal switch and wiring for proper operation or short circuit.		

Removal and Installation

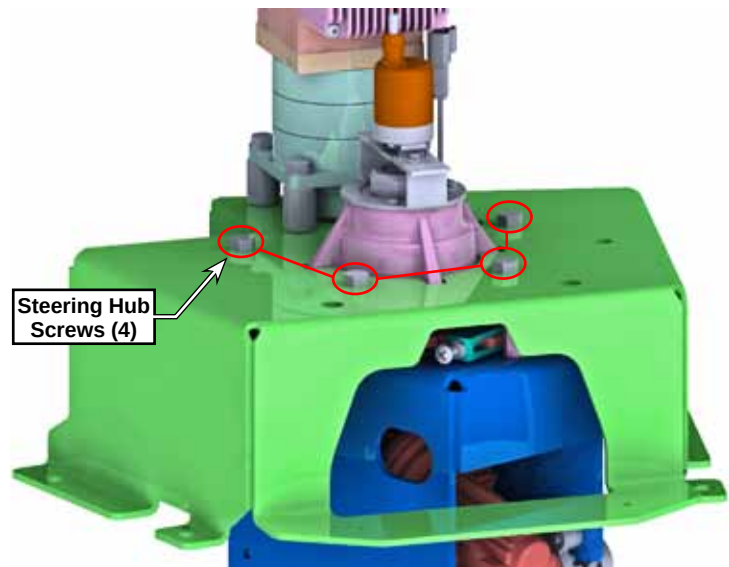
Drive Assembly

This procedure is a prerequisite procedure for gaining easier access to some of the drive components.

1. Drain both the recovery and solution tanks.
2. Remove the 4 screws and washers that secure the front nose to the recovery tank, and remove the front nose.
3. Disconnect the main battery connector for safety, any time you are working near the drive system.
4. Disconnect the drive motor electrical connector.
5. Disconnect the drive position encoder electrical connector.
6. Loosen the 2 setscrews that secure the encoder to the top of the steering spindle.
7. Remove the 3 screws that secure the encoder's mounting bracket to the top of the steering hub, and lift the encoder assembly from the hub.
8. Using a 6-mm hex key, remove the cap screw that secures the chain retainer to the drive housing.
9. Rotate the drive assembly to the side until the chain tensioning screw is accessible.
10. Loosen the chain tensioning screw, and disengage the chain from the steering disk.
11. Make sure the chain is free from the steering motor gear.
12. Optional: To keep the chain from flopping around during the drive removal, you can reengage it on the steering disk, but make sure it is clear of the steering motor gear.



13. Loosen the 4 screws that secure the steering hub to the steering housing.
 - The far-left screw in the image to the right is below the solution tank. You may choose to loosen that screw as much as possible before tipping the machine on its side.
14. Place a protective mat on the ground to the side of the machine.
15. Close the hood over the recovery tank, and secure it from opening while the machine is laying on its side.
16. Remove the squeegee assembly.
17. Remove the main batteries.



CAUTION: *The machine is heavy. Make sure you have the adequate manpower available to lay the machine on its side without causing any personal injury or machine damage.*

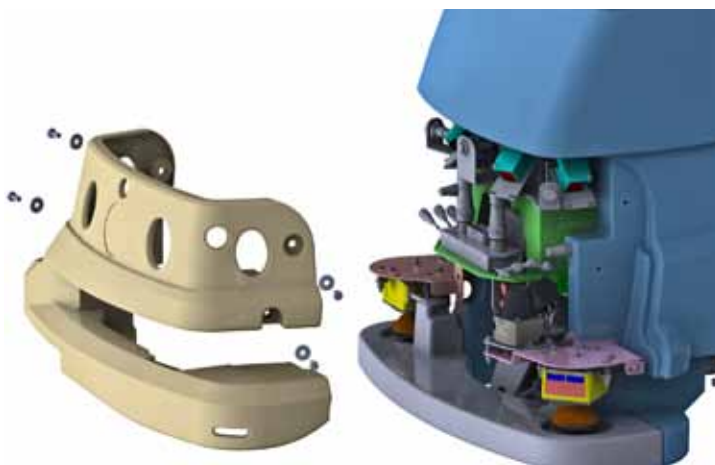
18. Carefully tip the machine on its side.
 - Make sure the front wheel is pointing forward, and the rear wheel is chocked to prevent the machine from moving during the tipping.
 - Avoid using the steering wheel as a gripping handle. It will stress the mounting bracket, but more importantly, it is attached to a hinged cover.
 - Pay close attention to the forward sensors, and add blocking under the solution tank as necessary to prevent the sensor brackets from taking any weight of the machine.
19. While supporting the weight of the drive assembly, finish removing the 4 screws that secure the steering hub to the steering housing.
20. Carefully slide the drive assembly out of the machine.
 - Make sure the steering chain is clear of the steering motor gear.
 - Pay close attention to the small encoder shaft at the top of the steering spindle to avoid damage.
21. After the batteries are reinstalled and connected to the charger, plug the charger into facility power for 30 seconds to reset CANBus communication.
22. After replacement, adjust the steering chain tension as described in [“Steering Chain Maintenance and Adjustment”](#) on page 207.
23. Adjust the Drive Position Encoder as described in [“Drive Wheel Angle Sensor Centering”](#) on page 107.

Drive Wheel Motor

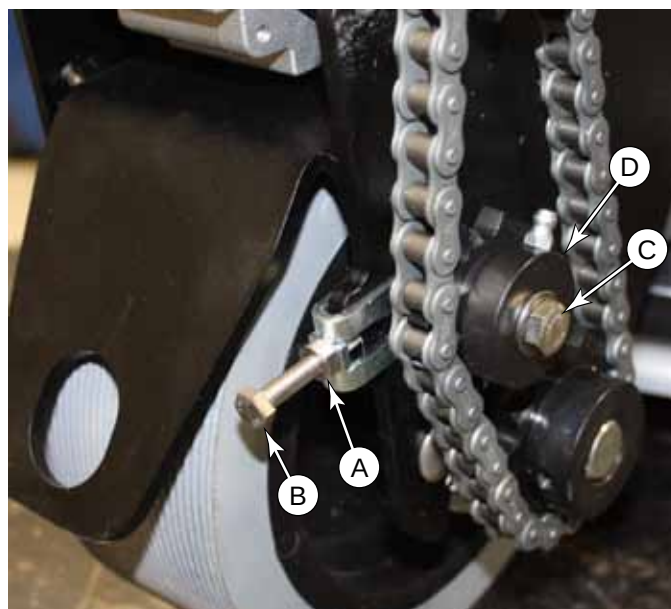
1. Remove the 4 screws and washers that secure the front nose to the recovery tank, and remove the front nose.
2. Disconnect the main battery connector.
3. Chock the rear wheels to prevent the machine from moving.



CAUTION: Once the drive chain is removed in the steps below, the machine will not have any braking.



4. Disconnect the wheel motor electrical connector.
5. Loosen the tension of the drive chain:
 - a. Using a 10mm wrench, loosen the jamb nut (A) from the adjuster screw (B).
 - b. Loosen the adjuster screw (B) several turns.
 - c. Using two 13mm wrenches, loosen the axle bolt (C) of the idler sprocket (D), enough for the sprocket to slide. (The bolt has a Nylok nut on the back side.)
 - d. Slide the sprocket inward until the chain is slightly slack.
 - Note that there probably is not enough slack to remove the chain. The chain will be removed later.

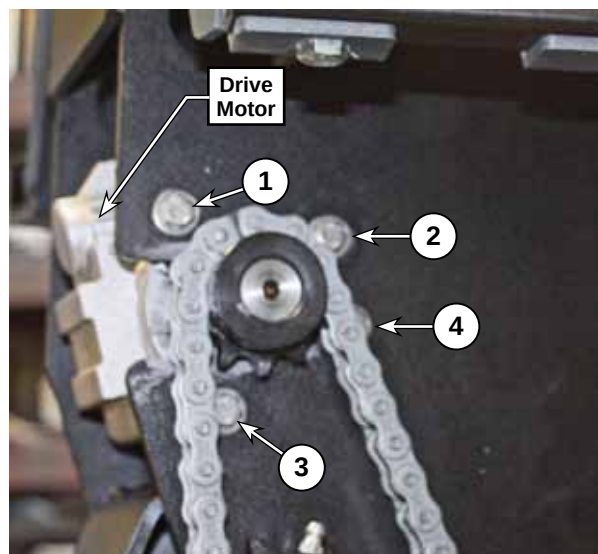


6. Remove the first 3 screws that secure the drive motor (gearbox) to the wheel assembly, and loosen the 4th screw. This should permit the sprocket to lower enough to remove the drive chain.



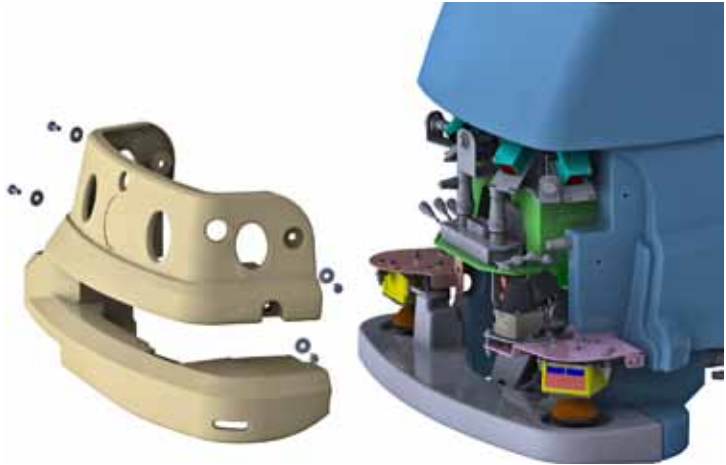
Note: Use the reverse sequence of inserting the screws to reinstall the chain and motor.

7. Remove the drive chain.
8. Finish removing the drive motor, and slide it out the front of the wheel assembly.
9. When complete, adjust the drive chain tension as described in the [“Drive Chain Maintenance and Adjustment”](#) on page 173.



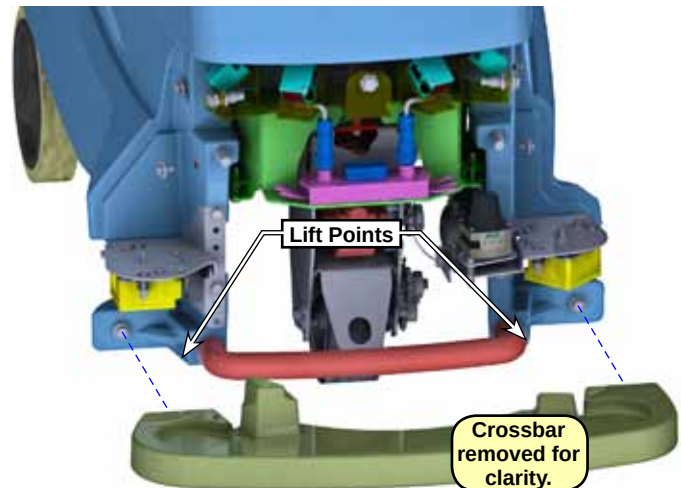
Drive Wheel and Wheel Bearings

1. Remove the 4 screws and washers that secure the front nose to the recovery tank, and remove the front nose.
2. Disconnect the main battery connector.
3. Chock the rear wheels of the machine.
4. Before raising the machine, you may want to slightly loosen the axle bolt described in [Step 8](#), below.

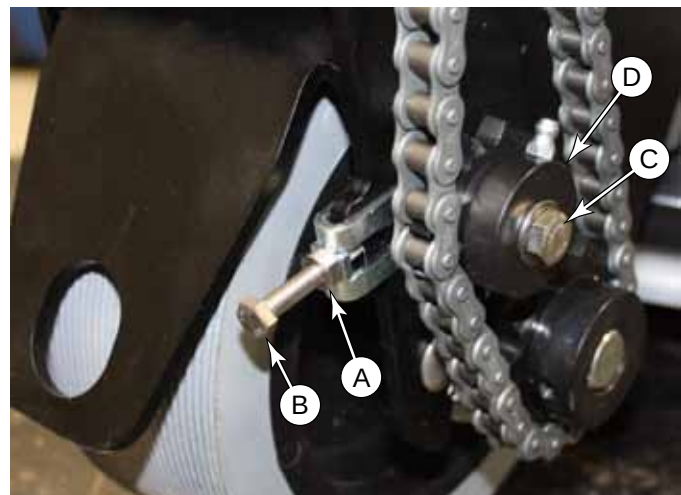


Note: Lift the machine by the bottom of the recovery tank. Do not lift or support the machine by the crossbar. The crossbar is not designed to take the weight of the machine.

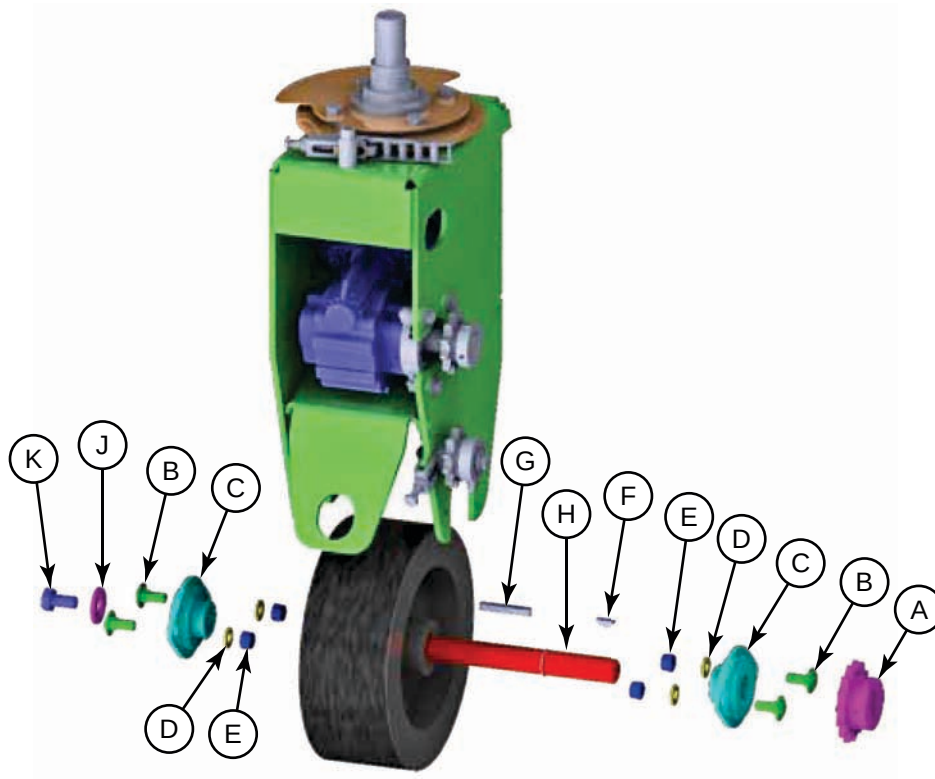
5. Raise the front of the machine about 2 inches (50 mm), and support the machine with blocks or stands.



6. Loosen the tension of the drive chain:
 - a. Using a 10mm wrench, loosen the jamb nut (A) from the adjuster screw (B).
 - b. Loosen the adjuster screw (B) several turns.
 - c. Using two 13mm wrenches, loosen the axle bolt (C) of the idler sprocket (D), enough for the sprocket to slide. (The bolt has a Nylok nut on the back side.)
 - d. Slide the sprocket inward until the chain is slightly slack.



7. Loosen the two setscrews on the drive sprocket **(A)**, and remove the sprocket and drive chain. Take care not to lose the woodruff key **(F)**.
8. Remove the axle bolt **(K)** and washer **(J)** from the end of the axle.
9. Remove the four Nuts **(E)**, washers **(D)**, and carriage bolts **(B)** that secure the two flanged bearings **(C)** to the wheel frame, and lower the wheel and axle out of the frame.
10. Slide the bearings **(C)** off the axle shaft **(H)**.



11. If replacing the wheel, slide the axle shaft out toward the drive side of the wheel. Take care not to lose the flat key **(G)**.
12. When complete, adjust the drive chain tension as described in the [“Drive Chain Maintenance and Adjustment”](#) on page 173.

Specifications

Sample Shop Voltage Measurements

The following tables contain some “real world” shop voltage measurements to help you recognize what “normal” looks like.

- Unless otherwise noted, all voltage readings are referenced to the main ground lug in the electrical bay.
- Some pin numbers are listed out of sequence when measurements require pin-to-pin voltage references instead of the main ground lug
- Values of “+Bat” mean the result is direct battery voltage without any resistive device in the circuit.
- Values of “ $\approx 24V$ ” represent full battery voltage, regardless of the circuit path.

Drive Controller J4 Connector					
Pin#	Wire	Color	Function	Condition	Value
1	W256	YEL	CAN1 H		2.60V
2	W257	GRN	CAN1 L		2.54V
3	W130	ORN	E-Stop In	Inactive, Raised	+Bat (25.5V)
				Active, Depressed	0.005V
4	W061	ORN-GRN	EM Brake Out	Inactive, Brake Set	$\approx 24V$ (25.1V)
				Active, Brake Released	1.1V then 7.8V
5					
6	W378	VIO-BLK	Speed Pot Gnd Out		0.034V
7					
8	W059	GRY	KSI In		+Bat (25.1V)
9	W305	BLU-BLK	Curtis Prog Tx		0.020V
10	W299	BLU-RED	Steering Ready In	Ready	6.0V
				Not Ready (Initial at power on)	11.9V
11	W298	BLU-VIO	Auto OK In	Wheel Encoder, Right (Sensor Ground)	24.5V
				Safety Shut Off	0.016V
				Manual or Record Mode	0.035V
12	W306	GRN-GRY	Curtis Prog Rx		0.025V
13	W375	GRY	Go Pedal Switch In	Open	0.034V
				Closed	5.3V
14	W377	GRN-ORN	Speed Limit Pot In	Max Speed	0.034V
				Min Speed	5.3V
15					
16	W307	BLK	Curtis Prog GND		0.005V
17	W304	BLK-WHT	Curtis Prog +17V		18.6V
18	W371	YEL-WHT	Speed and Go Pdl +5V Out	Ref Pin 6	5.34V

Drive Controller J4 Connector					
Pin#	Wire	Color	Function	Condition	Value
19	W410	GRN-BLU	Operator Presence In	Open, Not Depressed	0.006V
				Closed, Depressed	25.06V
20	W291	YEL-BLU	K3 Relay Coil Out	Active (Step on machine)	1.1V
				Inactive (Step off machine)	25.0V
21					
22					
23					

Drive Motor Amp Draw	
Amps	Condition
6-11 Amps	Deck up, squeegee up, full solution tank, full speed, on a hard level floor, drive in a straight line, 24±1 VDC.



22 - Steering System

Functional Description

The Liberty SC50 uses a steer-by-wire system; meaning that there is no mechanical linkage between the steering wheel and the drive wheel. A Rotary Hall Effect Steering Wheel Position Sensor (voltage-source analogous to a potentiometer) is connected to the steering wheel shaft and communicates steering commands to the steering controller.

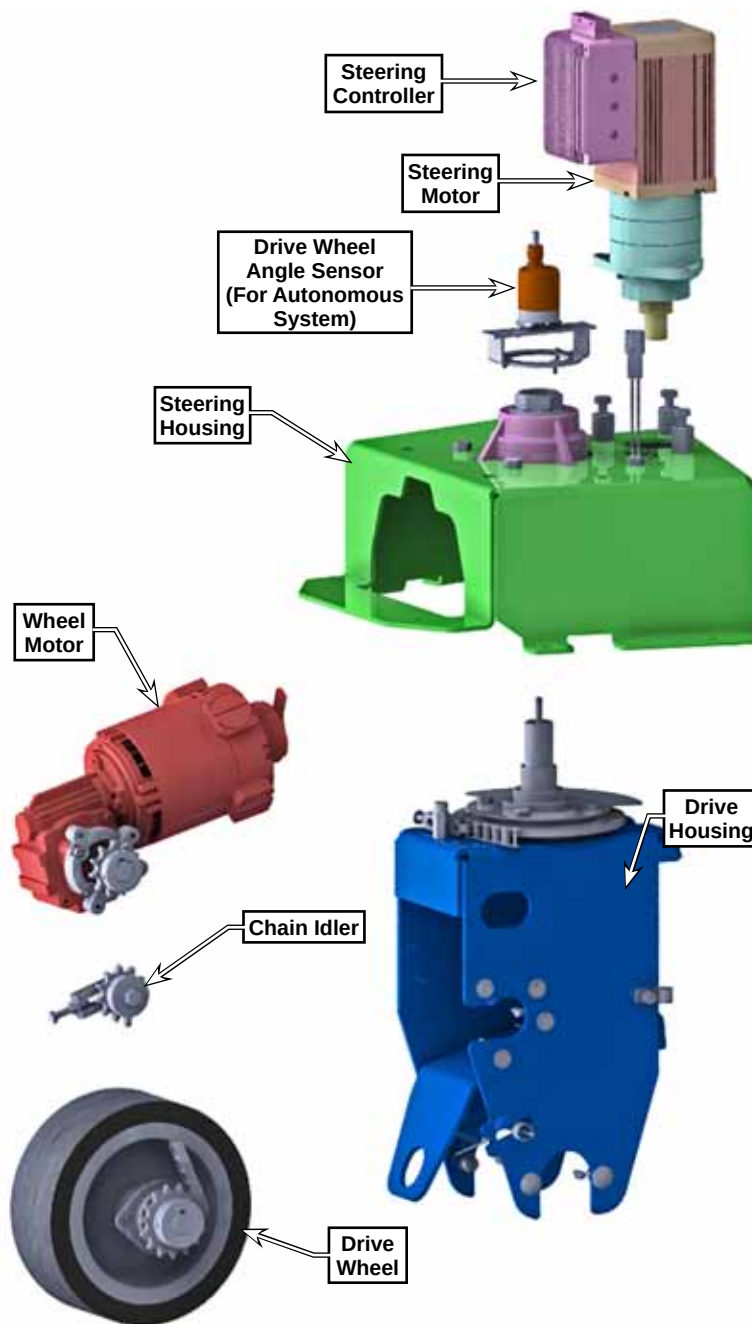
The steering controller operates the steering actuator motor to control the direction of the machine. The controller and motor are incorporated into a single integrated module.

The steering actuator motor uses a chain drive around the chain disk of the lower wheel assembly to steer the machine. This chain disk contains a sensor flag and proximity sensor to provide feedback to the steering controller whether the drive wheel is pointing to the left or the right.

When the machine is operating in manual mode, steering commands come directly from the Steering Wheel Position Sensor on the steering wheel shaft. The sensor includes integrated circuitry that produces a linear voltage output proportional to the position of the steering wheel.

When the machine is operating in autonomous mode, the steering controller receives steering commands from the Main Machine Controller, which in turn, receives them from the Autonomous Interface Module. This communication between the Main Machine Controller and steering controller takes place on the CAN-1 CANBus.

The Drive Wheel Angle Sensor is actually part of the autonomous system, and permits the autonomous controller to directly observe the direction the machine is being steered.



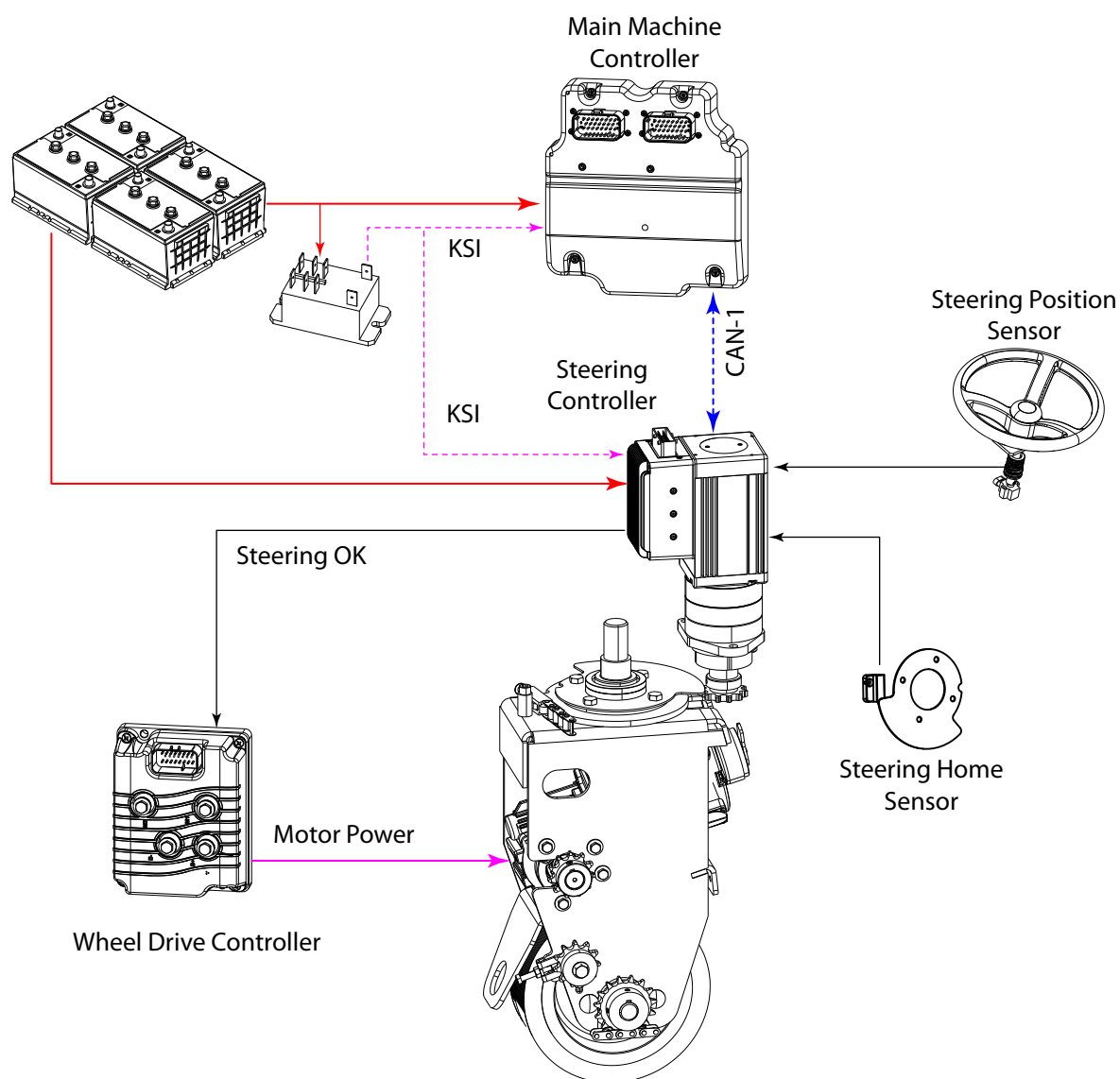
Steering Controller

The steering controller is integrated directly into the steering actuator motor, and is visible as an aluminum heatsink on the side of the motor. The steering controller receives unswitched battery power through a 15 amp circuit breaker for its drive power, but control power comes from the KSI output that is controlled by the Main Machine Controller. Because steering function is critical to all operations, it has no external interlocks that will disable it except for the KSI input and CANBus commands from the Main Machine Controller.

However, for safety, the steering module does output an interlock of its own, which enables or disables the drive controller if the steering module is not ready. This interlock output is disabled if the steering module encounters an error, or is in the middle of a homing or registration operation.

Upon initialization, the steering module will examine the Steering Home Sensor to determine whether the steering is turned left or right. The controller will turn the wheel in the opposite direction until it detects a transition in the Steering Home Sensor, which signifies the forward steering direction. The controller will then turn the wheel to coincide with the output of the Steering Wheel Position Sensor. When the steering module is initialized and ready, lowers the voltage of the Steering Ready signal from 12 volts to 6 volts.

In autonomous mode, the steering controller receives all of its steering commands from the Main Machine Controller via the CAN-1 CANBus.



Steering Actuator

As mentioned, the steering actuator and steering controller are integral components of one another. The steering actuator consists of a remotely commutated, 3-phase, permanent magnet, brushless DC motor. The output of this motor passes into a 2-stage planetary gearset for speed reduction and increased torque. The gearbox is permanently greased and seal for life.

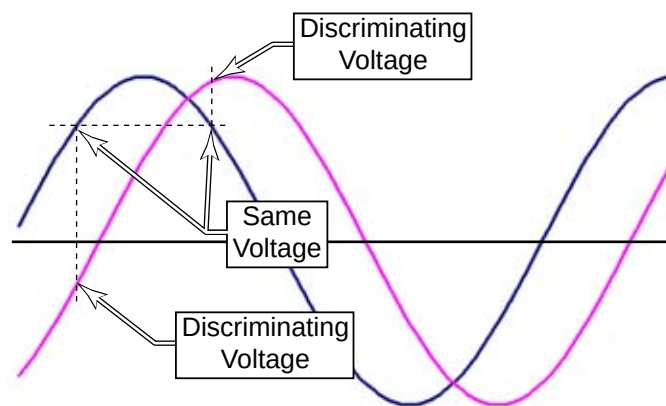
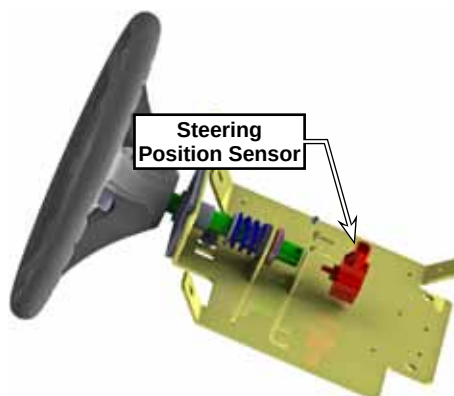
Steering Wheel Position Sensor

The steering wheel position sensor is a rotary hall effect sensor. Because hall effect sensors are most frequently encountered as binary (On/Off) proximity sensors, this may not be immediately intuitive. But the true hall effect is more analog than binary, and its output will be proportional to the distance being sensed.

A single hall effect element with a moving magnetic field will output a voltage which is relative to the distance of the magnet. This varying voltage can be used to determine a rotational position because the magnet moves closer and further from the sensor as the shaft rotates. There is one limitation to this, however, in that this voltage alone cannot determine if the magnet is to the left or right (clockwise or counterclockwise) from the sensor. The same voltage will be shown for both. A second hall effect element provides this distinction to give the total sensor 360 degree resolution.

The internal voltages for the hall effect elements can be represented as overlapping sinusoidal signals. To make this information more usable to the system, the sensor itself contains electronic circuitry that translates these separate voltages into a single linear voltage that varies with rotational angle. The sensor's output range is 0.5 volts to 5.0 volts, but because the steering wheel is mechanically limited to approximately 270 degrees, the actual output range will be slightly narrower, approximately in the 1 to 4 volt range.

This narrowed range is of further importance, because the steering controller uses the outer limits as a reserved fault-detection area. If the steering controller receives either of these outer limit voltages (0.5 or 5.0 V), it will interpret them as a steering input fault.



Maintenance and Adjustment

Steering Spindle Bearings

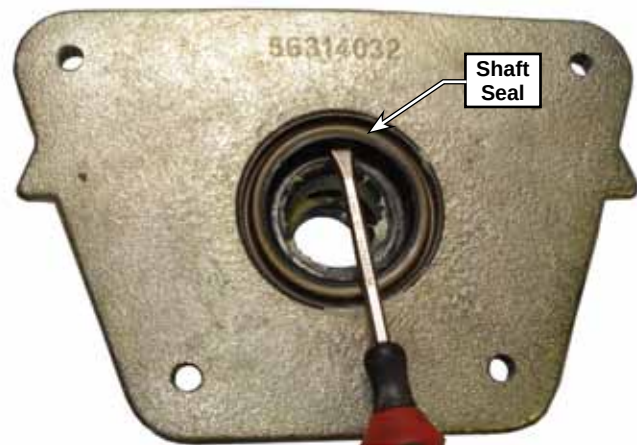
The steering spindle bearings need to be periodically inspected and repacked with grease. The bearings should be inspected for signs of wear, but as long as they remain well greased and properly adjusted, wear should be minimal.

1. Remove the [Drive Assembly](#) described on page 194. Using an adjustable wrench or a 1-7/16" box wrench, remove the Nylok retaining nut from the steering spindle.
2. Lift the bearing hub off the steering spindle.

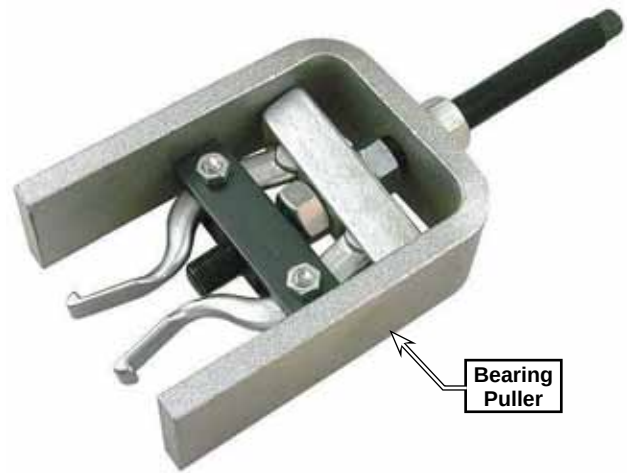


The bearing hub contains a shaft seal, thrust bearing, and a half-sealed shaft bearing. The thrust bearing is tapered and designed to support the weight of the machine. The shaft bearing provides additional lateral support to the steering spindle. The shaft bearing has a dust seal one side, but open cage on the inside for grease. The shaft seal should always be replaced whenever servicing the bearings.

3. Using either a seal puller or a screwdriver, pry out the shaft seal from the underside of the bearing hub. Discard the seal.
4. Remove the bearing cone from the hub.
5. Clean the grease out of the inside of the bearing hub. If a solvent is used, make sure the hub is completely dry before applying any new grease.
6. Inspect the shaft bearing for signs of wear.
 - The inner ring should feel firm without play.
 - The inner ring should turn freely and smoothly without stutters or pitting.
 - The inner ring should not freewheel when spun. If the bearing freewheels, it has become worn and should be replaced.
7. Inspect the bearing cup for wear or damage.



8. Clean the bearing cone, and inspect for damage or wear in the rollers. If a solvent is used, make sure it is completely dry before repacking the grease.
9. If the shaft bearing or bearing race need to be replaced, used an appropriate bearing puller. There are many styles. One version is shown to the right.
10. If the bearings are being replaced, use a bearing press to install the bearing cup and shaft bearing.
 - You may wish to pack the shaft bearing with grease before pressing it in place.
11. Pack the shaft bearing with grease.
 - a. Place a blob of grease on your thumb, and pack the grease down into the bearing balls while swiping your thumb toward the center.
 - b. Continue packing grease all the way around the bearing until you are sure the grease is packed all the way into the area.
12. Pack the bearing cone with grease.
 - a. Place a large blob of grease in your palm.
 - b. Press the open side of the bearing (larger diameter) into the edge of the grease blob, and scrape the bearing across your palm away from the main blob.
 - c. Continue packing grease all the way around the bearing until you see it squeezing out the other side.
13. Place the bearing cone in the hub. Make sure the tapered cone matches the tapered cup and is not inserted backward.
14. Gently press in a new shaft seal, taking care to not distort it.
15. Insert the steering spindle through the bearing hub and secure it with the Nylok nut. Torque the nut to 20 lb•ft.
16. Reinstall the drive assembly back into the machine.



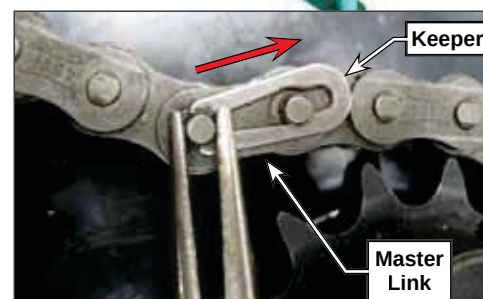
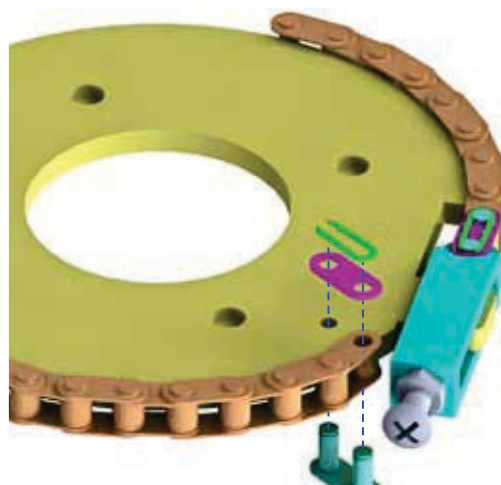
Steering Chain Maintenance and Adjustment

This is a general followup procedure for servicing the steering chain either independently, or as conclusion to other procedures.

Chain Removal

If the chain needs to be removed from the steering disk, the master link in the chain can be removed and the chain separated. To remove the masterlink, use a small pliers to push the keeper back and off of the posts, as shown. (Place one jaw on the post, and one jaw on the clip, and squeeze the pliers closed.) Then remove the plate and link.

After the chain is reassembled, the same technique is used for installing the clip across the link posts. Place one jaw of the pliers against the link post, and the other jaw against the back of the clip, and squeeze the pliers closed.

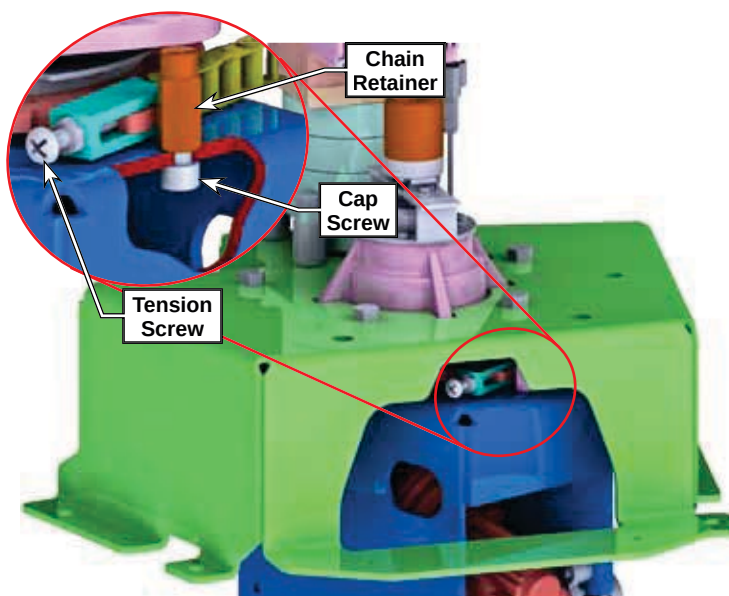


Chain Tension



Note: If the chain requires repeated re-tensioning, it is a sign that the chain has worn and needs replacement. Inspect all of the sprockets for wear too. A worn chain can wear the sprockets, and vice versa.

1. Loosen the jamb nut on the tensioning screw.
2. Tighten the tensioning screw until the chain has .06 to .25 in (1.5 to 6.4 mm) deflection at the midpoint between gears.
3. Retighten the jamb nut.

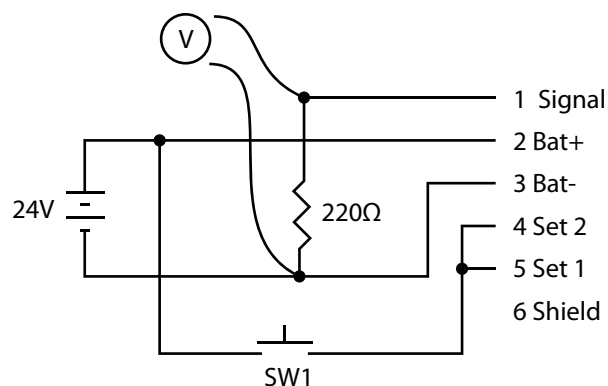


Drive Wheel Angle Sensor Centering

The steering controller calculates the drive wheel position based on the number of revolutions the motor's rotor has made and the gear ratio between the motor and the drive wheel (including the steering chain). This is sufficient for human/manual control, but is not sufficient for autonomous operation. The drive wheel angle sensor tells the Autonomous controller what the actual front wheel steering angle is, without any calculation required.

It is important for proper operation that these two position determination methods are in agreement. The drive wheel angle sensor is an intelligent-type encoder, and this procedure resets the center-position of the encoder to match the center position of the steering controller.

1. Reboot the machine (with service mode access) to force the steering controller to re-home the drive wheel, and detect the home position sensor.
2. Navigate to the A4 Steering Controller menu, and observe the "Position Actual" entry.
3. Turn the steering wheel until the "Position Actual" entry reads 0.
4. Without moving the steering wheel, turn the machine off.
5. Connect the Reset Cable (Part number 56122727) to battery power. For convenience, you can use the main ground lug and K2 relay post in the electrical bay. Otherwise, directly to the machine battery.
6. Unplug the electrical connector to the Drive Wheel Angle Sensor, and connect the Reset Cable to the sensor.
7. If you want confirmation of the reset, connect a voltmeter to the test port of the reset cable.
8. Press and hold the reset button for about 2 seconds.
9. After the reset, the voltage from the test port should be equal (or very close, depending on your meter) to 2.6 volts.
10. Disconnect the Reset Cable, reconnect the sensor, and re-power the machine.

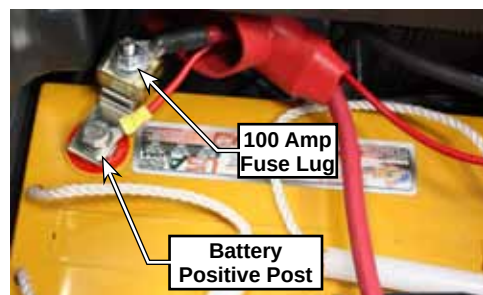
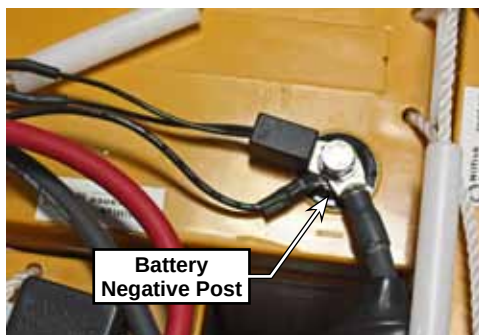
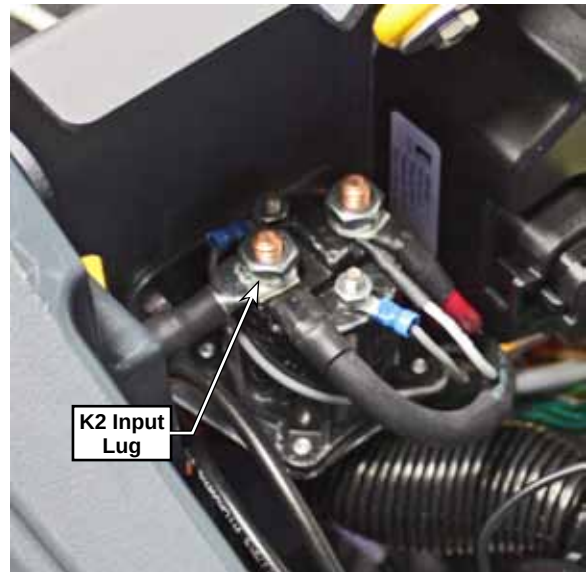
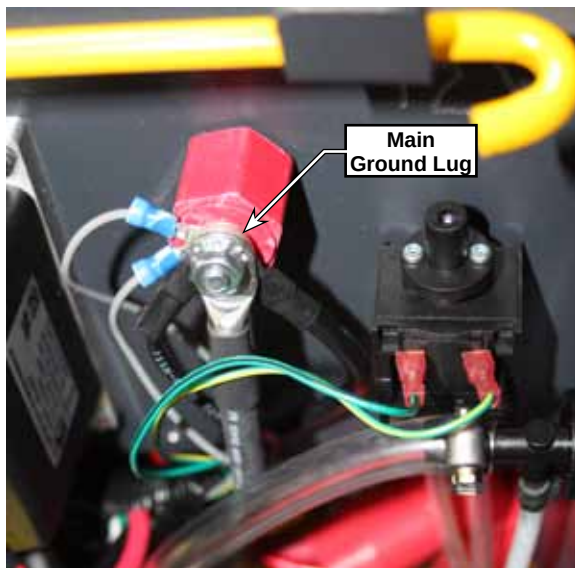


Troubleshooting

Terminology

Voltage measurements are always taken between two points. The first point is the location of interest, and the second point is the reference point. These designations are irrespective of polarity, and the reference point may be at a higher voltage than the test point. Some of the common reference points used in the troubleshooting descriptions are shown below.

- **Main Ground Lug:** This is the main distribution point (node) for all battery negative connections throughout the system.
- **K2 Input Lug:** This is the main distribution point (node) for all battery positive connections throughout the system. (Note that the K2 output lug serves only the Power module.)
- **Battery Posts:** These reference points are generally used only when the two distribution nodes above are suspect.



Rebooting

Many troubleshooting procedures are initiated with a machine reboot. However, this may not fully reset all controllers, as they have direct battery power supplied to them, as opposed to only KSI power. This includes the MMC, Steering controller, and Autonomy controller. If a “hard reboot” or “power cycle reboot” is called for, shut down the machine, disconnect the main battery connector for 30 seconds, and then re-power the machine.

Steering Controller Error Codes

4-001 Analog Inputs Fault

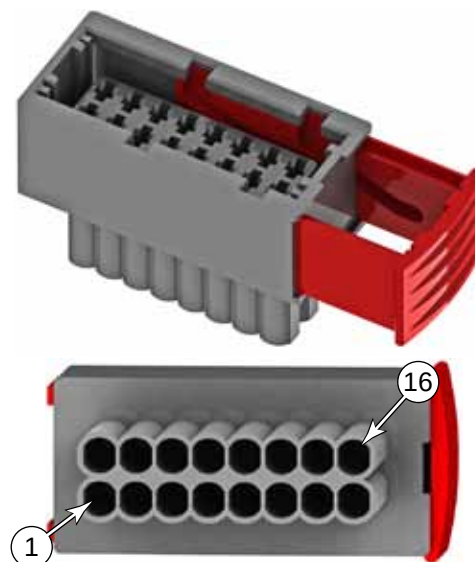
Description	Both analog inputs are out of range.	
Setting Conditions	Both analog inputs exceed 5.5 volts.	When Monitored Always
Possible Causes	The two analog inputs are not related, so the most likely cause is a damaged harness with multiple short circuits to a higher voltage source. It may also signify a faulty steering controller.	
Initial Action	Check the Analog In 0 and Analog In 1 voltages in the steering controller service menu.	
Troubleshooting Steps		
1. Check the analog input voltages a. Check the voltage between J5-5 and the main ground lug. b. Check the voltage between J5-13 and the main ground lug. – If both voltages are above 5.5 volts, repair or replace the harness. – If both voltages are below 5.5 volts and the error persists, replace the steering controller.		

4-002 Supply Voltage Low

Description	The steering controller's internal power stage DC Link voltage is low.	
Setting Conditions	The internal bus voltage is below 12 volts.	When Monitored Always
Possible Causes	• Loose or corroded power connection to the steering controller. • Faulty steering controller.	
Initial Action	Check the reported DC Link Circuit voltage in the steering controller service menu.	

Troubleshooting Steps

1. Power down the machine.
2. Place voltmeter probes into the electrical connector and observe the voltage as the machine powers up and the DC bus charges.
 - a. Check the voltage between J5-8 and J5-7 (or J5-15 if easier)
 - b. Check the voltage between J5-16 and J5-15 (or J5-7 if easier)
 - If the voltages remain at or near battery voltage at all times, replace the steering controller module.
 - If the voltages drop more than 5 volts below battery voltage at any time, continue with the next locations to isolate the circuit.
 - c. Check the voltage between J5-8 or J5-16 and the main ground lug.
 - If the voltage does not drop, the fault lies in the ground circuit.
 - d. Check the voltage between J5-7 or J5-15 and the K2 input lug.
 - If the voltage does not drop, the fault lies in the positive circuit. (Make sure to check the connectors at the CB3 circuit breaker.)

**4-003 Steer Motor Temp Limit**

Description	(False Code) The steering controller believes the steering motor is over temperature.	
Setting Conditions	This is an internal controller error, because the steering system, as equipped, does not use a motor temperature sensor.	When Monitored Always
Possible Causes		
Initial Action	If the error persists, replace the steering controller module.	

Troubleshooting Steps

--

4-004 A4 High Temp Limit

Description	The steering controller temperature is too high.	
Setting Conditions	The power stage of the steering controller has exceeded 85 °C	When Monitored Always
Possible Causes	• Steering obstruction or binding. • Faulty steering motor.	
Initial Action	Confirm the temperature reading from the steering controller service menu. Power down the system and allow it to cool	
Troubleshooting Steps		
• Inspect the steering system for obstruction. • Use the service menu to observe the steering motor amperage while driving. The amperage will vary, but should remain below 10 amps. – If the amperage routinely exceeds 10 amps, replace the steering motor assembly. – If the amperage remains normal but the temperature exceeds normal, replace the steering controller module.		

4-005 Current Sensor Error

Description	The steering controller has detected that its internal current sensor is reporting motor amperage that is not consistent with the conditions.	
Setting Conditions	Amperage offset exceeds 5%.	When Monitored Always
Possible Causes	Faulty steering controller	
Initial Action	Replace the steering controller module.	
Troubleshooting Steps		

4-006 Internal Cntrlr Short

Description	Short circuit in the steering internal power stage	
Setting Conditions		When Monitored Always
Possible Causes	• Faulty steering controller • Faulty steering motor	

Initial Action**Troubleshooting Steps**

1. With the machine powered down, manually pivot the drive assembly side to side to check for a locked rotor condition in the motor.
2. Partially remove the [Steering Controller Module](#) described on page 225, so that the motor leads can be accessed.
3. Disconnect the motor leads from the controller, and check the resistance of the motor windings.(A to B, B to C, C to A).
 - If any of the resistance readings are below 0.10 ohms, replace the steering assembly.
 - If the resistance readings are normal, and the motor is free to turn, replace the steering controller module.

4-007 Supply Voltage High

Description	DC link voltage is too high.	
Setting Conditions	The internal DC link voltage exceeds 39 volts.	When Monitored Always
Possible Causes	Faulty steering controller module.	

Initial Action**Troubleshooting Steps**

--

4-008 Motor Position Sensor

Description	The motor commutator sensors are reporting an illegal value.	
Setting Conditions	The three commutator sensors are showing all high or all low outputs.	When Monitored Always
Possible Causes	- Faulty sensor(s) - Faulty wiring between the controller and motor.	

Initial Action**Troubleshooting Steps**

- Partially remove the [Steering Controller Module](#) described on page 225, so that the motor leads can be accessed.
- Examine the commutator electrical connector and wires for obvious damage.
- Make sure all tools are clear, and no foreign objects are near the exposed steering controller, and then re-power the machine.
- Check the commutator supply voltage between the black (GND) and red (+V) wires.
 - If the voltage is not at or near 5 volts, replace the steering controller module.
- Check the 3 commutator sensor voltages from the black (GND) wire to each of the Blue, Green, & White wires.
 - If all 3 voltages are at or near 0 volts, replace the steering actuator assembly.
 - If more than 1 voltage is at or near 5 volts, replace the actuator assembly.
 - If only 1 voltage is at or near 5 volts, make note of which wire was active, and continue to step 6 to jog the actuator and retest.
- Leave the voltmeter probe on the wire with the 5 volt reading.
- Bump the drive wheel to the side slightly to cause the steering actuator motor to rotate, until you notice the voltmeter reading change to 0 volts.
 - If after several attempts you do not see the voltage change to 0 volts, check the 3 voltages to see if more than 1 wire is measuring 5 volts. Continue.
- Re-check the 3 voltages.
- Repeat the above steps for the 3rd wire.
 - If at any time, more than 1 sensor showed 5 volts, replace the steering actuator assembly.
 - If at any time, all 3 sensors showed 0 volts, replace the steering actuator assembly.
 - If each sensor, one at a time, showed 5 volts while the other two were at 0 volts (correct commutator operation), replace the steering controller module.

4-009 5V Output Shorted J5-4

Description	The internal 5-volt power supply voltage is out of range.	
Setting Conditions	The steering controller has detected that its internal 5-volt power supply is below 4.5V or above 5.5V	When Monitored Always
Possible Causes	• Short circuit in the commutator sensors. • Short circuit to power in steering home sensor circuit. • Faulty power supply	

Initial Action**Troubleshooting Steps**

1. With the machine running, verify the condition.
 - a. Go to the Service menu, Steering Controller, and record the “Analog In 1 (mV)”. (It should be near 5000 millivolts, or 5.0 volts.)
 - b. Check the voltage between J5-4 and J5-14.
 - c. Check the voltage between J5-13 and J5-14.
 - If the voltage from J5-4 is at or near 5 volts, the controller is reporting a false error. Replace the steering controller module.
 - If the 3 voltages are not in agreement, there is likely a problem with the jumper between J5-4 and J5-13.
2. Power down the machine, and disconnect the J5 connector
3. Check the resistance from J5-4 to all other J5 contacts (except J5-11 and J5-13).
4. Check the resistance from J5-11 to all other J5 contacts (except J5-4 and J5-13).
 - If any resistance reading shows less than open-circuit, repair or replace the harness between the J5 connector and the steering home sensor.
5. Partially remove the [Steering Controller Module](#) described on page 225, so that the motor leads can be accessed.
6. Disconnect the commutator sensor connector.
7. Reconnect the J5 connector.
8. Make sure all tools are clear, and no foreign objects are near the exposed steering controller, and then re-power the machine.
 - Disregard any new commutator sensor errors.
 - If the 5V power supply error clears, the fault is located in the commutator sensors. Replace the steering actuator assembly.
 - If the 5V power supply error persists, replace the steering controller module.

4-010 12V Out Shorted J5-3

Description	The internal 12 volt power supply is out of range.	
Setting Conditions	The internal 12-volt power supply was detected to be either below 9.8 volts or above 13.5 volts.	When Monitored Always
Possible Causes	• Steering controller fault • Short circuit in the steering ready signal to the drive module.	

Initial Action**Troubleshooting Steps**

1. Verify the condition.

This is an internal power supply, and there is no direct measurement location. However, the Steering Ready signal to the drive controller uses a PWM output from this power supply. Because this is a PWM output, this test is only an approximation of the actual 12-volt supply when the steering module is not ready.

a. Check the voltage between J5-3 and J5-7 while the machine is booting up (before the steering module is "Ready").

- During boot-up, the signal should be near 12 volts, but when the steering controller is ready, the voltage will drop to 6 volts.
- If the voltage when not-ready is between 9.8 and 13.5 volts, the condition is not real and the steering module needs to be replaced. (The controller is reporting a false error.)
- If the voltage when not-ready is below 9.8 or above 13.5 volts, the condition is real. Continue below.

2. Isolate the Drive controller.

a. Shut down the machine and disconnect the J4 connector from the drive controller.

b. Recheck the voltage between J5-3 and J5-7 while the machine is booting.

- If the condition clears, the drive controller is at fault. Replace the drive controller.
- If the condition persists, continue.

3. Shut the machine down and disconnect the J5 connector.

4. Check the resistance between J5-3 and all other J5 contacts.

- If any reading is less than an open circuit, repair or replace the harness between the steering controller and the drive controller.
- If all readings show open circuit, replace the steering controller module.

4-011 S8 Home Pos Sw Open

Description	No reference switch is connected to the Steer servo.
--------------------	--

Setting Conditions	Sampled reference current less than 100 μ A	When Monitored
		Always

Possible Causes	• Steering controller misconfigured. • Faulty internal power supply
------------------------	---

Initial Action**Troubleshooting Steps**

- If a 5-volt power supply error (4-009 5V Output Shorted J5-4) is also reported, diagnose that error first.
- Reboot the machine. If the error persists, replace the steering controller module.

4-012 Home Pos Not Found

Description	Wheel home position not found.	
Setting Conditions	During initialization, the wheel home sensor did not transition from either opened or closed when expected.	When Monitored Always
Possible Causes	• Metallic debris on the wheel home sensor. • Open or short circuit in wheel home sensor circuit.	
Initial Action	If a 5-volt power supply error (4-009 5V Output Shorted J5-4) is also reported, diagnose that error first.	

Troubleshooting Steps

- The steering home sensor/switch is a magnetically operated reed switch, with physical contacts. The switch contacts close in the presence of ferrous metal.
 - When the machine turns to the right, the home switch should close.
 - When the machine turns to the left, the home switch should open.
1. Isolate the failure mode.
 - a. Turn the steering wheel to the approximate center position (straight ahead).
 - b. Initialize the machine.
 - If the drive wheel turns hard-left, and stays left, the home switch failed to open (short circuit). See step 2.
 - If the drive wheel turns hard-right and stays right, the home switch failed to close (open circuit). See step 3.
 2. Check for a short circuit causes.
 - a. Disconnect the main battery connector for safety while working near the drive system.
 - b. Inspect the steering home sensor for metallic debris on the surface. Clean as necessary.
 - c. Disconnect the steering home sensor connector at the sensor.
 - d. Re-power the machine.
 - If the drive wheel still turns to the left during initialization, the harness between the sensor and steering controller is shorted.
 - If the drive wheel now turns to the right, the sensor (switch) is shorted. Replace the steering home sensor.
 3. Check for Open circuit causes.
 - a. Disconnect the main battery connector for safety while working near the drive system.
 - b. Disconnect the steering home sensor connector at the sensor.
 - c. Turn the drive wheel hard-right, and check the resistance between contacts 1 and 2 of the sensor connector.
 - If the resistance is not at or near 0 ohms, replace the steering home sensor.
 - If the resistance is at or near 0 ohms, reconnect the sensor and continue.
 - d. Disconnect the J5 connector from the steering controller.
 - e. Check the resistance between contacts J5-4 and J5-11.
 - If the resistance is at or near 0 ohms, and the error persists, replace the steering controller module.
 - If the resistance is showing open-circuit, repair or replace the harness between the sensor connector and the steering controller.

4-013 Command mode error**4-014 CAN Communication Flt**

Description	Invalid command from the main machine controller.	
Setting Conditions	The steering controller received a command that was not valid for the current operational state.	When Monitored Always
Possible Causes	• CANBus interference • Communication loss	
Initial Action	Reboot the machine. Diagnose all other fault codes first.	
Troubleshooting Steps		

4-015 Checksum Error

Description	Memory checksum error.	
Setting Conditions	Checksum error will occur after a parameter-set is downloaded. It should clear after power recycle.	When Monitored Always
Possible Causes		
Initial Action	Reboot the machine. If the error persists, replace the steering controller module.	
Troubleshooting Steps		

4-016 Initialization Fault

Description	Invalid parameter loaded during initialization.	
Setting Conditions		When Monitored Always
Possible Causes		
Initial Action	Reboot the machine. If the error persists, replace the steering controller module.	
Troubleshooting Steps		

4-021 A4 Amps Exceeds Limit

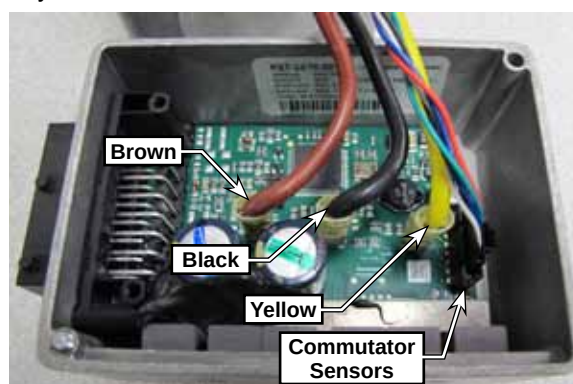
Description	The steering motor amperage exceeded hardware limits. Steering function disabled.	
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Setting Conditions	Same	When Monitored
		Always

Possible Causes	• Motor failure • Obstruction to steering movement.
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Initial Action**Troubleshooting Steps**

1. Disconnect the main battery connector for safety while working near the drive system.
 - Manually turn the drive to feel for physical obstruction.
 - Inspect the steering chain for obstruction or foreign body.
 - Inspect the steering spindle bearings.
2. Partially remove the [Steering Controller Module](#) described on page 225, so that the motor leads can be accessed.
3. Make note of the motor lead order for later replacement, and disconnect all 3 motor leads from the circuit board.
4. Check the motor winding resistances from Brown to Black, then Black to Yellow, then Yellow to Brown.
 - If any of the resistance readings are less than 0.10 ohms, replace the steering actuator assembly.
 - If none of the resistance measurements are less than 0.10 ohms, replace the steering controller module.

**4-022 Limit Switches**

Description	False error. The steering controller believes both steering limit switches are active, but the machine does not utilize limit switches.	
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Setting Conditions	J5-9 and J5-12 inputs are active.	When Monitored
		Always

Possible Causes	• Damage to the J5 connector. • Faulty steering controller module.
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Initial Action	Reboot the machine. If the error persists and no damage is detected in the J5 connector, replace the steering controller module.
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Troubleshooting Steps

4-023 Encoder Error

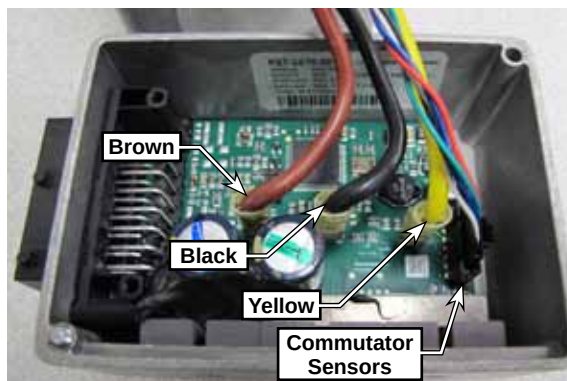
Description	False error. The steering controller believes the position feedback encoder is faulty, but this function is not used.	
Setting Conditions		When Monitored Always
Possible Causes	• Faulty steering controller module.	
Initial Action	Reboot the machine. If the error persists, replace the steering controller module.	
Troubleshooting Steps		

4-024 Stator Winding Open

Description	The steering controller has detected no current flowing in one or more motor windings.	
Setting Conditions	Same	When Monitored
		Always
Possible Causes	- Disconnected motor lead. - Failed motor.	

Initial Action**Troubleshooting Steps**

1. Partially remove the [Steering Controller Module](#) described on page 225, so that the motor leads can be accessed.
2. Check to see if any of the motor leads are loose or disconnected from the controller circuit board.
 - As necessary, repair or replace any loose spade terminals. Otherwise continue.
3. Make note of the motor lead order for later replacement, and disconnect all 3 motor leads from the circuit board.



4. Check the motor winding resistances from Brown to Black, then Black to Yellow, then Yellow to Brown.
 - If any of the resistance readings are greater than 1 ohm, replace the steering actuator assembly.
 - If none of the resistance measurements are greater than 1 ohm, replace the steering controller module.

4-025 *Steer Control Temp Hot*

Description	Steering controller temperature is high.	
Setting Conditions	The temperature of the power stage of the steering controller exceeds 68°C, but has not yet reached the limit of 85°C	When Monitored Always
Possible Causes	Steering obstruction or motor failure	
Initial Action	Allow the machine to cool, and determine if the error repeats.	

Troubleshooting Steps

1. Disconnect the main battery connector for safety while working near the drive system.
 - Manually turn the drive to feel for physical obstruction.
 - Inspect the steering chain for obstruction or foreign body.
 - Inspect the steering spindle bearings.

4-026 *A4 Amps High Range*

Description	The steering motor amperage exceeded software limits.	
Setting Conditions	Same	When Monitored Always
Possible Causes	• Obstruction to steering movement.	

Initial Action**Troubleshooting Steps**

1. Disconnect the main battery connector for safety while working near the drive system.
 - Manually turn the drive to feel for physical obstruction.
 - Inspect the steering chain for obstruction or foreign body.
 - Inspect the steering spindle bearings.

4-027 *Analog Sum Fault***4-028 *Parallel Pot Fault***

Description	False error--not used. These are error detection faults for the two analog inputs. The steering controller is not configured to use them.	
Setting Conditions		When Monitored Always
Possible Causes		

Initial Action Update machine firmware. If the error persists, replace the steering controller module.

Troubleshooting Steps

4-029 Strg Sensor Shrt to 5V

Description	The steering controller has detected that analog inputs 0 and 1 are shorted.	
Setting Conditions	The analog inputs are tracking with one another.	When Monitored Always
Possible Causes		
Initial Action	Examine the J5 connector for short circuit. If the error persists, replace the steering controller module.	
Troubleshooting Steps		

4-030 Analog Input 1 Fault

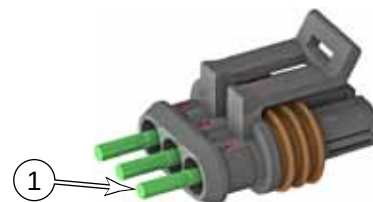
Description	Analog input 1 is out of range. This input is just a voltage reference for the 5-volt power output from the steering module.	
Setting Conditions		When Monitored Always
Possible Causes	• Open or short circuit at the J5 connector • Faulty steering controller	
Initial Action		
Troubleshooting Steps		
• If error (4-009 5V Output Shorted J5-4) is also reported, diagnose that fault first. • Otherwise, repair or replace the harness at the J5 connector.		

4-031 Steering Wheel Sensor

Description	The steering position sensor (steering wheel) input is out of range.	
Setting Conditions	The analog input-0 (J5-5) value is above or below the software setting limits.	When Monitored Always
Possible Causes	- Faulty sensor - Shorted or disconnected sensor wire.	

Initial Action**Troubleshooting Steps**

1. Open the Service menu, Steering Controller menu, and scroll down to Analog In 0 (mV) entry.
2. Turn the steering wheel hard-left.
 - The analog input should approach, but not equal 0 volts (0.5 nominal)
3. Turn the steering wheel hard-right.
 - The analog input should approach, but not equal 5 volts. (4.5V nominal)
4. Compare the readings
 - If the readings change as the wheel is turned, but exceed their nominal values, the sensor needs replacement.
 - If the readings remain at 0 volts no matter the wheel position, proceed to step 5.
 - If the readings remain at or above 5 volts no matter the wheel position, proceed to step 7.
5. Isolate the cause for under-voltage.
 - a. Check the voltage between pin 1 (Red) and pin 2 (Black) at the steering position sensor connector.
 - If the voltage is not at or near 12 volts, proceed to step 6.
 - Otherwise continue.
 - b. Check the voltage between pin 3 (Brn-Blu) and Pin 2 (Black).
 - If the voltage is 0 volts, replace the sensor.
 - If the voltage is not 0 volts, repair or replace the harness between the sensor and the steering module.
6. Isolate the loss of 12 volt power.
 - a. Are the wheel encoders and/or solution flow sensor functional?
 - If the other sensors are functional, the harness is at fault. Repair or replace the harness between the main machine controller and the steering sensor.
 - b. Check the voltage between J1-7 and J1-5 at the main machine controller.
 - If the voltage is not at or near 12 volts, replace the Main Machine Controller.
 - If the voltage is at or near 12 volts, repair or replace the harness.
7. Isolate the cause for over-voltage.
 - a. Disconnect the steering position sensor connector at the sensor.
 - b. Recheck the input voltage above.
 - If the voltage drops to 0 volts, the sensor is at fault. Replace the steering position sensor.
 - If the voltage remains over-voltage, repair or replace the harness between the steering wheel and the steering module.

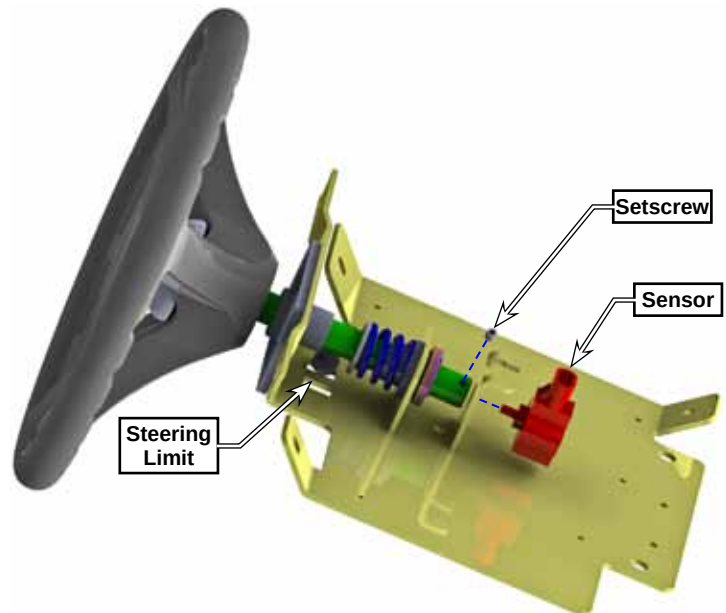


Removal and Installation

Steering Sensor

Removing the steering sensor is fairly straightforward. When replacing the sensor, it is important to make sure the shaft-flat on the sensor is aligned with the setscrew location on the steering shaft.

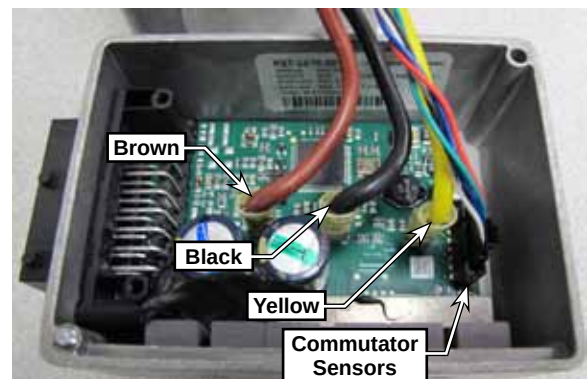
1. Disconnect the battery to protect the electronic systems.
2. Disconnect the steering sensor electrical connector.
3. Turn the steering wheel fully left or fully right, such that the setscrew location is accessible.
4. Loosen the setscrew, and slide the sensor out from its mounting tabs on the steering frame.
5. During replacement, make sure the shaft-flat on the sensor is aligned with the setscrew location of the steering shaft.



Steering Controller Module

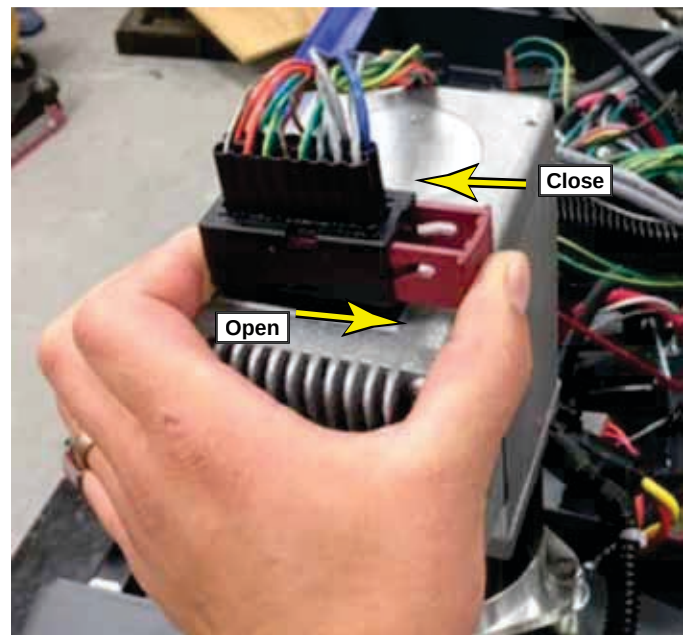
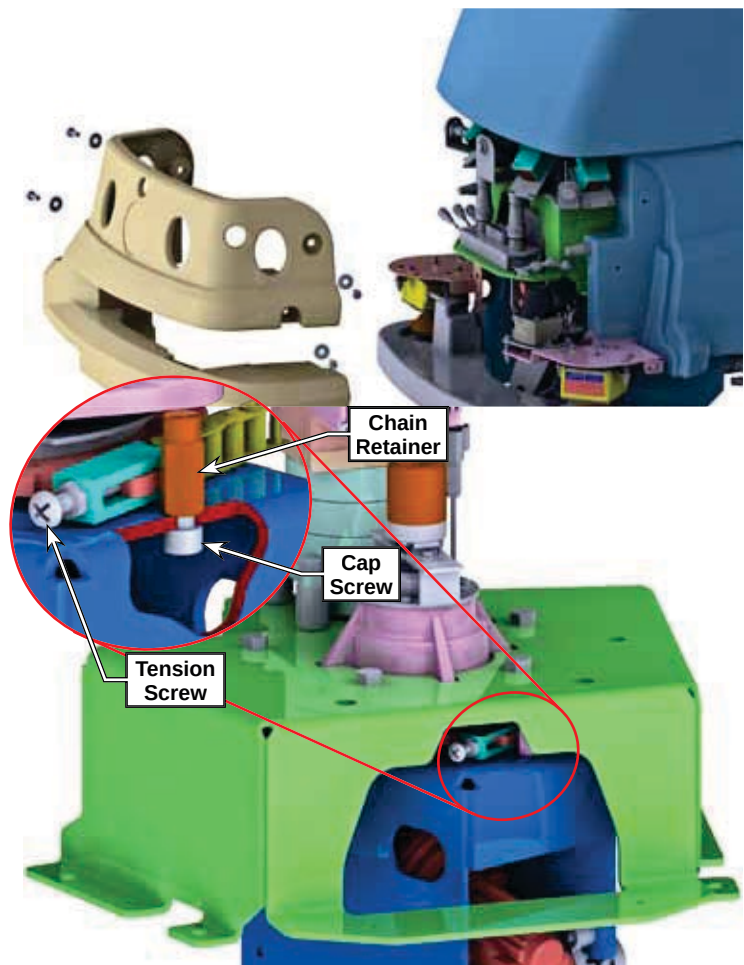
The steering controller module can be replaced separately from the actuator if the module is faulty. However, note that if the actuator is faulty, then the whole assembly must be replaced, including the controller (refer to [Steering Controller and Actuator](#) described on page 226).

1. Disconnect the electrical connector from the steering module. Slide the retaining clip to the side, and remove the electrical connector from the top of the steering control module. (see picture, next page).
2. Remove the 4 screws that secure the control module to the steering motor.
3. Note the wire color and position of the 3 motor wires, for later reassembly.
4. Carefully disconnect the motor and commutator wires from the control module.



Steering Controller and Actuator

1. Disconnect the main battery connector to protect the electronics.
2. Remove the 4 screws and washers that secure the front nose to the recovery tank, and remove the front nose.
3. Using a 6-mm hex key, remove the cap screw that secures the chain retainer to the drive housing.
4. Rotate the drive assembly to the side until the chain tensioning screw is accessible.
5. Loosen the chain tensioning screw, and disengage the chain from the steering disk.
6. Make sure the chain is free from the steering motor gear.
7. Disconnect the electrical connector from the steering module. Slide the retaining clip to the side, and remove the electrical connector from the top of the steering control module.



8. Remove the three mounting screws, washers, and spacers that secure the steering module to the steering frame, and remove the module.
9. After assembly, tension the steering chain as described in [“Steering Chain Maintenance and Adjustment”](#) on page 207



Specifications

Sample Shop Voltage Measurements

The following tables contain some “real world” shop voltage measurements to help you recognize what “normal” looks like.

- Unless otherwise noted, all voltage readings are referenced to the main ground lug in the electrical bay.
- Some pin numbers are listed out of sequence when measurements require pin-to-pin voltage references instead of the main ground lug
- Values of “+Bat” mean the result is direct battery voltage without any resistive device in the circuit.
- Values of “≈24V” represent full battery voltage, regardless of the circuit path.

Steering Controller J5 Connector					
Pin#	Wire	Color	Function	Condition	Value
1					
2	W393	YEL	CAN1 H		2.61V
3	W299	BLU-RED	Steering Ready (PWM) Out	Ready	6.0V
				Not Ready (Initial at power on)	11.9V
4	W389	BRN-GRN	+5V Sensor Supply Out		4.96V
5	W388	BRN-BLU	Steering Angle Sensor In	Full Left	0.84V
				Straight	2.6V
				Full Right	4.3V
6	W340	GRY	KSI In		25.1V
7	W345	BLK	Battery-	During steering	0.055V
8	W251	BLU-RED	Battery+	During Steering	24.9V
9	W505	ORN-GRN			
10	W396	GRN	CAN1 L		2.53V
11	W341	VIO-GRN	Steering Home Sensor In	Closed (Left)	0.015V
				Open (Right)	4.96V
12	W506	ORN-YEL			
13	W450	BRN-GRN	Analog 1 In (+5V)		4.96V
14	W390	BLK	Sensor Ground		0.038V
15	W344	BLK	Battery-	During steering	0.055V
16	W252	BLU-PNK	Battery+	During Steering	24.9V

24 - Electrical System

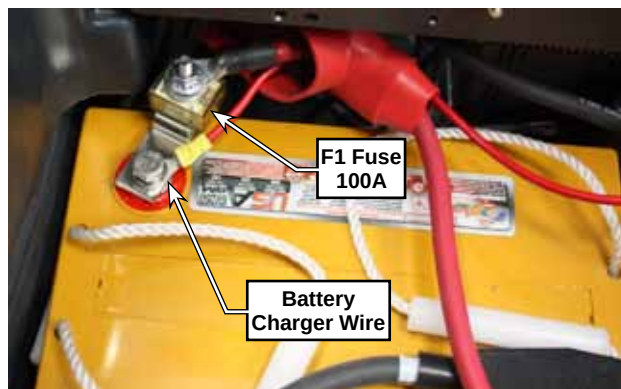
Functional Description

The Liberty SC50 is predominantly a distributed network of intelligent controllers. The electrical system describes those support aspects for the distributed controllers. This includes power and power control components, as well as the electrical backbone of the machine, including the main schematics and wiring harness diagrams.

The electrical system is 24-volt, and is powered by either two 12-volt or four 6-volt lead-acid batteries, or 1 to 6, 24-volt Li-Ion batteries.. The batteries are maintained with an onboard intelligent battery charger. The electrical system also utilizes several relays, which are controlled by the controllers, but themselves control power and/or enabling of the controllers.

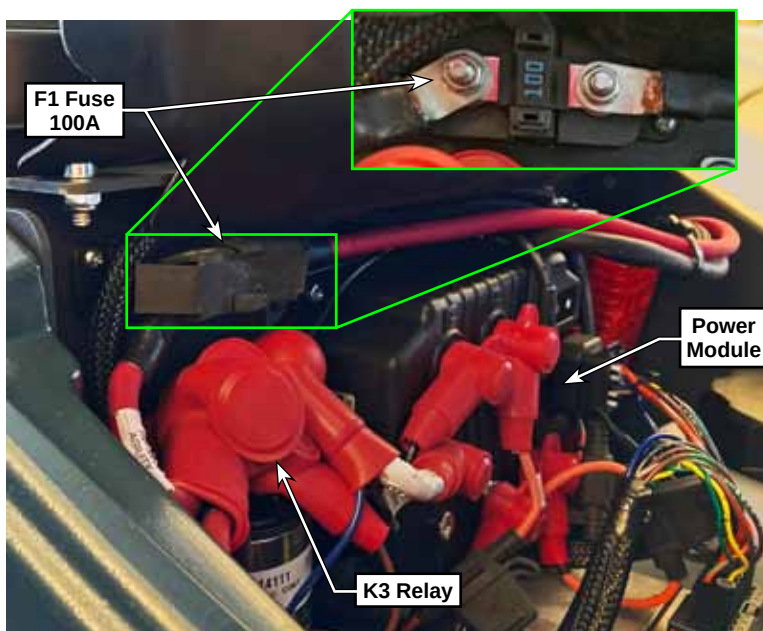
Fuses and Circuit Breakers

The F1 fuse is the system's main fuse for protecting against short circuit for all loads. For conventional lead-acid batteries, the F1 fuse is mounted directly onto the positive main battery terminal. At this location, the fuse protects all wiring within the machine as well as the batteries themselves.



Because Lithium-Ion batteries are internally protected for short circuit and overload, the F1 fuse doesn't need to be located right on the battery pack. Instead, the F1 fuse is located in the electrical bay above the power module.

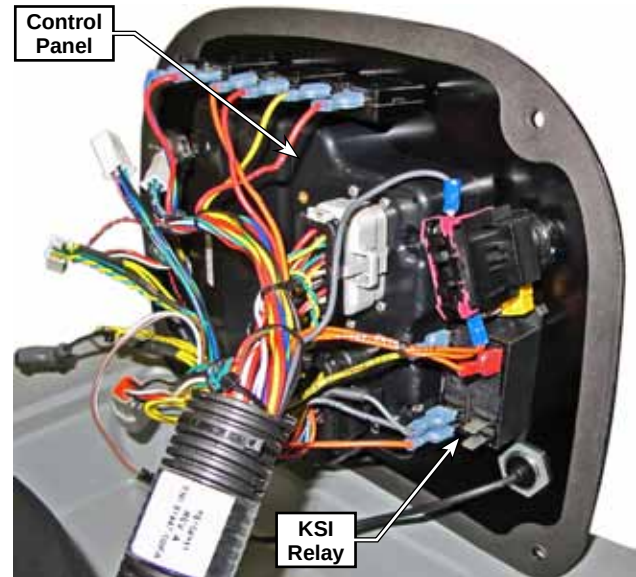
In addition to the main fuse, there are three resettable circuit breakers. CB1 (5A) protects the positive power input to the Main Machine Controller, including the first pole of the KSI relay. CB2 (5A) protects the second pole of the KSI relay, and everything downstream making use of KSI. CB3 (15A) protects the power input to the steering controller.



KSI Relay

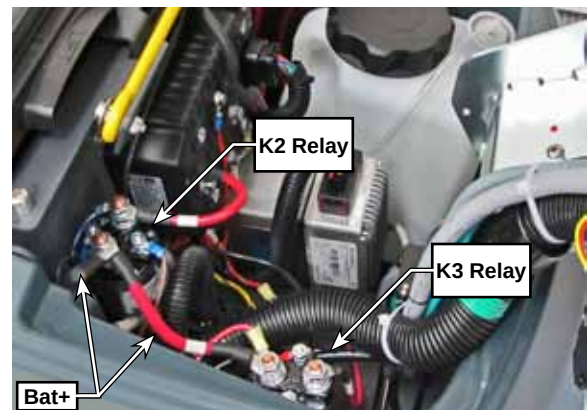
The name “KSI” originates from the acronym for Key Switch Input, and can be considered to carry that same function, even though it is not directly controlled by a key switch on the Liberty machine. The KSI relay is actually one of the most critical components on the machine. Either directly or indirectly, this relay controls all other machine functions.

The coil of the KSI relay is controlled by the Main Machine Controller (MMC), when the MMC connects the negative side of the coil to battery ground. This is a 2-pole relay (2 contacts), but only one set of poles is used. The output of the KSI relay is used to enable several functions of the machine. These include: Solution Solenoid • Horn • Solution Pump • Operator Present Switch • E-Stop Circuit • Power Module Logic Power • Power Module K2 Relay Coil • Drive Controller Logic Power • Drive Controller K3 Relay Coil • Steering Controller Enable • and Autonomous Controller Enable.



K2 and K3 Relays

These are the main power relays that provide high-amperage power to the Power Module (**K2**) and Drive Module (**K3**). In both cases, the positive side of the relay coil is controlled by the output of the KSI relay. This means that the relays cannot be energized unless the KSI relay is active. The negative side of each relay coil is controlled by its respective module; Power Module or Drive Module. This means that the module itself has control over its own high-power input.



E-Stop Switch

The E-stop switch is a normally closed switch, which means the function is active when the circuit is open or broken. It operates this way because it is a safety circuit, and is intended to “fail” in the active-mode if a wire were to be cut, as opposed to disabling the function, or preventing the activation of an E-stop condition if a wire is loose or broken.

The positive side of the E-stop switch receives battery-positive power through the KSI relay. This effectively means that the E-stop function is perceived as active whenever the KSI relay is not active. The other side of the E-stop switch passes to the interlock inputs of both the Main Machine Controller, and the Drive Controller.

Even though the Main Machine Controller will communicate an E-stop condition to all other modules, the direct connection to the Drive Controller ensures that the drive system will respond to an E-stop condition.

Low Voltage Cutout

The main machine controller is equipped with a low-voltage cutout feature to prevent over-discharging of the batteries. When the battery voltage falls below a defined threshold, some machine functions are disabled. These threshold values are dependant on the type of battery specified in the main controller. In the first stage of cutout, the scrub system is disabled, but the recovery system will remain active. At the second stage, even the recovery system will be disabled, but the drive system remains active.

The drive controller has its own cutback feature, separate from the main controller. When the drive controller senses battery voltage too low, it will reduce power output to the drive motor to protect the battery.

Cutout Level	Threshold-Wet	Threshold-AGM	Threshold-Lilon	Affected Systems
Stage 1	20.55	21.65		All scrub functions disabled
Stage 2	20.3	21.5		Both scrub and recovery disabled
Stage 3			BMC Determined	All machine power disabled

Onboard Battery Charger

An optional on-board battery charger is mounted on the bottom of the machine. This may be a Delta-Q IC650 for a standard machine, or an RC1000 for a Li-Ion machine. The charger is intelligent and semi-autonomous and charges the batteries when the machine is plugged in to facility power.

The charger communicates with the Main Machine Controller (MMC) via the CAN-0 bus. The MMC tells the charger which charging profile it should be using based on the type of battery installed in the machine. The charger can also communicate battery and charger status back to the MMC.

To prevent any machine operation while the charger is plugged in, the charger contains an interlock relay which closes a circuit back to the MMC when ever the charger is plugged in. During normal operation, the Interlock Return signal is open circuited, which the MMC detects as a low-voltage. When the charger is plugged in, the Interlock Return is connected to battery+ by the relay, and the MMC detects this as a high-voltage.



Note: If the battery charger is disconnected from the batteries, when it gets re-connected, it will not have CANBus communication enabled. This will result in a controller error code of 1-708 for loss of communication. To reset communication, plug the charger into facility power (as though charging the batteries) for 30 seconds.



Ultraviolet Germicidal Irradiation (UVGI) Option

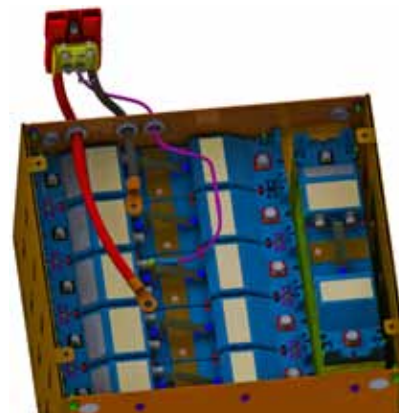
The machine may be equipped with an Ultraviolet Germicidal Irradiation (UVGI) system. This consists off an electronic ballast mounted above the operator's platform, a lamp housing mounting frame below the operator's platform, and the ultraviolet lamp holder below the operator's platform. The purpose of the lamp mounting frame is to provide quick disconnect of the lamp housing for maintenance and/or transporting the machine over uneven surfaces. The purpose off the ballast is to provide 44 volts to the lamps while limiting the current through the bulbs.

Refer to the "UVGI Accessory Instructions for Use" document 56091255 for operation and maintenance of the UVGI system.

Lithium-Ion Battery Option

The SC50 can be equipped with lithium-ion batteries, with 1 to 6 modules, however, 3 is the default size. Each battery contains its own controller, called the Battery Management System (BMS), and all of the BMS modules communicate with each other. The battery with the highest serial number (typically the newest) in the pack acts as the master controller and communicates the with main machine controller via the CAN-0 bus.

The Li-Ion option requires a few changes to the electrical system. A new cable is added to the Anderson connector (main battery connector) that provides CANBus between the batteries and the MMC and also includes a battery control circuit. The new CANBus connects to the spare maintenance port (X287) under the MMC.



DC/DC Converter

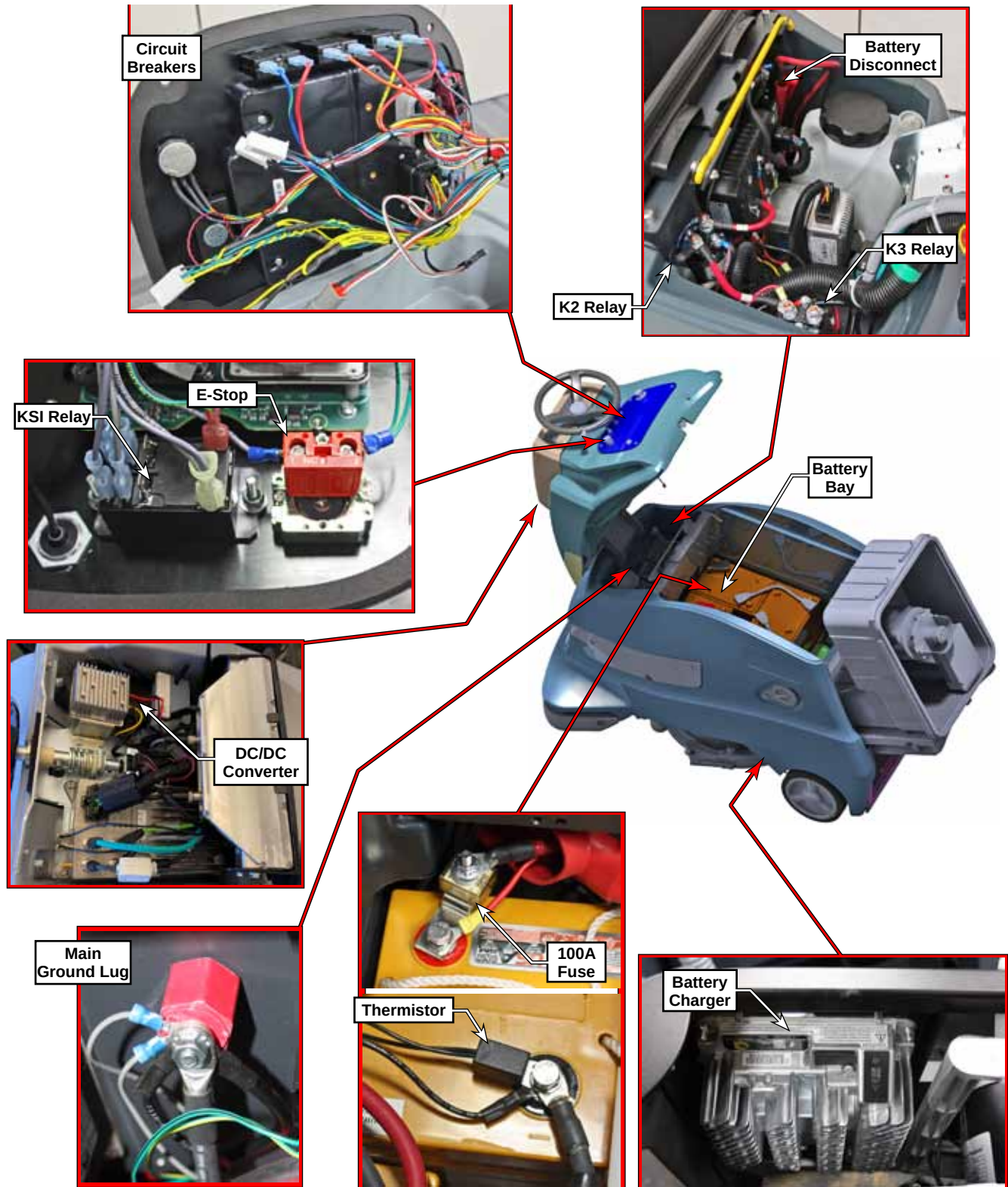
If the machine is equipped with Li-Ion batteries, it must also have a DC-to-DC converter installed too. The DC/DC converter is a switching power supply that ensures that the Autonomous controller always receives 24 volts regardless of the battery voltage. This is required because lithium-ion batteries produce a higher voltage than the equivalent lead-acid battery type, and this voltage is higher than the maximum voltage rating of the Autonomous controller. As a switching power supply, the DC/DC converter can provide the regulated 24-volt output regardless whether the battery voltage is as low as 9 volts or as high as 40 volts.

When the DC/DC converter is not present, connectors X356 and X357 in the autonomy bay are connected together. When the converter is present, it is inserted between those connectors.

Li-Ion Technical Data

Nominal Voltage	25.9 Volts
Capacity per Module	64 Amp-Hour
Max. Current per Module	60A
Weight per Module	10.5 kg (23 lbs)
Operating/Charging Temperature	0°C to 45°C (32°F to 113°F)
Storage Temperature	-20°C to 55°C (-4°F to 130°F)

Component Locations



Maintenance And Adjustments

Battery Charging Profile (Algorithm) Setting

Quick Tip

To check or change the battery charging profile, in the Delta-Q IC650 battery charger do the following:

1. Plug the charger into an AC power source, just long enough to wake up the charger, and then unplug the charger. (Otherwise, the charger will show as being off-line.)
2. Navigate to the Configuration, Charger Algorithm menu.
3. The charger algorithm is identified by number, and cross references to the numbers shown in the table to the right.



Note: If Lithium Ion batteries are set in the Configuration, Battery menu, the charge algorithm is automatically set to 339.

Profile	Parameters
3	T105 constant power dv/dt
5	Trojan 30XHS
6	Deka 8G31 Gel
7	J305 constant power dVdt
11	Generic 200-255Ah flooded dv/dt
12	Exide DF06240 Sonnenschein Gel
21	Exide 200-300Ah Flooded Constant power dv/dt.
26	Deka 8GGC2 Gel
42	Discover AGM 80-150Ah
43	Discover AGM 200-400Ah
51	Exide Sonnenschein DF 180Ah Gel
52	Exide Sonnenschein DF 105Ah Gel
71	Generic 140-200Ah flooded constant power dV/dt
72	Generic 250-335Ah flooded constant power dVdt
73	Generic 400Ah flooded constant power dVdt
141	AGM 300-415Ah Fullriver DC
151	AGM 200-260Ah Fullriver DC
274	IUU profile for Betta Battery 8-EVFJ-100Ah
339	Lithium Ion

Troubleshooting

General Electrical Troubleshooting

Diagnosing machine failures commonly involves testing electrical components and tracing electrical circuits as they pass throughout the machine. This section is intended to provide you with the general information necessary to identify an electrical circuit from a schematic, and physically trace it and test it within the machine itself, as well as common steps necessary to test the electrical components making up that circuit.

[“Electrical Circuit Diagram”](#) on page 272:

The main electrical circuit diagram (previously referred to as the “Ladder Diagram”) provides the electrical functions of the circuits, modules, and components, but does not necessarily represent the physical locations of those components. This describes the raw interaction between components to achieve their functions.

The Circuit Diagram serves as the main launching point for all other electrical information, in that it also contains device labels, connector identifiers, and even wire colors. This information is described in [“Understanding the Features of the Electrical Circuit Diagram”](#) on page 268.

[“Wiring Harness Diagrams”](#) on page 281:

The main purpose of the wiring harness diagram is to trace the physical connections for each discrete wire in the system. Every wire in the machine’s harness is given a unique wire-number identifier. The significance of this is that even though the schematic shows a continuous circuit from one electrical connector to another, that circuit may be made up from one or more individual wire segments spliced together. Each of those segments has its own unique number, and those numbers are even printed directly on the physical wires.

[“3D Harness Diagrams”](#) on page 291

The 3D harness diagrams show the wire and cable routing through the machine and the locations of all electrical connectors. This provides a visual correlation between a connector’s location and the connector ID number. If a connector ID is known, then its location on the machine can be determined. Conversely, if a connector on the machine is being examined, its ID number can be found and then used to look up the corresponding pinout table.

[“Electrical Connector Pin-Out Assignments”](#) on page 299:

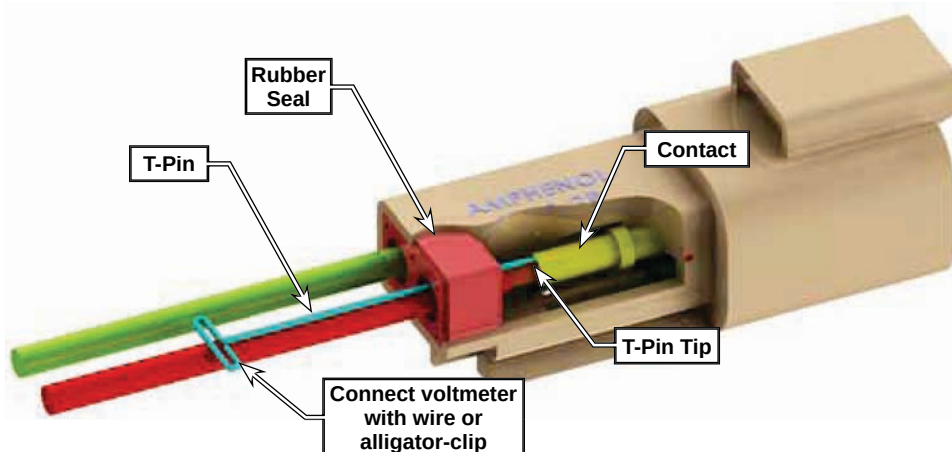
Both the Circuit Diagram and Harness Diagram identify connector numbers throughout the system. J-connectors are those that are physically connected to a device or module, such as the Main Machine Controller. X-connectors are those that are in-line connectors between harnesses or other groups of wires, including extension wires that may be integral to a particular component. Some, but not all X-connectors are shown in the schematic, but all X-connectors are shown in the wiring harness diagram.

These tables are used to identify which wires pass through each connector, and at what location within that connector. Each table is accompanied by a graphic to identify the pin numbers. The table then correlates each of those pin numbers with the wire number, wire color, and functional description of the wire. 3D views of the connectors are shown, so that you can be certain which side of the connector you are looking at when identifying which pin is pin-#1.

Back-Probing Connector Voltages

An invaluable tool for diagnosing system performance is to be able to monitor voltages while the system is active. This requires measuring voltages without disconnecting the devices to be measured. The best location for accessing a circuit is from the back side of an electrical connector. However, many of the connectors used in the machine are moisture resistant, and have seals where the insulated wire enters the connector body.

It is important that the seal not be damaged, as the connector may then corrode over time. Standard voltmeter probes are too large to slip past the seal without damaging it. The best alternative is to take a T-type push pin, blunt the sharp tip slightly so it doesn't cut the seal, and insert the pin along the wire until it reaches the metal contact inside the connector housing. A permanent probe could be fabricated by soldering a wire lead to the end of the pin, or you can connect your voltmeter probe with an alligator-clip.



Testing Cables

Secondary to testing active voltages, inspecting cables for open-circuit or short-circuit is one of the most valuable troubleshooting techniques available to the technician. Testing for open circuit is pretty straight forward--if you don't have continuity from one end of a circuit to the other, the circuit is open.

Short-circuit detection can be more complex, because it requires testing all adjacent conductors for undesirable continuity. Compounding the problem is that the testing is conclusive only if a short-circuit is detected, but it cannot prove that a short-circuit does not exist. That's because not every wire in a harness bundle necessarily terminates at the same electrical connector being tested.

Open Circuit Testing

Testing for an open circuit requires disconnecting the wiring harness at both connectors that the circuit in question passes through. The circuit's connector contact locations are identified in the [“Electrical Connector Pin-Out Assignments”](#) on page 299. Ohmmeter probes are placed on the two appropriate contacts, and continuity (at or near 0 ohms) is tested for.

If the two connectors are too far apart for ohmmeter test leads to be connected, you can install a shorting jumper on the contacts at one connector. This creates a return path back to the first connector, where you can place both ohmmeter probes. The shorting jumper is typically placed between the ground circuit and the circuit in question, but any known good circuit can be used as the return path.



Short Circuit Testing

Testing for short circuits also requires disconnecting both connectors of the harness, but the reason is to ensure that the device (controller, sensor, motor, etc.) is not causing a false positive reading on the ohmmeter. Continuity is tested for between the connector contact in question, and all other contacts in the connector. If the circuit in question is passing between control modules, then the testing should be repeated at both connectors.

Connector Probe Kit

To make it easier to connect a multimeter to the small contacts in connectors, you can make a simple test probe kit. The probes are fabricated using a mating contact and a lead wire. You may even choose to make duplicate probes, with long lead wires and short lead wires.

The table below lists all contact sizes used in the machine, as well as their Digikey part number. They can be ordered from <https://www.digikey.com/>.



Note: Some of the common connectors below are offered in either stamped or machined bodies. You may choose which type you prefer.



Probe Contact Type		Digikey Part #	Connector Mate	Contact
0.6 mm Pin		1195-5472-ND	Autonomous Round Connectors	
0.6 mm Socket		277-13553-ND		
1 mm Pin	Stamped	1734-1146-1-ND	X163, X187, X208, X214, X215	
	Machined	277-13549-ND		
1 mm Socket	Stamped	1734-1150-1-ND	X78, X189 X173	
	Machined	277-12296-ND		
1.5 mm Pin	Stamped	889-1050-1-ND	J1, J2, J3, J4, J6, X157, X190, X191, X193, X194, X242, X280	
	Machined	889-1461-ND		
1.5 mm Socket	Stamped	889-1051-1-ND	Various off-harness connectors	
	Machined	889-1470-ND		
0.7 mm Rect. Pin		WM1841CT-ND	X231	
0.7 mm Rect. Socket		WM1837-ND	X137	
1.5 x 0.8 Rect. Pin		A105024CT-ND	X241, X128	
1.2 mm Rect. Socket		WM2501CT-ND	X210, X279	
2.5 x 0.8 mm Rect. Pin		WM17540-ND	X128, X203	
2 x 0.3 mm Spade		A24783CT-ND	J5 Steering	

Battery Charger Error Codes

8-E001 High battery voltage

Description	Battery voltage too high.	
Setting Conditions	The battery voltage is higher than the software setting.	When Monitored Charging
Possible Causes		
Initial Action		
Troubleshooting Steps		
• Check the battery voltage and cable connections. • Check battery size and condition. • This error will automatically clear once the condition has been corrected.		

8-E002 Low battery voltage

Description	Battery voltage too low to start a charge cycle.	
Setting Conditions	Algorithm dependent – typically 0.1V/cell.	When Monitored Charging
Possible Causes		
Initial Action		
Troubleshooting Steps		
• Check the battery voltage and cable connections. • Check battery size and condition. Batteries may be overdischarged. • Use another charger to bring the batteries above the minimum voltage. • This error will automatically clear once the condition has been corrected.		

8-E003 Charge timed out**Description****Setting
Conditions****When Monitored**

Charging

Possible Causes**Initial Action****Troubleshooting Steps**

- Charger output reduced due to high temperatures. Operate at lower ambient temperature.
- Charger output reduced due to low AC voltages. Check AC voltage.
- Check for shorted or damaged cells.
- Poor battery health. Replace battery.
- Very deeply discharged battery. Retry charge.
- Poorly connected battery. Check connections.
- This error will automatically clear once the charger is reset by cycling DC or by loss of AC for over 10 minutes.

8-E004 Battery below min volt**Description**

Battery could not be trickle charged up to the minimum voltage. May also be used for other battery-related errors depending on the algorithm.

**Setting
Conditions****When Monitored**

Charging

Possible Causes**Initial Action****Troubleshooting Steps**

- Check for shorted or damaged cells.
- Poor battery health. Replace battery.
- Check DC connections.
- This error will automatically clear once the charger is reset by cycling DC or by loss of AC for over 10 minutes.

8-E007 Bat. Ah limit reached

Description	Charge amp-hour Limit reached. Algorithm dependent.
--------------------	---

Setting Conditions	When Monitored
---------------------------	-----------------------

When Monitored	Charging
-----------------------	----------

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|---|
| <ul style="list-style-type: none"> • Charger output reduced due to high temperatures. Operate at lower ambient temperature • Charger output reduced due to low AC voltages. Check AC voltage. • Check for shorted or damaged cells. • Poor battery health. Replace battery. • Very deeply discharged battery. Retry charge. • Poorly connected battery. Check connections. • This error will automatically clear once the charger is reset by cycling DC or by loss of AC for over 10 minutes. |
|---|

8-E008 Batt Temp Out of Range

Description	Battery temperature out of range. Algorithm dependent.
--------------------	--

Setting Conditions	When Monitored
---------------------------	-----------------------

When Monitored	Charging
-----------------------	----------

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|--|
| <ul style="list-style-type: none"> • Cool or warm batteries as needed. • Check temperature sensor and connections. • This error will automatically clear once the condition has been corrected. |
|--|

8-E012 Reverse polarity

Description	Battery connected with reverse polarity.
--------------------	--

Setting Conditions	When Monitored
---------------------------	-----------------------

When Monitored	Always
-----------------------	--------

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|---|
| <ul style="list-style-type: none"> • Reverse the charger connections to the battery. |
|---|

8-E013 *Bat. not taking current*

Description	The battery is not taking a charge.
--------------------	-------------------------------------

Setting Conditions	
---------------------------	--

When Monitored

Charging

Possible Causes	High resistance connection
------------------------	----------------------------

Initial Action

Troubleshooting Steps

- | |
|--|
| <ul style="list-style-type: none"> • This error will automatically clear once the charger is reset by cycling DC or AC. |
|--|

8-016 *Software upgrade fail***8-018 *Software upgrade fail***

Description

Setting Conditions

When Monitored

Updating

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|---|
| <ul style="list-style-type: none"> • Ensure the USB flash drive is properly formatted and is not corrupted. • Ensure the USB flash drive does not draw excessive current. • Copy the install files to the USB flash drive again. • Retry the update by reinserting the USB Flash Drive into the charger. • If software updates continue to fail, replace the charger |
|---|

8-017 *USB error*

Description	USB mount/unmount error
--------------------	-------------------------

Setting Conditions

When Monitored

Updating

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|--|
| <ul style="list-style-type: none"> • Remove and re-insert the USB Drive. • Ensure the USB flash drive is properly formatted and is not corrupted. • Ensure the USB flash drive does not draw excessive current. • If the condition persists then remove AC and battery for minimum 30 seconds and retry charger. |
|--|

8-019 Software Rev Incorrect

Description	Hardware build does not support software version	
Setting Conditions		When Monitored Updating
Possible Causes	The charger hardware does not support the new software version trying to be programmed. Existing SW is left running.	
Initial Action		
Troubleshooting Steps		

8-E020 Active algo not set

Description	No active algorithm selected	
Setting Conditions	When Monitored Charging	
Possible Causes		
Initial Action		
Troubleshooting Steps		
Reboot the machine, and plug the charger into facility power for 30 seconds. If the error persists, replace the charger.		

8-E021 Active algo not set

Description	High battery voltage while charging. Algorithm dependent – typically 2.8V/cell	
Setting Conditions	When Monitored Charging	
Possible Causes		
Initial Action		
Troubleshooting Steps		
• When already full, some new batteries may exhibit this error. Cycle the batteries and see if it reoccurs. • Check battery size and condition. Resistive batteries in poor condition may cause this. Some new batteries if charged when already full will also cause this. Cycle the batteries a few times. • Check the battery voltage and cable connections. • This error will automatically clear once the condition has been corrected.		

8-E022 Low battery voltage

Description	Low battery voltage while charging. Algorithm dependent – typically 0.1V/cell
--------------------	---

Setting Conditions	When Monitored Charging
---------------------------	-----------------------------------

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|--|
| <ul style="list-style-type: none"> • Another device may be drawing current from the battery. • Check the battery voltage and cable connections. • Check battery size and condition. Batteries may be over-discharged. Use another charger to bring the batteries above the minimum voltage. • This error will automatically clear once the condition has been corrected. |
|--|

8-E023 AC voltage high

Description	High AC voltage error (>270VAC)
--------------------	---------------------------------

Setting Conditions	When Monitored Charging
---------------------------	-----------------------------------

Possible Causes	AC voltage is too high. Connect charger to an AC source that provides stable AC between 85 - 270 VAC / 45-65 Hz. This error will automatically clear once the condition has been corrected.
------------------------	---

Initial Action

Troubleshooting Steps

8-E024 Failed to initialize

Description	Charger failed to turn on properly
--------------------	------------------------------------

Setting Conditions	When Monitored Charging
---------------------------	-----------------------------------

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|--|
| <ol style="list-style-type: none"> 1. Disconnect AC input and battery for 30 seconds. 2. Reconnect the battery first, and then plug the charger into facility power for 30 seconds. 3. Unplug the charger and reboot the scrubber. 4. If error persists, replace the charger |
|--|

8-E025 AC voltage dipped

Description	The AC voltage is too low.
--------------------	----------------------------

Setting Conditions	AC voltage has dipped below 80 VAC 3 times in 30 seconds	When Monitored Charging
---------------------------	--	-----------------------------------

Possible Causes

Initial Action

Troubleshooting Steps

8-026 USB Script Failed

Description	One or more USB script commands failed
--------------------	--

Setting Conditions	When Monitored Updating
---------------------------	-----------------------------------

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|--|
| <ul style="list-style-type: none"> • Ensure the USB flash drive is properly formatted. • Ensure the right update package is being used. • Copy the install files to the USB flash drive again. • Retry the update by reinserting the USB Flash Drive into the charger. |
|--|

8-027 USB overcurrent fault

Description	USB overcurrent fault
--------------------	-----------------------

Setting Conditions	When Monitored Updating
---------------------------	-----------------------------------

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|--|
| <ul style="list-style-type: none"> • USB hardware overcurrent protection has been tripped. Remove and reinsert USB flash drive. If condition persists, try using a different USB flash drive. |
|--|

8-E028 Incompatible algo

Description	Algorithm error
Setting Conditions	When Monitored Charging
Possible Causes	
Initial Action	
Troubleshooting Steps	
Update charger software, continue to use existing algorithm or select a different charging algorithm that is compatible.	

8-E029 CAN bus error

Description	Cannot transmit on CAN bus
Setting Conditions	When Monitored Charging
Possible Causes	The CANBus has to be functional for this error to be reported to the Main Machine Controller.
Initial Action	
Troubleshooting Steps	
- Disconnect AC input and battery for 30 seconds. - Reconnect the battery first, and then plug the charger into facility power for 30 seconds. - If error persists, replace the charger	

8-E030 CAN HeartBeat-1 timeout

Description	CAN heartbeat timeout from Main Machine Controller
Setting Conditions	When Monitored Charging
Possible Causes	The CANBus has to be functional for this error to be reported to the Main Machine Controller.
Initial Action	
Troubleshooting Steps	
- Disconnect AC input and battery for 30 seconds. - Reconnect the battery first, and then plug the charger into facility power for 30 seconds. - If error persists, replace the charger	

8-E031 *ADC Vref out of range*

Description	The Vref for the ADC measurements has triggered an alarm
--------------------	--

Setting Conditions	When Monitored Charging
---------------------------	-----------------------------------

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|--|
| <ol style="list-style-type: none"> 1. Disconnect AC input and battery for 30 seconds. 2. Reconnect the battery first, and then plug the charger into facility power for 30 seconds. 3. If error persists, replace the charger |
|--|

8-E036 *Battery temp sensor*

Description	Battery Temperature Sensor (Thermistor) is open or shorted
--------------------	--

Setting Conditions	When Monitored Charging
---------------------------	-----------------------------------

Possible Causes

Initial Action

Troubleshooting Steps

- | |
|--|
| <ol style="list-style-type: none"> 1. Make sure the charger is not plugged in to facility power. 2. Make sure the main battery negative post is at a reasonable room temperature (not too hot or too cold). 3. Disconnect the X194 harness connector from the charger. 4. Check the resistance between contacts 5 and 14 of the harness connector. <ul style="list-style-type: none"> – If the resistance is less than 10k ohms, but not near 0 ohms, the charger may be at fault. – If the resistance is open-circuit, See step 5 to isolate the cause. – If the resistance is short circuit, See step 6 to isolate the cause. 5. Isolate an open circuit cause: <ol style="list-style-type: none"> a. Recheck the resistance reading at the splice-points adjacent to the thermistor on the negative battery post. <ul style="list-style-type: none"> – If the resistance is open-circuit, replace the thermistor. – If the resistance is below 10k ohms but not near 0 ohms, repair or replace the harness between the charger and thermistor. 6. Isolate a short-circuit cause: <ol style="list-style-type: none"> a. Open (cut) one of the splice points near the thermistor, and check the resistance of the thermistor itself. <ul style="list-style-type: none"> – If the resistance is at or near 0 ohms, replace the thermistor. – If the resistance is below 10k ohms but not near 0 ohms, repair or replace the harness between the charger and thermistor, including the splice point that you cut. |
|--|

8-E037 *CANdownload failure*

Description	CAN Open reprogramming failed	
Setting Conditions		When Monitored
		Bootup
Possible Causes		
Initial Action	Reboot the machine.	
Troubleshooting Steps		

8-E038 *Fan failure***8-E040** *Fan voltage low*

Description	False Error. This charger model does not have a fan.	
Setting Conditions	When Monitored	
	Charging	
Possible Causes		
Initial Action		
Troubleshooting Steps		

8-F001 *LLC excessive leakage***8-F002** *PFC excessive leakage***8-F003** *PFC long boost time***8-F004** *Calibration failed***8-F005** *Excess relay volt drop*

Description	Internal charger fault	
Setting Conditions		When Monitored Charging
Possible Causes		
Initial Action		
Troubleshooting Steps		
1. Disconnect AC input and battery for 30 seconds. 2. Reconnect the battery first, and then plug the charger into facility power for 30 seconds. 3. If error persists, replace the charger		

Lithium-Ion Battery Error Codes

Machine-Level Codes (10-1xx)

The level-100 error codes are generated by the Main Machine Controller based on reading a warning registry from the Battery Management System. These do not have the associated lower-level codes, which are discussed below.

Upper-Level Codes (10-2xx)

To simplify communication between the Main Machine Controller (MMC) and the battery pack, the Master Battery module (MBMS) of the pack listens to the CAN messages from all of the remaining battery modules, and periodically broadcasts a summary message(s) for the MMC to listen for. In other words, instead of listening for and sorting out hundreds of messages from all of the individual batteries, the MMC only has to listen for a few specific message headers.

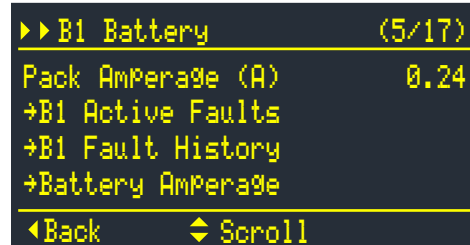
One of these message headers contains a summary of any error codes reported by the individual battery modules. These are referred to as Upper-Level error Codes (UL-Codes) and lack specific module IDs and are sometimes generalized from one or more specific error conditions.

Lower-Level Codes (0x##)

The error codes presented in the tables below represent the high-level, or machine-level codes that are “pushed” to the MMC when an error is detected in the battery pack. Within the battery pack, the specific battery module will generate a low-level error code (**LL-Code**) that isn’t “pushed” to the MMC, and is available only when the MMC “polls” the battery pack for active or historical error codes.

Sometimes knowing the LL-Code can provide helpful information, such as which battery module initiated the error, or specific information regarding the cause of the upper-level code.

Unfortunately, because the LL-Codes aren’t pushed to the MMC along with the upper-level code, it is necessary to search through either active faults or the fault histories, to determine what LL-Codes are present and for which module.



```

>> B1 Battery (5/17)
Pack AmPerage (A) 0.24
→ B1 Active Faults
→ B1 Fault History
→ Battery AmPerage
◀ Back      ▶ Scroll
  
```

Finding LL-Codes

In the code tables below, there will be some guidance whether it should be necessary to locate any LL-Codes or not. If the code is an active code, you can view the active codes in the service menu to determine which battery module set the code. To determine which of the LL-Codes applies to the UL-Code you’re investigating, you will have to search through the code history for each module in the pack. Refer to [Module Specific Sub-menus](#) described on page 43.

Error Code Index

10-100	Low battery voltage	250
10-101	Low reserve capacity SOC	250
10-102	Reserve capacity SOC	250
10-103	Over/Under discharge temperature	250
10-104	Over/Under charge temperature	250
10-107	Max current recuperation	250
10-111	CAN Bus failure	250
10-112	Set deactivation enable	251
10-114	Set node ID process enable	251
10-115	Unknown warning	251
10-202	Overcharge Recuperation	251
	0x3a Overcharge current due to recuperation	
	0x3b Overcharge cell voltage due to recuperation	

10-203 Charge current short	252
0x15 Short-circuit current during charging	
10-204 Discharge current short	252
0x19 Short-circuit current during discharging	
10-205 Battery pack max SPN	253
0x0d Module over voltage	
10-206 Discharge FET fault.	253
0x35 Discharge FET is shorted.	
10-207 Charge FET fault	254
0x36 Charge FET is shorted. .	
10-208 Charge max current	254
0x16 Over current during charging	
0x17 Over current during charging	
0x32 A value close to limit of the ADC is measured.	
10-209 Discharge max current.	255
0x1a Over current during discharging	
0x1b Over current during discharging	
0x34 A value close to limit of the ADC is measured.	
10-210 Undercharge alarm	255
0x09 Cell under voltage during discharge	
0x29 A value close to limit of the ADC is measured.	
10-211 Overcharge alarm	256
0x08 Cell over voltage during charge	
0x2a A value close to limit of the ADC is measured.	
10-212 Over/Under charge temperature	256
0x01 Cell over temperature during charging	
0x02 Cell under temperature during charging	
0x03 Chrg FET's above temp limit during charging	
10-213 Over/Under discharge temperature	257
0x04 Cell over temperature during Discharging	
0x05 Cell under temperature during Discharging	
0x06 Dischrg FET's above temp limit during dischrg	
10-214 Module defective	258
0x0a Cell voltage too low	
0x0f Module voltage differs from sum of cell voltages.	
0x10 Measured module voltage too low	
0x2b Cell temperature sensor value too high	
0x2d FET temperature sensor value too high	
10-215 Unknown Error	259
0x38 Discharge Error Lock (0x04, 0x05, 0x06)	
0x3c 24-volt supply below limit	
0x3d 24-volt supply above limit	
0x40 Parameter outside range	
N/A Uncategorized Errors.	260
0x0b Severe Cell imbalance within a module	
0x1d Difference of current measurement	
0x2c Cell temperature sensor value too low	
0x2e FET temperature sensor value too low	
0x39 Charge Error Lock	
0x3e Node-ID are not assigned	
0x3f Node-ID conflict	

10-100 Low battery voltage

Description The battery pack voltage is approaching minimum threshold.

Possible Causes

Troubleshooting Steps

- Charge the batteries

10-101 Low reserve capacity SOC**10-102 Reserve capacity SOC**

Description The battery pack State of Charge is approaching, or at, minimum reserve capacity.

Possible Causes

Troubleshooting Steps

- Charge the batteries.

10-103 Over/Under discharge temperature**10-104 Over/Under charge temperature**

Description The battery pack temperature is above threshold during charging or discharging.

Possible Causes

Troubleshooting Steps

- Allow the batteries to warm/cool, and/or move the machine to a more appropriate environment.

10-107 Max current recuperation

Description The battery pack experienced maximum current input during regenerative braking.

Possible Causes

Troubleshooting Steps**10-111 CAN Bus failure**

Description The battery pack experienced a CAN Bus failure.

Possible Causes

Troubleshooting Steps

- Inspect the data connections between battery modules.

10-112 Set deactivation enable**10-114 Set node ID process enable**

Description	The battery pack is initiating a shutdown or startup process.
--------------------	---

Possible Causes

Troubleshooting Steps

10-115 Unknown warning

Description	The battery pack has set an uncategorized warning flag.
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Possible Causes

Troubleshooting Steps

10-202 Overcharge Recuperation

Description	Over current or voltage during regenerative braking.	LED Behavior	
		Reporting	Others
Related LL-Codes	0x3a <i>Overcharge current due to recuperation</i>	Solid Red	Solid Red
	0x3b <i>Overcharge cell voltage due to recuperation</i>	Solid Red	Solid Red
Setting Conditions	0x3a: The regenerative braking current exceeds 65 Ampere for more than 3 seconds or 85 Ampere for more than 50 milliseconds 0x3b: The regenerative braking voltage exceeds 4.25 Volts at any cell		
Possible Causes	Excessive regenerative braking.		
Module Response	0x3a The affected module disconnects its positive terminal. 0x3b All modules disconnect. • Cycle the battery disconnect to reset the batteries.		
Troubleshooting Steps			
• Because this is typically a pack-level cause, unless it is a repetitive error, identifying the specific reporting module is not required.			

10-203 Charge current short

Description	Short-circuit current during charging	LED Behavior	
		Reporting	Others
Related LL-Codes	0x15 <i>Short-circuit current during charging</i>	Solid Red	Solid Grn
Setting Conditions	• The charge current for a module exceeds 320 Ampere for more than 100 μS.		
Possible Causes	Faulty battery charger		
Module Response	• All modules in the pack disconnect their positive terminals. • Cycle the battery disconnect to reset the batteries.		
Troubleshooting Steps			
• Because this is typically a pack-level cause, unless it is a repetitive error, identifying the specific reporting module is not required.			

10-204 Discharge current short

Description	Short-circuit current during discharging	LED Behavior	
		Reporting	Others
Related LL-Codes	0x19 <i>Short-circuit current during discharging</i>	Solid Red	Solid Grn
Setting Conditions	• The discharge current for a module exceeds 320 Ampere for more than 100 μS.		
Possible Causes	This can happen if the power terminals are shorted, if the capacitance of the load is too big (Inrush) or if a single module is driving an excessive load.		
Module Response	• The affected module disconnects its positive terminal. • Cycle the battery disconnect to reset the batteries.		
Troubleshooting Steps			
• If a single module is driving a large portion of the load, then identifying the reporting module becomes more significant.			

10-205 Battery pack max SPN

Description	Module over voltage	LED Behavior	
		Reporting	Others
Related LL-Codes	<i>0x0d</i> <i>Module over voltage</i>	Solid Red	Solid Grn
Setting Conditions	A 24-volt module exceeds 31.5 Volts A 36-volt module exceeds 45 volts		
Possible Causes	Faulty charger		
Module Response	24V Mod: If the module voltage exceeds 4.5V x number of serial cells (7 cells for 24-volt module), charging is stopped. Charging is resumed if the module voltage drops by 1V. Only the specific module will open the Charge FET. 36V Mod: If the module voltage exceeds 4.5V x number of serial cells (10 cells for 36-volt module), charging is stopped. Charging is resumed if the module voltage drops by 1V. Only the specific module will open the Charge FET.		
Troubleshooting Steps			
• Because this is typically a pack-level cause, unless it is a repetitive error, identifying the specific reporting module is not required.			

10-206 Discharge FET fault

Description	Discharge FET is shorted.	LED Behavior	
		Reporting	Others
Related LL-Codes	<i>0x35 Discharge FET is shorted.</i>	Flash Red	Solid Red
Setting Conditions	The module detects that its discharge FET is closed when commanded to be open.		
Possible Causes	Battery module failure		
Module Response	Failed FET Discharging cannot be stopped and recharge is not possible. The module must be replaced. Caution: there will be voltage on the module's power terminals as the module is unable to disconnect the positive terminal.		
Troubleshooting Steps			
This is a module-specific failure and the module must be identified. However, the code is most likely active, so it will be easier to identify the module.			

10-207 Charge FET fault

Description	Charge FET is shorted. .	LED Behavior	
		Reporting	Others
Related LL-Codes	0x36 Charge FET is shorted. .	Flash Red	Solid Red
Setting Conditions	The affected module is unable to open its charge FET to disconnect power from the positive terminal		
Possible Causes	Battery module failure		
Module Response	Failed FET Charging cannot be stopped. The module must be replaced.		
Troubleshooting Steps			
This is a module-specific failure and the module must be identified. However, the code is most likely active, so it will be easier to identify the module.			

10-208 Charge max current

Description	Over current during charging	LED Behavior	
		Reporting	Others
Related LL-Codes	0x16 <i>Over current during charging</i>	Solid Red	Solid Red
	0x17 <i>Over current during charging</i>	Solid Red	Solid Red
	0x32 <i>A value close to limit of the ADC is measured.</i>	Flash Red	Solid Grn
Setting Conditions	0x16: The charge current in a module exceeds 65 Amps for more than 3 seconds 0x17: The charge current in a module exceeds 85 Amps for more than 50 ms 0x32: The charge current in a module exceeds 400 Amps		
Possible Causes	0x16 & 0x17: This can only happen if the charger is defective. 0x32: Battery mismatch or miswiring.		
Module Response	0x16 All modules disconnect their positive terminals. . 0x17 All modules disconnect their positive terminals. • Cycle the battery disconnect to reset the batteries. 0x32 The affected module disconnects its positive terminal and cannot be reset. The module must be replaced.		
Troubleshooting Steps			
• Because one of the LL-Codes is module specific, and its activation requires the module to be replaced, the Fault History Codes must be examined to determine which code is set and which module is affected.			

10-209 Discharge max current

Description	Over current during discharging	LED Behavior	
		Reporting	Others
Related LL-Codes	0x1a <i>Over current during discharging</i>	Solid Red	Solid Grn
	0x1b <i>Over current during discharging</i>	Solid Red	Solid Grn
	0x34 <i>A value close to limit of the ADC is measured.</i>	Flash Red	Solid Grn
Setting Conditions	0x1a: The discharge current in a module exceeds 65 Amps for more than 3 seconds 0x1b: The discharge current in a module exceeds 85 Amps for more than 50 ms 0x34: The discharge current in a module exceeds +600 Amps		
Possible Causes	• 0x1a & 0x1b: This can happen if the power for a single module is too high or if all other modules are depleted and disengage. The remaining module cannot support the load of the machine. • 0x34: If a discharge current value of more than 600A is measured, the module cannot be reset and must be replaced.		
Module Response	0x1a The affected module disconnects its positive terminal 0x1b The affected module disconnects its positive terminal • Cycle the battery disconnect to reset the batteries. 0x34 The affected module disconnects its positive terminal and cannot be reset. The module must be replaced.		
Troubleshooting Steps			
• Because one of the LL-Codes is module specific, and its activation requires the module to be replaced, the Fault History Codes must be examined to determine which code is set and which module is affected.			

10-210 Undercharge alarm

Description	Cell under-voltage during discharge		LED Behavior	
			Reporting	Others
Related LL-Codes	0x09	Cell under voltage during discharge	Solid Red	Solid Grn
	0x29	A value close to limit of the ADC is measured.	Flash Red	Solid Grn
Setting Conditions	0x09	A cell block in a module is empty (Fully depleted).		
	0x29	The voltage in a cell block is measured to be above +5-Volt		
Possible Causes	0x09	When a cell block in a module is depleted, the complete module is disconnected from the pack. The remaining modules in a pack will continue to operate.		
	0x29	The only way the voltage can exceed 5V is if the measurement circuitry has failed. The module must be replaced.		
Module Response	0x09	The affected module disconnects its positive terminal. The module is reset by connecting a charger and charge to a minimum 2%		
	0x29	The affected module disconnects its positive terminal The module cannot be reset		
Troubleshooting Steps				
Because one of the LL-Codes is module specific, and its activation requires the module to be replaced, the Fault History Codes must be examined to determine which code is set and which module is affected.				

10-211 Overcharge alarm

Description	Cell over-voltage during charge		LED Behavior	
			Reporting	Others
Related LL-Codes	0x08	Cell over voltage during charge	Solid Red	Solid Red
	0x2a	A value close to limit of the ADC is measured.	Flash Red	Solid Grn
Setting Conditions	0x08	The voltage in any cell block exceeds 4.25 Volts for more than 3 seconds.		
	0x2a	The voltage of a cell block is too close to the limit of the A/D converter		
Possible Causes	0x08:	A cell over-voltage above 4.25V during charge in any module terminates charge of all modules.		
	0x2a:	A cell voltage over 5V during charge can only happen if the charger is defect or a non-authorized charger is used.		
Module Response	0x08	The affected module disconnects its positive terminal. The module is reset by connecting a load.		
	0x2a	The affected module disconnects its positive terminal The module cannot be reset		
Troubleshooting Steps				
Because one of the LL-Codes is module specific, and its activation requires the module to be replaced, the Fault History Codes must be examined to determine which code is set and which module is affected.				

10-212 Over/Under charge temperature

Description		LED Behavior	
		Reporting	Others
Related LL-Codes	0x01	Cell over temperature during charging	
	0x02	Cell under temperature during charging	
	0x03	Chrg FET's above temp limit during charging	
Setting Conditions	0x01	The cell temperature in a module exceeds limit for charging. Typically +50 °C (+122 °F).	
	0x02	The cell temperature in a module is below limit for charging. Typically 0 °C (+32 °F).	
	0x03	The Charge FET's in a module exceeds the limit. Typically +90 °C (+194 °F)	
Possible Causes	Excessive environmental temperatures with elevated charging rates.		
Module Response	All	All modules disconnect their positive terminals. Charging is automatically resumed when temperature condition subsides..	
Troubleshooting Steps			
Because this is typically a pack-level cause, unless it is a repetitive error or contrary to ambient temperatures, identifying the specific reporting module is not required.			

10-213 Over/Under discharge temperature

Description	A cell or charge FET is out of temperature range during discharge.		LED Behavior	
			Reporting	Others
Related LL-Codes	0x04	Cell over temperature during Discharging	Solid Red	Solid Red
	0x05	Cell under temperature during Discharging	Solid Red	Solid Red
	0x06	Dischrg FET's above temp limit during dischrg	Solid Red	Solid Red
Setting Conditions	0x04: The cell temperature in a module exceeds 60 °C (140 °F) during discharge 0x05: The cell temperature in a module is below -20 °C (-4 °F) during discharge 0x06: The discharge FETs in a module exceed 90 °C (194 °F)			
Possible Causes	Excessive environmental temperatures with elevated discharging rates.			
Module Response	All	Discharging on all modules are stopped. Discharging can only be resumed by charging or Off/On activation if the temperature of all cells in all modules are within range		
Troubleshooting Steps				
Because this is typically a pack-level cause, unless it is a repetitive error or contrary to ambient temperatures, identifying the specific reporting module is not required.				

10-214 Module defective

Description	Internal module problem.	LED Behavior	
		Reporting	Others
Related LL-Codes	0x0a <i>Cell voltage too low</i>	Flash Red	Solid Grn
	0x0f <i>Module voltage differs from sum of cell voltages.</i>	Solid Red	Solid Grn
	0x10 <i>Measured module voltage too low</i>	Solid Red	Solid Grn
	0x2b <i>Cell temperature sensor value too high</i>	Flash Red	Solid Grn
	0x2d <i>FET temperature sensor value too high</i>	Flash Red	Solid Grn
Setting Conditions	0x0a : A cell block in a module is deeply discharged 0x0f : Voltage difference between total module and accumulated cell blocks too big 0x10 : Module voltage is less than 14 volts 0x2b : A Cell temperature sensor in a module is shorted 0x2d : A FET temperature sensor in a module is shorted		
Possible Causes	0x0a: If a cell block in the module is deep discharged, the module will permanently disconnect from the pack. The module must be replaced. 0x0f: The difference of the sum of single cell voltages and the module voltage is too high. Allowed difference is 7V for a 24-volt module, or 10V for a 36-volt module. 0x10: The module voltage is less than 14V for 24V module, or 20V for a 36V module. Reset condition: increase by 1V. 0x2b: A cell temperature sensor reports a temperature above 125 °C, which typically means that a temperature sensor is shorted. The module is permanently disconnected from the pack. The remaining modules in a pack are working normally. The module must be replaced. 0x2d: A FET temperature sensor reports a temperature above 125 °C, which typically means that a temperature sensor is shorted. The module is permanently disconnected from the pack. The remaining modules in a pack are working normally. The module must be replaced.		
Module Response	0x0a: The module will permanently disconnect from the pack. The module must be replaced. 0x0f: The affected module disconnects its positive terminal. The module resets automatically when the difference is within range 0x10: The affected module disconnects its positive terminal. The module resets if the voltage increases to 15V for a 24-volt module, or 21V for a 36-volt module. 0x2b: The module is permanently disconnected from the pack. The module must be replaced. 0x2d: The module is permanently disconnected from the pack. The module must be replaced.		
Troubleshooting Steps			
• Because all of the LL-Codes are module specific, and an activation of some requires the module to be replaced, the Fault History Codes must be examined to determine which code is set and which module is affected.			

10-215 Unknown Error

Description	Internal module error	LED Behavior	
		Reporting	Others
Related LL-Codes	0x38 <i>Discharge Error Lock (0x04, 0x05, 0x06)</i>	Solid Red	Solid Grn
	0x3c <i>24-volt supply below limit</i>	Flash Red	Solid Grn
	0x3d <i>24-volt supply above limit</i>	Flash Red	Solid Grn
	0x40 <i>Parameter outside range</i>	Flash Red	Solid Grn
Setting Conditions	0x38: Cell or FET temperature outside limit during discharge 0x3c: Internal supply voltage below limit 0x3d: Internal supply voltage above limit 0x40: The parameter settings does not fit the actual module		
Possible Causes	0x38: This flag is set in combination with Error 0x04 / 0x05 / 0x06. 0x3c: 24V supply of the BMS is lower than 16V. The module must be replaced 0x3d: 24V supply of the BMS is higher than 26V. The module must be replaced 0x40: The version of the module is identified from the SW via an external ID resistors. If the ID resistor coding doesn't fit to the programming of the specific variant (24V / 36V / 48V), this failure is set. The module must be replaced		
Module Response	0x38: All modules in the pack disconnect their positive terminals. Discharge is resumed by Off/On activation if the temperature of all cells and FET's in all modules are within range 0x3c: The affected module disconnects its positive terminal. Cannot reset. The module must be replaced. 0x3d: The affected module disconnects its positive terminal. Cannot reset. The module must be replaced. 0x40: The affected module disconnects its positive terminal. Cannot reset. The module must be replaced.		
Troubleshooting Steps			
• Because all of the LL-Codes are module specific, and an activation of some requires the module to be replaced, the Fault History Codes must be examined to determine which code is set and which module is affected.			

N/A Uncategorized Errors

Description	No Upper Level Code is reported for these LL-Codes.	LED Behavior	
		Reporting	Others
Related LL-Codes	0x0b Severe Cell imbalance within a module	Solid Red	Solid Grn
	0x1d Difference of current measurement	Flash Red	Solid Grn
	0x2c Cell temperature sensor value too low	Flash Red	Solid Grn
	0x2e FET temperature sensor value too low	Flash Red	Solid Grn
	0x39 Charge Error Lock	Solid Red	Solid Red
	0x3e Node-ID are not assigned	Flash Org	Solid Grn
	0x3f Node-ID conflict	Flash Org	Flash Org
Setting Conditions	0x0b The imbalance of the cell blocks in a module exceeds 200mV.		
	0x1d The filtered and unfiltered current measurement differs by 10%.		
	0x2c A cell temperature sensor reports a temperature below -40 °C		
	0x2e A FET temperature sensor reports a temperature below -40 °C.		
	0x39 This flag is set in combination with Error 0x01, 0x02, 0x03.		
	0x3e Node-ID are not assigned		
	0x3f Node-ID conflict		
Possible Causes	0x0b If the cell block imbalance inside a module exceeds 200mV, the module will open both FETs and disconnect charging and discharging.		
	0x1d The filtered and unfiltered current measurement differs by 10%. This can only happen if there is a hardware failure in the current measurement circuitry. The module must be replaced		
	0x2c A cell temperature sensor reports a temperature below -40 °C, which typically means that a temperature sensor is disconnected		
	0x2e A FET temperature sensor reports a temperature below -40 °C, which typically means that a temperature sensor is disconnected.		
	0x39 This flag is set in combination with Error 0x01, 0x02, 0x03.		
	0x3e The module cannot communicate on CAN and charging on this module is not possible		
	0x3f The module cannot communicate with other Nodes on CAN and charging is not possible		
Module Response	0x0b The affected module disconnects its positive terminal. If the cell imbalance drops below 100mV, the module can be reset.		
	0x1d The affected module disconnects its positive terminal. Cannot reset. The module must be replaced.		
	0x2c The affected module disconnects its positive terminal. Cannot reset. The module must be replaced.		
	0x2e The affected module disconnects its positive terminal. Cannot reset. The module must be replaced.		
	0x39 All modules in the pack disconnect their positive terminals. Charging is automatically resumed when the temperature of all cells and FET's in all modules are within range		
	0x3e The affected module disconnects its positive terminal. Perform Node-ID assignment		
	0x3f All modules in the pack disconnect their positive terminals. Perform Node-ID assignment or remove external equipment with a Node-ID		

Troubleshooting Steps

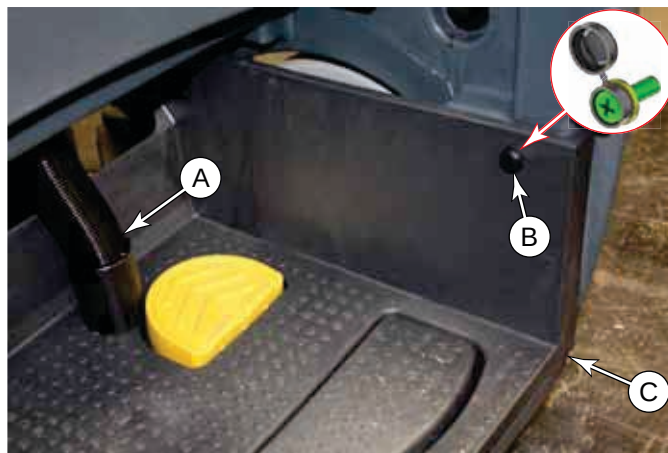
- Because these errors will not trigger an upper level code, the Fault History Codes must be examined to determine which code is set and which module is affected.

Removal and Installation

Operator Platform

Removal of the operator platform is a prerequisite procedure for accessing sensors and components below the platform.

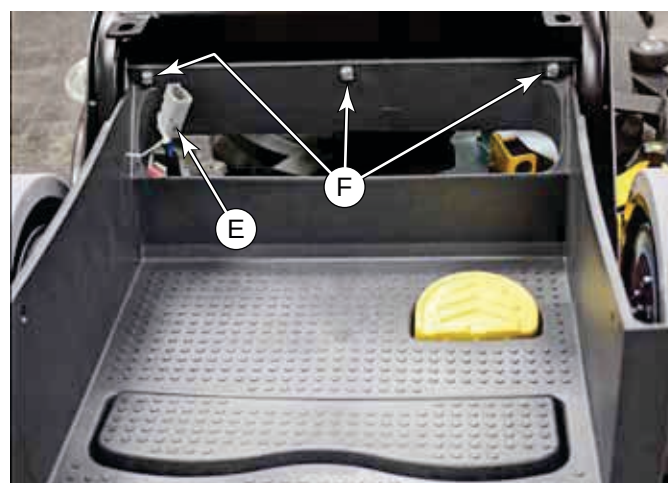
1. Disconnect the recovery hose (A) from the squeegee.
2. Pry up the screw cap from the two screws (B) on the sides of the platform, and remove the screws, washers, and cap retainers.
3. Remove the two screws (C) from the rear of the platform.



4. Disconnect the two wheel encoder electrical connectors (D). (To allow the platform enough room to remove the necessary cable ties below.)
5. Disconnect the operator controls electrical connector (E).
6. As necessary, free up any cable ties that would prevent the platform from being removed.



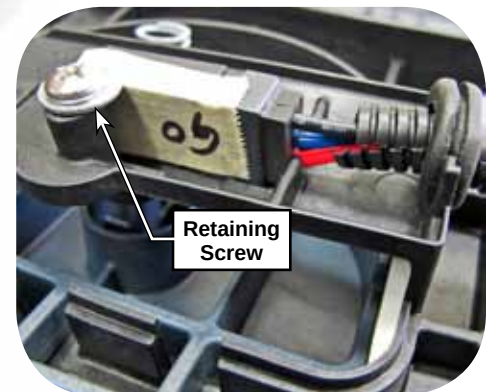
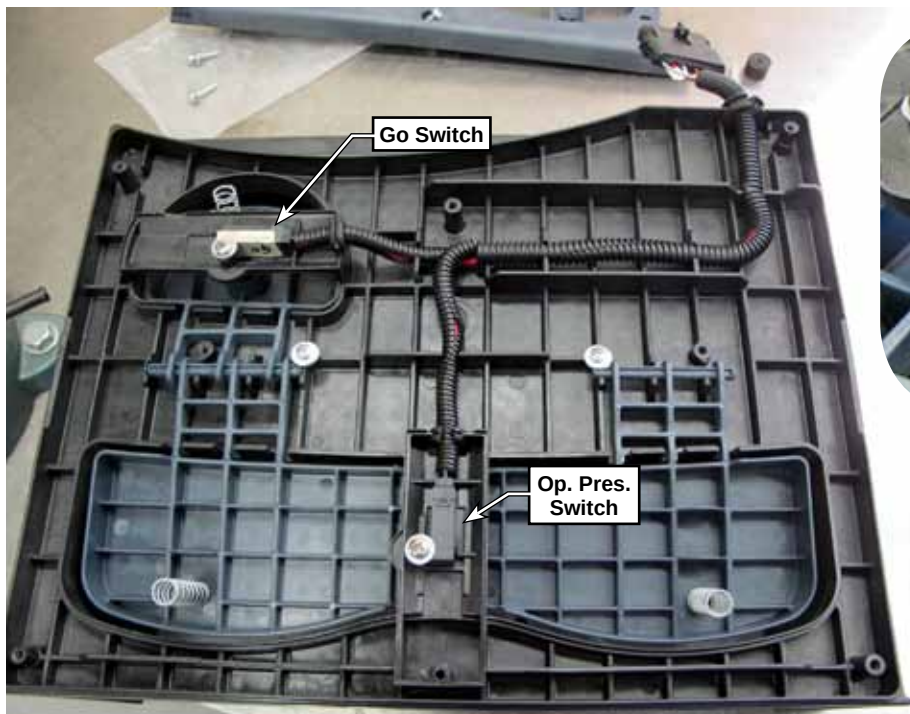
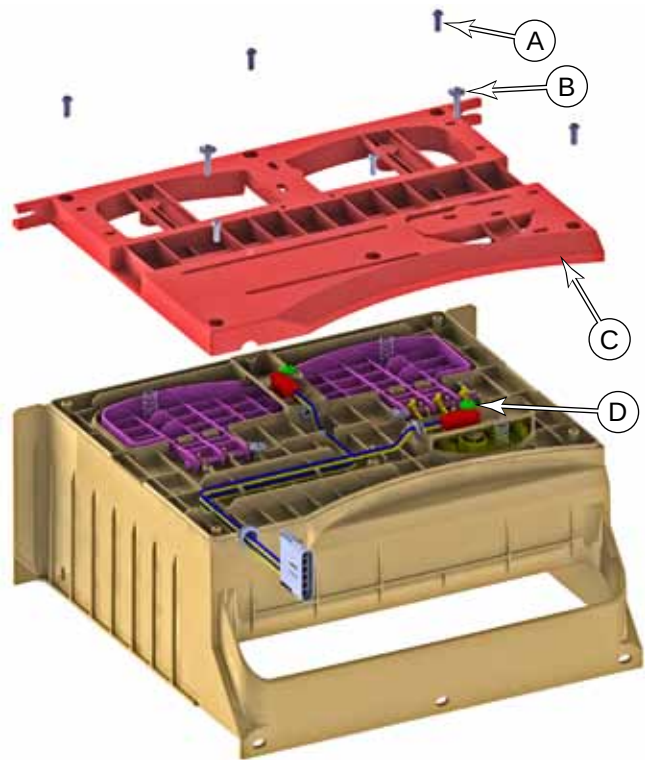
7. Remove the three rear platform screws (F), and remove the platform.



Platform Switches

There are two micro switches inside the operator's platform for machine control. The Operator Present switch is below the larger pedal, and the Go switch is below the smaller pedal.

1. Remove the [Operator Platform](#) described on page 261.
2. Turn the platform over on a flat work surface and remove the 6 perimeter screws (A), and two washer-head interior screws (B).
3. Carefully remove the bottom cover (C) from the platform. Note that there are several springs below this cover. Take care to not lose them.
4. Remove both retaining screws (D), and lift both switches and wiring harness out of the platform.
 - During replacement, note that the switch with the longer wire is the Operator Present switch.



Batteries (Lead-Acid)

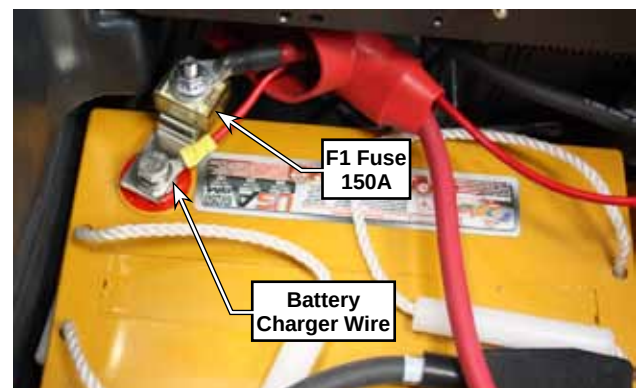
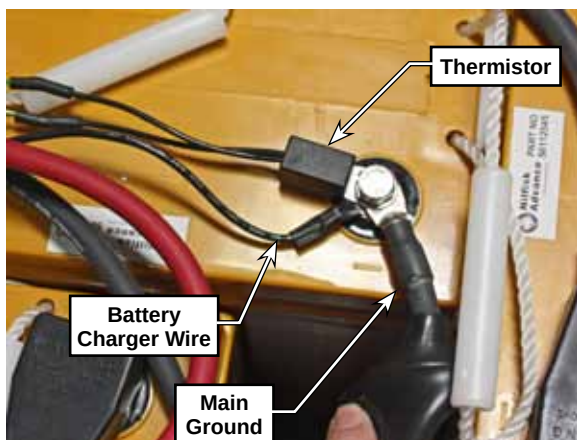
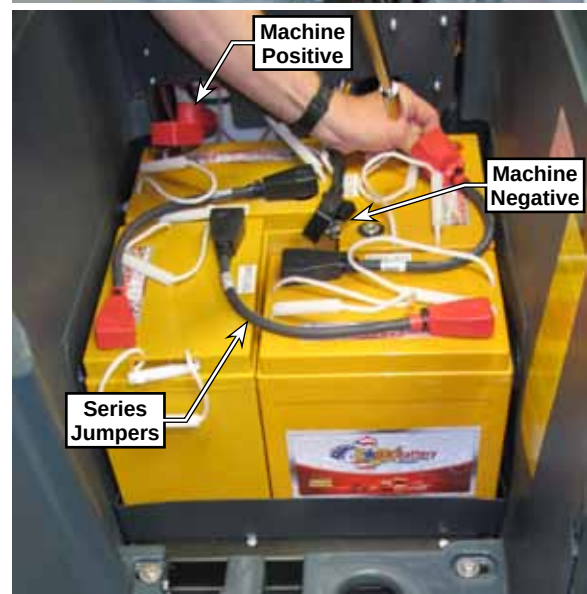
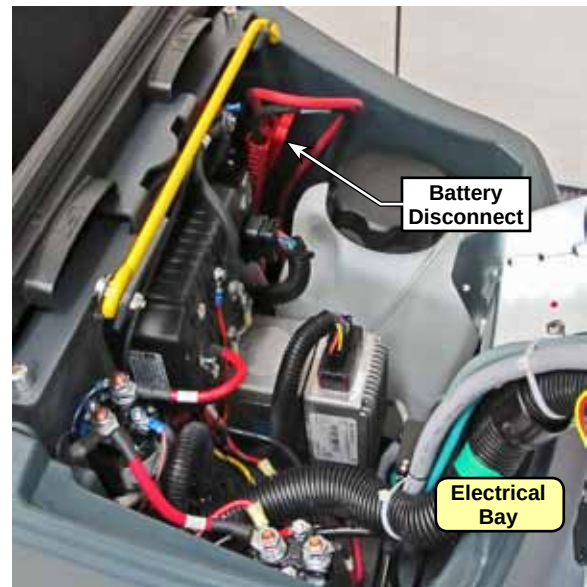


CAUTION: It is important to unplug the main disconnect before removing battery cables to avoid power spikes to the control modules that otherwise are always receiving power.

1. Shut down the machine, wait at least 15 seconds after the dropoff sensors turn off, and disconnect the main battery disconnect in the electrical bay.
2. Drain and remove the [Recovery Tank](#) described on page 346.
3. Disconnect the machine negative terminals, including:
 - Main ground
 - Thermistor
 - Battery Charger
4. Disconnect the machine positive terminals, including:
 - F1 Fuse
 - Battery Charger
5. Disconnect the series jumpers from the remaining batteries.
6. Lift the 4 batteries out of the battery bay and set them aside.



Note: After the batteries are reinstalled, plug the battery charger into facility power for 30 seconds to reset the CANBus communication.



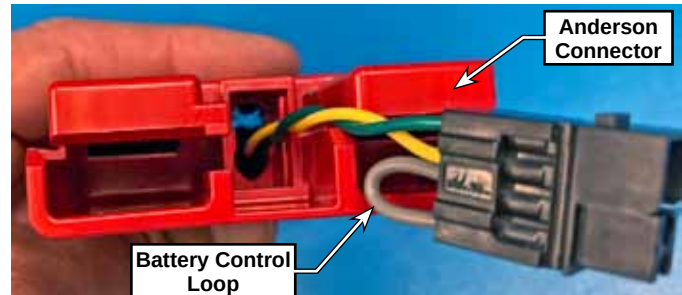
Batteries (Lithium Ion)



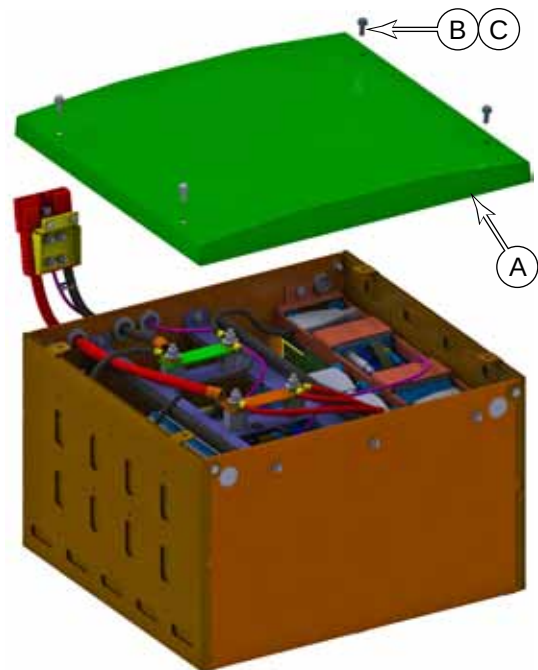
CAUTION: The power-down and disconnection sequence is critical to the health of the machine's controllers and also the Lithium Ion batteries themselves. Note the following:

- Make sure the Autonomous controller is powered down before turning off or disconnecting the batteries (see [Step 1](#)).
- Make sure the batteries are turned off and disconnected before removing any ground wire (see [Step 2](#)).

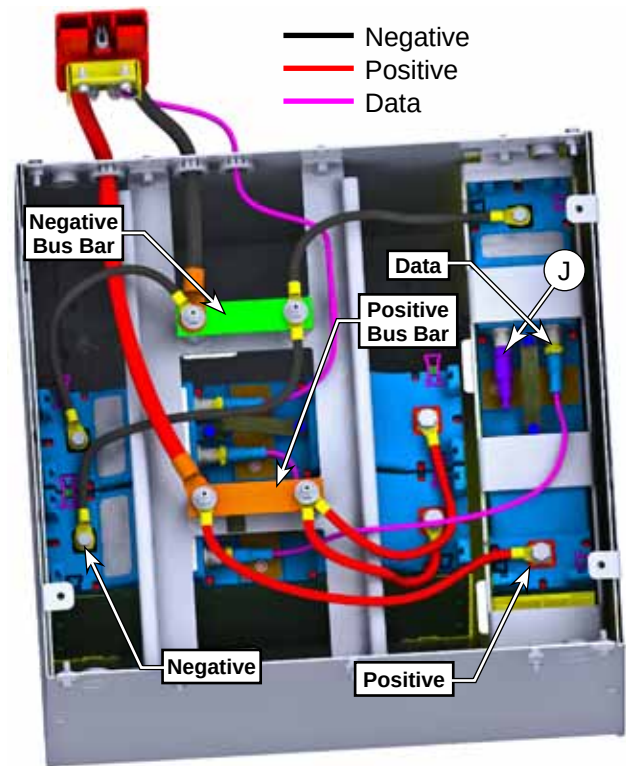
1. Shut down the machine and wait at least 15 seconds after the dropoff sensors turn off. This ensures the Autonomous controller is fully powered down.
2. After the machine is fully powered down, disconnect the batteries by unplugging the Anderson Connector (Battery Disconnect). This also disconnects the battery control loop, which turns all of the BMS modules off inside the battery pack.



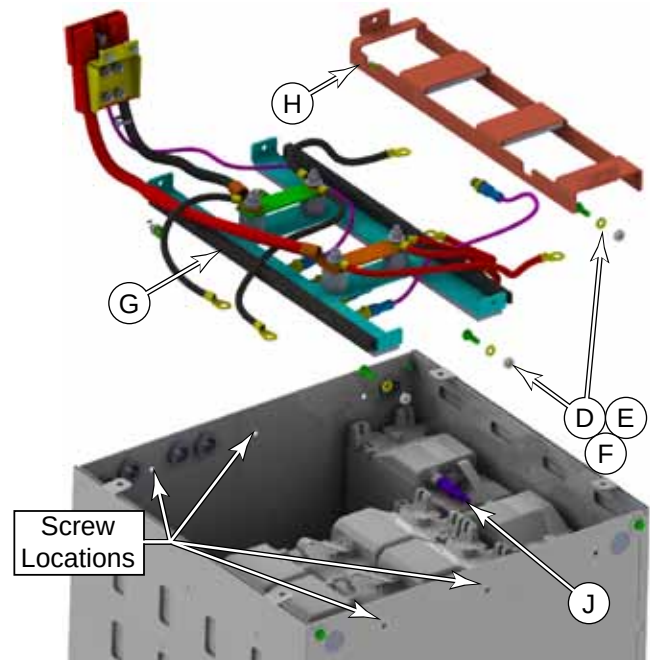
3. Drain and remove the [Recovery Tank](#) described on page 346.
4. Remove the four screws (B) and washers (C) that secure the battery box cover (A), and remove the cover.



5. Disconnect all of the data cables from the batteries.
 - Even if only one battery is being replaced, the support frames must be removed, which requires all cables to be removed.
 - Note the location of the termination resistor (**J**), and if applicable, transfer it to the new battery.
6. Disconnect the Negative wires from all of the battery lugs.
 - The wires may be left connected to the bus bars if desired.
7. Disconnect the Positive wires from all of the battery lugs.
 - The wires may be left connected to the bus bars if desired.



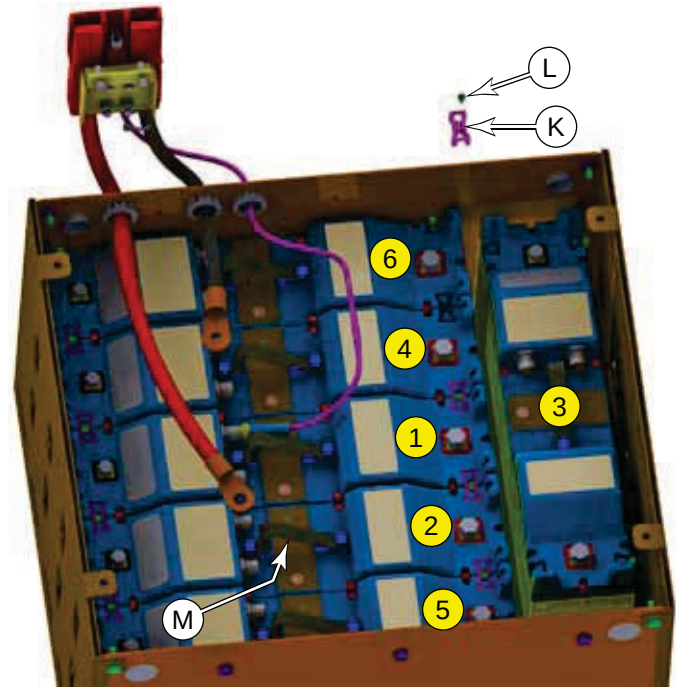
8. Remove the four screws (**D**), washers (**E**), and nuts (**F**) that secure the bus bar frame (**G**) to the battery box, and lift the frame out of the battery box and set it to the side. (The main cables to the machine are still connected.)
9. Remove the two screws (**D**), washers (**E**), and nuts (**F**) that secure the side battery frame (**H**) to the battery box, and lift the frame out of the battery box.



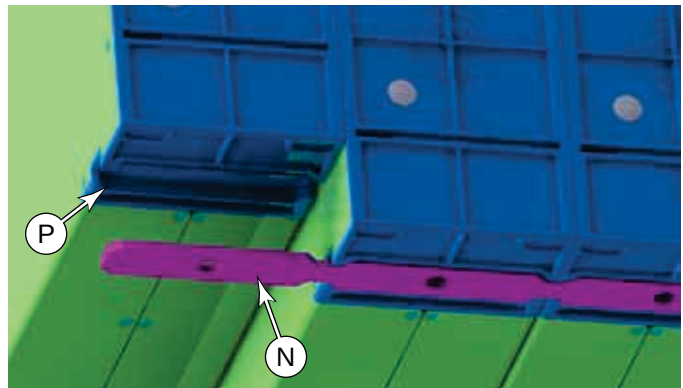
10. As necessary, remove the screws (**L**) and “Dogbone” connectors (**K**) that tie adjacent batteries to one another.
11. As necessary, lift the battery(ies) out of the battery box using the lifting handle (**M**).

Battery Placement

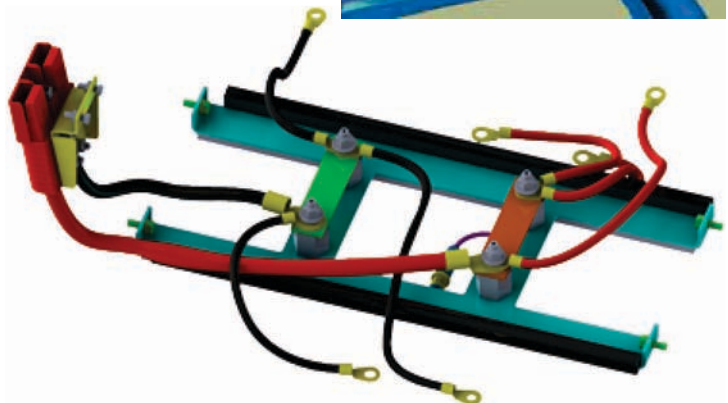
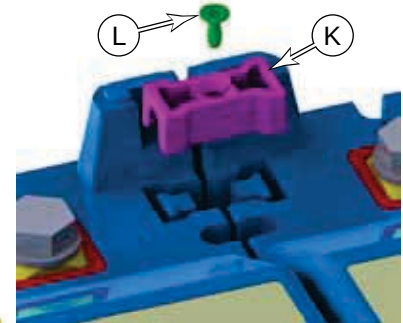
- The battery box can hold anywhere from 1 to 6 Lithium Ion batteries.
- For purposes of weight distribution, populate the batteries according to the numbers shown to the right.
- It is permissible to mix old and new batteries, however all batteries must be of the same voltage and model.



12. Place the batteries into the battery box.
 - The lateral batteries (**1,2,4,5,6**) should have the ground lug toward the left side of the machine.
 - The single lineal battery (**3**) should have the ground lug toward the front of the machine.
13. The bottom of the battery box has guide rails (**N**) to keep the batteries from moving. Make sure the recess (**P**) of the battery is seated onto the guide rail.



14. Place a dogbone connector (**K**) between adjacent batteries and tighten the expansion screw (**L**) to clamp them together.
 - The dogbone connectors are asymmetrical and fit only one way. This is to ensure that adjacent batteries are oriented positive-to-positive and negative-to-negative.
 - Do not overtighten the expansion screw.
15. Connect all of the battery Positive lugs to the positive bus bar. Balance the number of wires landing on each of the bus bar studs.
16. Connect all of the battery Negative lugs to the negative bus bar. Balance the number of wires landing on each of the bus bar studs.
17. Connect the battery closest to the front of the machine to the incoming data connector, and then daisy-chain connections to the remaining batteries.
18. Install the termination resistor (**J**) to the last battery (position #3).



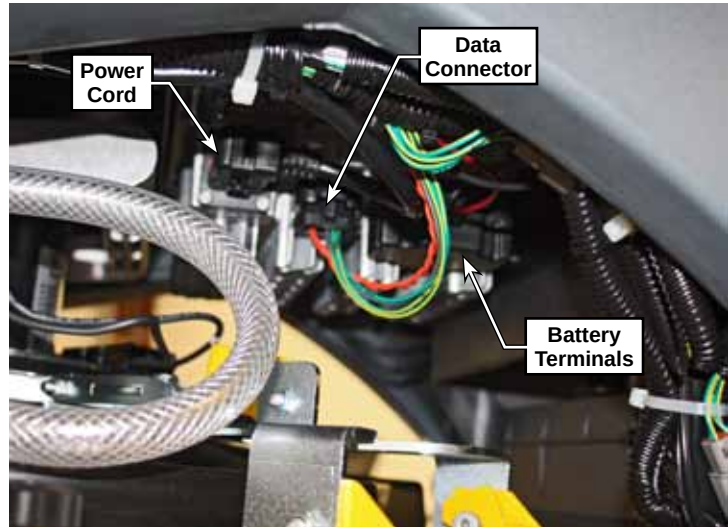
Battery Charger

The battery charger is located below the main chassis just behind the scrub deck.

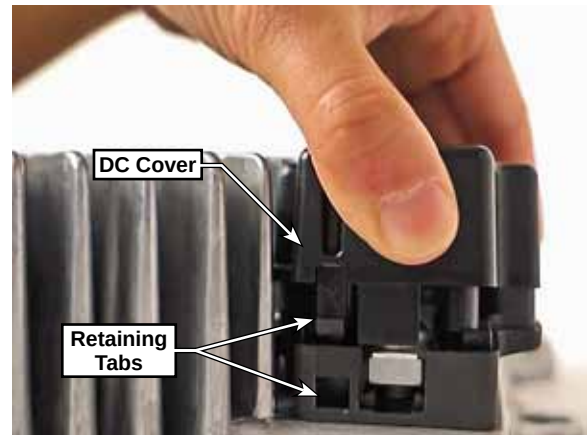


CAUTION: Risk of arc-flash burns. The battery terminals at the charger are on unfused wires from the battery. Make sure to disconnect the main batteries before working on the charger.

1. For easier access to the charger, lower the scrub deck and press the E-stop button to disable machine functions, and then power down the machine with the E-stop depressed.
2. Wait for the Autonomous controller to power down (15 seconds after the dropoff sensors turn off), and then disconnect the main battery connector in the electrical bay.
3. Remove the [Recovery Tank](#) described on page 346.
4. Remove the [Batteries \(Lead-Acid\) described on page 263](#)
5. From the left side of the machine, squeeze the retaining latch, and remove the AC power cord from the charger.



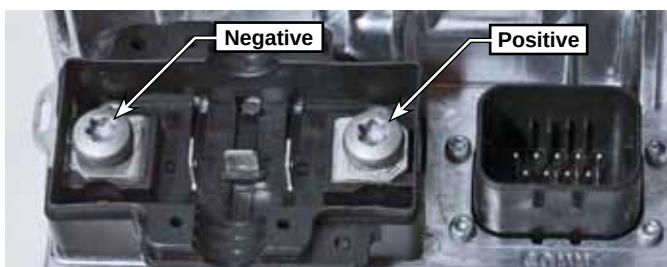
6. Remove the data connector from the charger
7. Using a small screwdriver, press in on the two retaining tabs, and lift off the DC cover from the charger.
8. At this point, double-check to ensure that you disconnected the main battery connector discussed above. A short circuit on the DC wires will result in an arc-flash, and will severely damage the wiring harness all the way back to the batteries.
9. Using a T30 driver, remove the positive and negative battery connections from the charger.
 - During replacement, torque the screws to 4.5Nm (40 lb•in).



10. Remove the four retaining nuts that secure the charger to the chassis, and remove the charger.



Note: After the charger is reinstalled, plug the battery charger into facility power for 30 seconds to reset the CANBus communication.



Wiring Diagrams

Understanding the Features of the Electrical Circuit Diagram

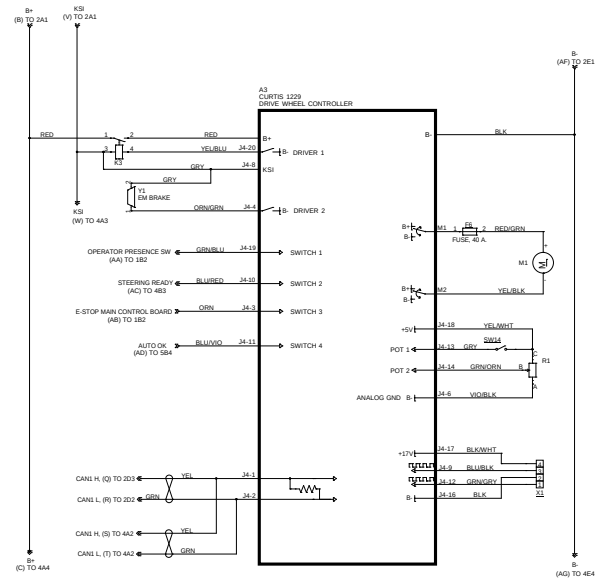
The style of the electrical circuit diagram is a hybrid of drawing types, borrowing various features from different schematic styles, such as ladder diagrams, net diagrams, and block diagrams. Owing to its history as a ladder diagram, power rails are typically represented as vertical lines to the left and right of the diagram.

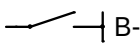
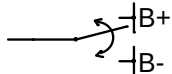
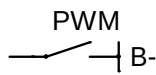
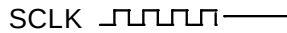
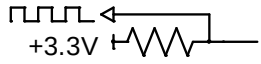
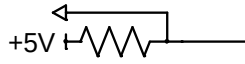
Similar to a net diagram, tags are used to represent some connections that either span pages, or would be too complex to draw as a single line trace. Borrowing from block diagrams, graphic symbols and icons provide a visible representation of internal functions of a device.

Positive voltage source(s) are represented by vertical “Rails” on the left side of the diagram, and the negative voltages source (typically only 1, being battery negative) is represented by a vertical Rail on the right side of the diagram. Devices are drawn between the two rails, and current flows from the positive rail, through the load, and to the negative rail.

Unique to the hybrid ladder diagram are the intelligent controllers that control if and when devices are connected to either positive or negative power. Even though not technically accurate, circuit symbols have been drawn inside the controller outlines to represent the electrical function that takes place inside. These represent the function, but not an actual device. For example, even though a symbol may look like a switch, it cannot be tested as though it was a real switch.

Some of the common controller internal symbols are described below:



	Output, Switch to positive or negative power. The controller serves to complete the circuit to the respective power source, most commonly battery negative.
	Output, Bi-directional switch to power These outputs are always in pairs, and are for reversible loads. • For forward direction, one output is positive and the other is negative. • For reverse direction, one output is negative and the other is positive. • For no movement, both outputs are the same, which may be positive, negative, or zero, depending on the controller.
	Pulse Width Modulation (PWM) Switch This is an electronic (transistor) switch that completes the circuit to either battery positive or battery negative power. The duty cycle between on and off states determines how much power the load receives.
	Digital Data Out This symbol indicates that the output is a digital stream of data pulses.
	Digital Data In, with Pullup This symbol represents a digital data stream input signal that is active-low, and the pullup resistor represents the open-circuit (inactive) signal voltage.
	Discrete Input with Pullup This symbol represents a binary (On/Off) input with a 5-volt pullup resistor. When the switch or sensor is off (open circuit) the pullup resistor makes the input equal 5 volts. When the switch or sensor is closed, the input typically goes to 0 volts.

Device Labeling

All of the components within the diagram carry various labels intended to assist in identifying those items in the actual machine, or to reference them to other drawings.

Device Numbers (Names):

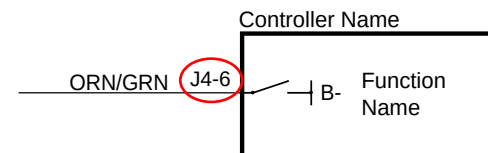
Each device is given its own unique identifier. The letter prefix identifies the type of device, such as “K” for a relay, “L” for a solenoid, “M” for motor, and “A” for a control module; just to name a few. Then each device within that class is given a unique number. For example, “K1” is the main KSI relay. However, because this particular relay serves a common function, it is also identified by a simple name too: “KSI” (Legacy for Key Switch Input).

Device numbers and device names (when they exist) are synonymous, but device names are preferred because they are easier to remember, so long as they are unique and descriptive. Device numbers are frequently used for the machine’s display, where character count is important.

Connector Contact Numbers:

All of the circuit lines going to any of the control modules will have indicators for their wire color and the connector pin-out location. When 2 colors are listed for a wire color, the first color is the main color and the second color is the color of a stripe on the wire.

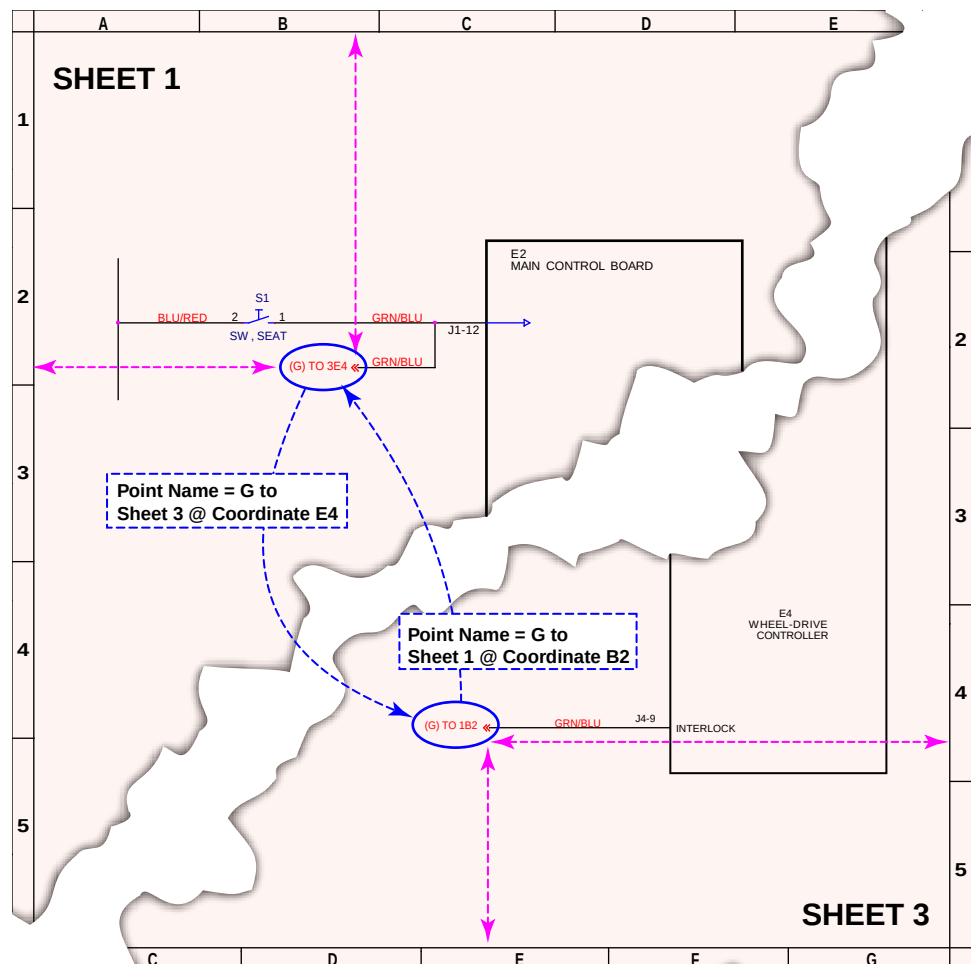
For the connector identifier example shown (J4-6), the first part “J4” represents the connector number, and the last part “6” represents the pin number within that connector. This information, along with the [“Electrical Connector Pin-Out Assignments”](#) on page 299 is used locate the physical wires on the machine.



Navigation

In some cases it is necessary to have references across different areas of a drawing. These references can point across the drawing sheet, or to different sheets in a multi-sheet schematic. The references are commonly referred to as “Tags”. At a minimum, tags typically have a name or designation, but they may also contain coordinate pointers to their counterpart.

In the sample diagram to the right, the output from the seat switch needs to connect to the Main Machine Controller on sheet #1 and also to the drive controller on sheet #3. The identifying name could be an actual name, such as (Seat Switch), or in this case, just a letter designator (G). Both ends of a tag will have the same identifier.



In addition to the identifier, the tag also contains coordinate information to help you locate the mating tag faster. So the first tag contains the coordinates of the second tag, and the second tag contains the coordinates of the first tag. The format of these coordinates are Sheet, Column, and Row.

These coordinates are part of the default title blocks on engineering drawings, and run around the perimeter of the drawing sheet. The columns are represented by the letters across the top/bottom of the drawing, and the rows are represented by the numbers down the sides of the drawing.

Using the Wiring Harness Diagram

The wiring harness diagram contains detailed information about the physical wiring within the machine. Every wire segment is listed. Every connector is listed. Even the hidden splice points between wires are listed. This information is useful for tracing a specific circuit as it passes through the machine.

Wire Numbers

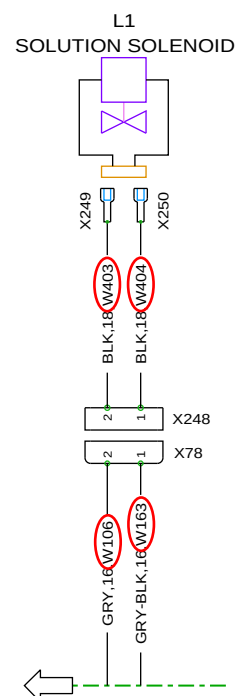
Every wire is labeled with 3 items: Wire color, Wire Gauge, and Wire Number. The wire number in the diagram is also printed on the actual wire used in the machine itself. The wire number can be used to locate both ends of any wire segment in the machine.

Even though an individual electrical circuit may pass from one electrical connector to another connector, that circuit may be made up from multiple wire segments. Each of those segments is identified in this diagram. The circuit may pass through a splice point (**SPL-##**) or an intermediate connector (such as shown to the right), but each wire has only 2 connection points.

To trace a complete circuit, you would need to search for both ends of any wire number, and see where they connect to the next wire segment. And then repeat this for each wire segment in the circuit.



Service Tip: We use the Circuit Diagram to trace a circuit, but use the harness diagram to trace the wires that make up that circuit.

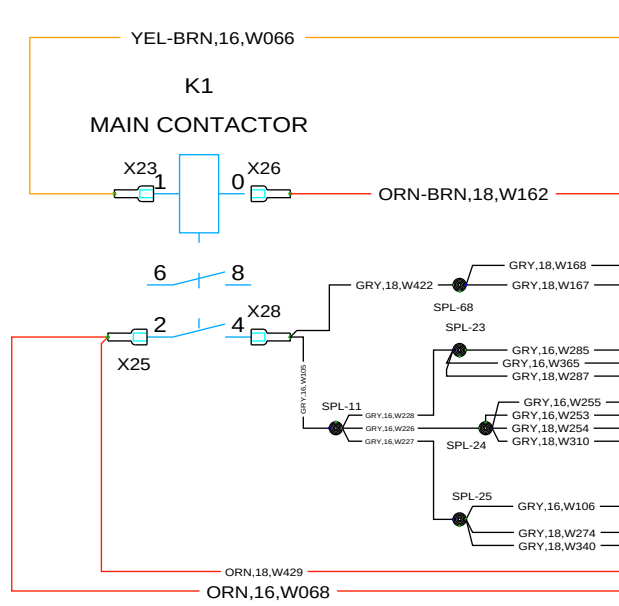


Splice Points

Another valuable piece of information in the harness diagram is whether splice points exist in a circuit. Splice points are used when a circuit needs to divide and travel on to multiple destinations. Each splice point also has its own unique identifier (SPL) number. Power distribution leaving the K1 (KSI) contactor is prime example of using multiple splice points to distribute this common circuit to multiple locations.

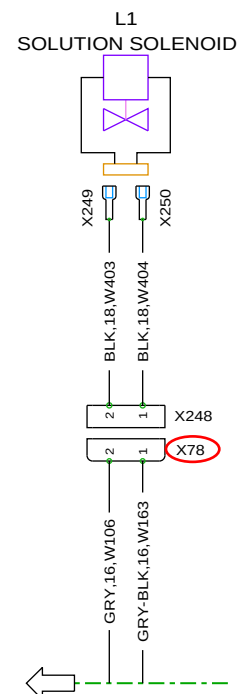
This knowledge can be helpful in troubleshooting. If multiple components fail, and it is discovered that they all share a common splice point, it can be concluded that a wire failure occurred at or upstream from that splice point.

Conversely, if only one component has failed, then it can be concluded that a wire failure has not occurred in an upstream wire segment.



Connector Numbers

Every harness connector throughout the system is given a unique connector ID number. The ID numbers can be used to locate the connector in the machine and to look up pin assignments in the [“Electrical Connector Pin-Out Assignments”](#) on page 299. This information is used for tracing circuits and electrical signals throughout the machine. When there are mating connectors to a device, the harness-side connector is shown for pin-out assignment.



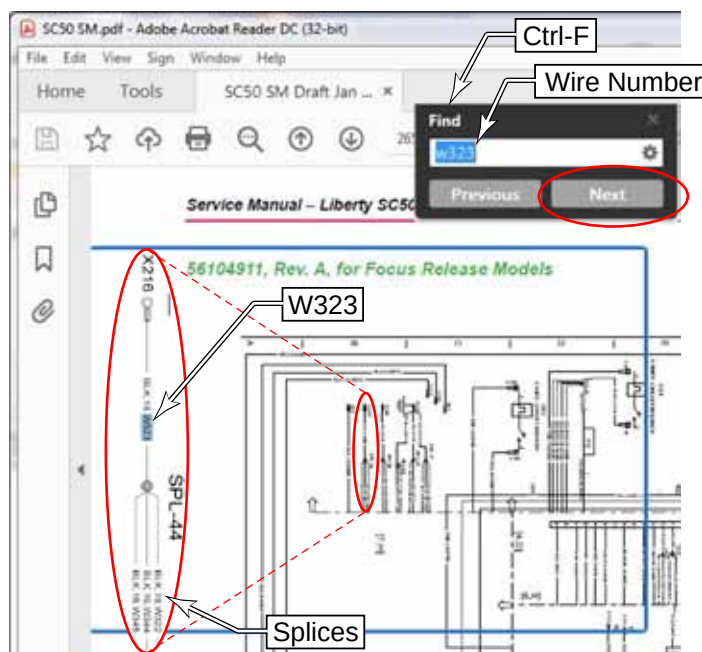
Acrobat Search to Trace a Circuit

Tracing a circuit that consists of a single wire from connector to connector is straight forward. However, when a circuit passes through multiple connectors and splice points, different ends of the circuit will have different wire numbers.

The built-in Acrobat search feature can assist you in tracing a circuit from its beginning, through any splice points, additional branches, and any termination point you may need to find.

Example:

- From the connector pin-out table, identify the wire number you wish to trace. (W323 in this example)
- Press Ctrl-F in your Acrobat viewer to open the search dialog.
- Enter the wire number as shown, and click on “Next”.
 - The first search result may start out with the pinout table, or in this case, a single wire connector will not have a pinout table entry. So the first result will be in the harness diagram.
- As necessary, press “Next” until the desired wire appears in the harness diagram.
 - In this case, the wire leads to a splice SPL-44, which splits the circuit off into 3 additional wires: W322, W344, & W345.
- Enter one of these new wire numbers into the search box and press next.
- The first result will be the nearby wire at the splice. Press “next” again to locate the other end of the wire.
 - The 3 wires in this example lead to Battery Negative to the DC/DC Converter, and 2 connections to the Steering Controller (J5-7 & J5-15).

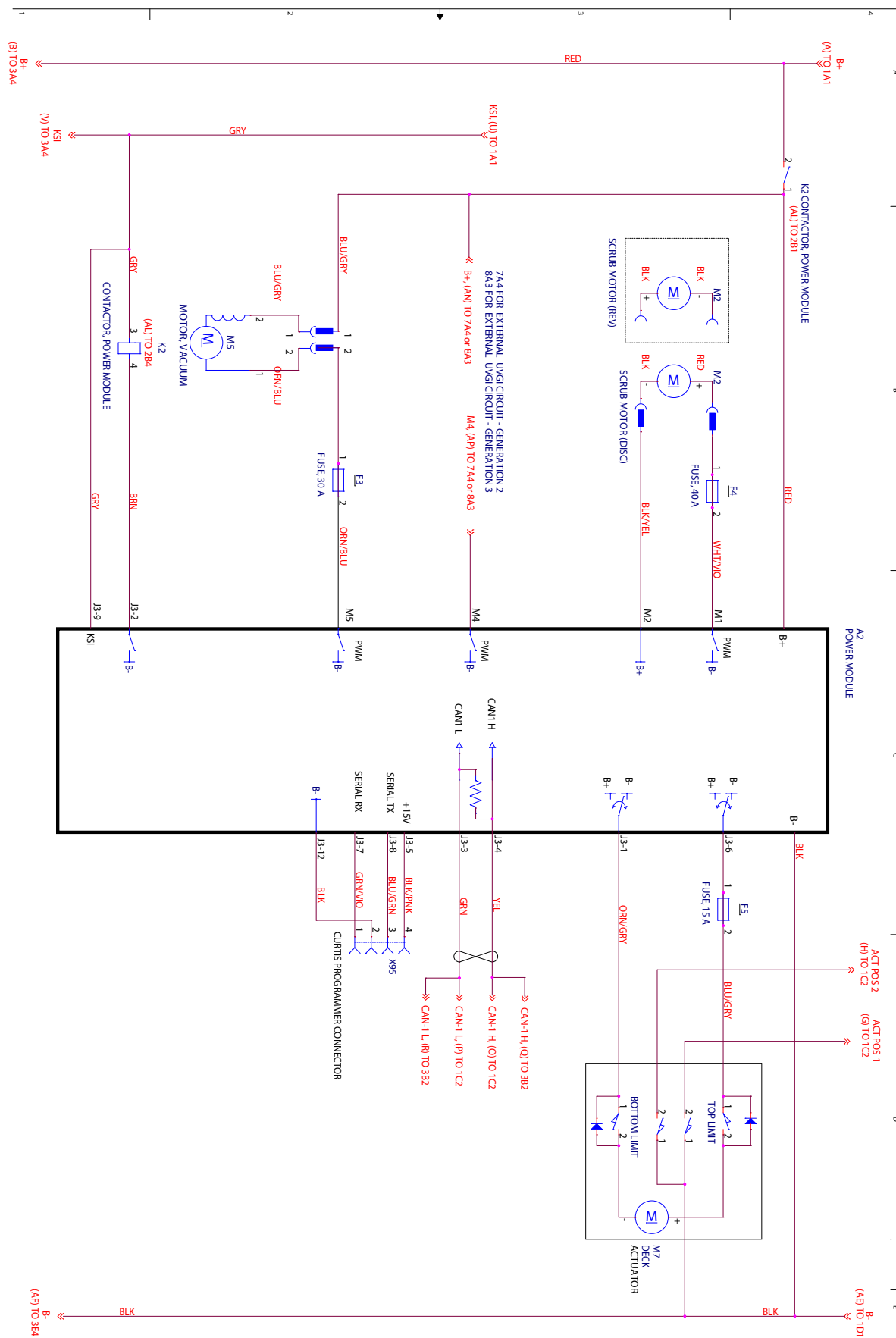


Drawing 56125010, Rev. A

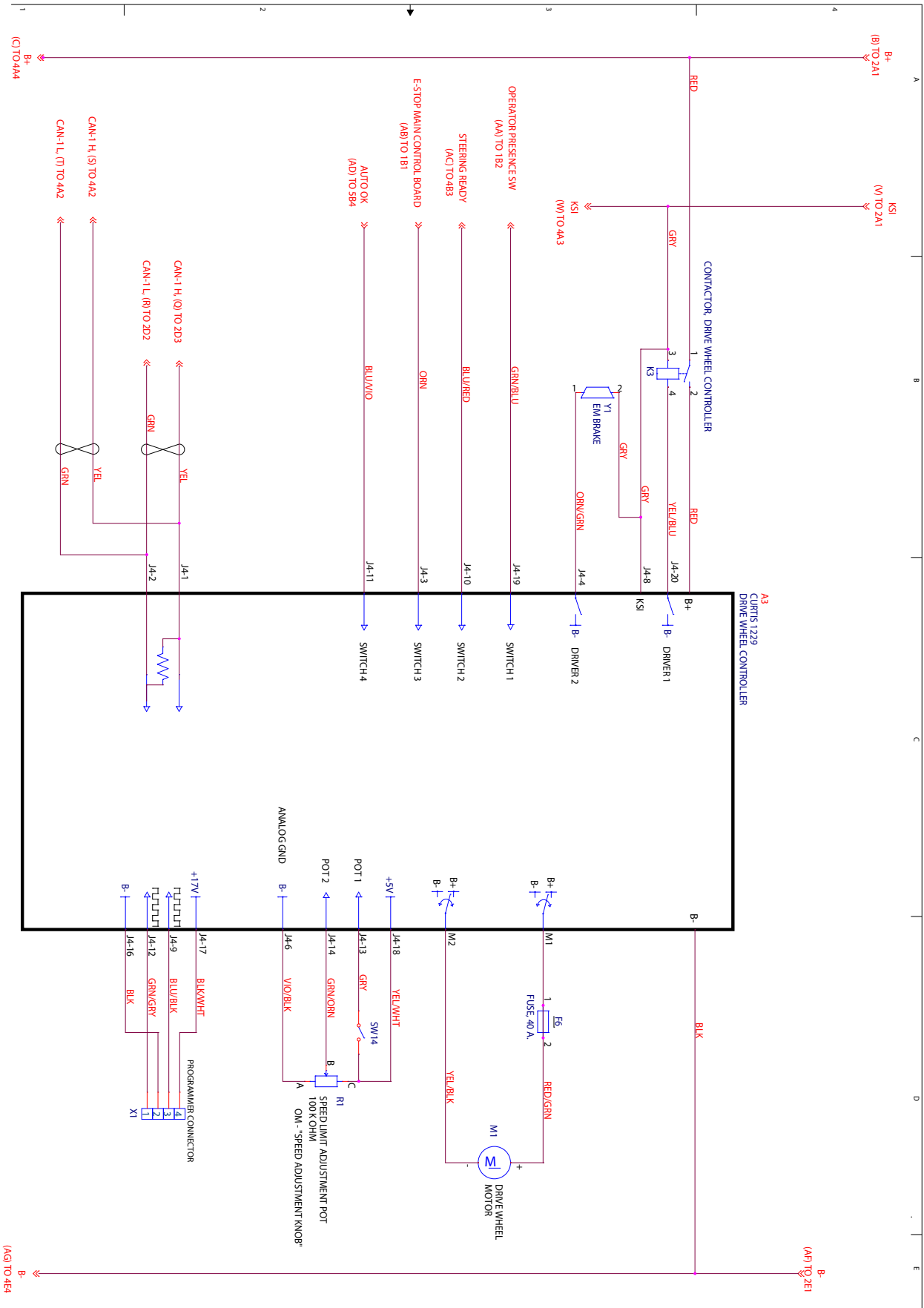
The diagram illustrates the electrical architecture of the main machine controller. Key components and their connections include:

- Battery Pack (BT1):** A lithium-ion battery pack providing power to the system. It is connected to the main machine controller (A1) via terminals B+ and B-.
- Main Machine Controller (A1):** The central processing unit, which interfaces with various modules and sensors.
- Communication Modules:**
 - USB:** Connected to the controller via USB GND and USB pins.
 - RS485:** Used for communication with the chassis ground and RS485 module.
 - CAN Bus:** Multiple CAN bus lines (CAN-0 L, CAN-0 H, CAN-1 L, CAN-1 H) are connected to various modules, including the battery charger and autonomous controller.
- Sensors and Actuators:**
 - Flow Sensor (SOLUTION):** Monitors the flow of the solution.
 - Recovery Tank (FULL):** A sensor indicating the full status of the recovery tank.
 - Speaker:** Provides audio feedback.
 - LED Status Bar:** Indicates the operational status of the system.
 - Motor (M10):** A solution pump motor.
 - Relay (K1):** A battery charger interlock relay.
 - Switches:** Operator presence switches and emergency stop switches.
- Wiring Details:** The diagram shows specific wire colors and terminal numbers for each connection, ensuring correct installation.

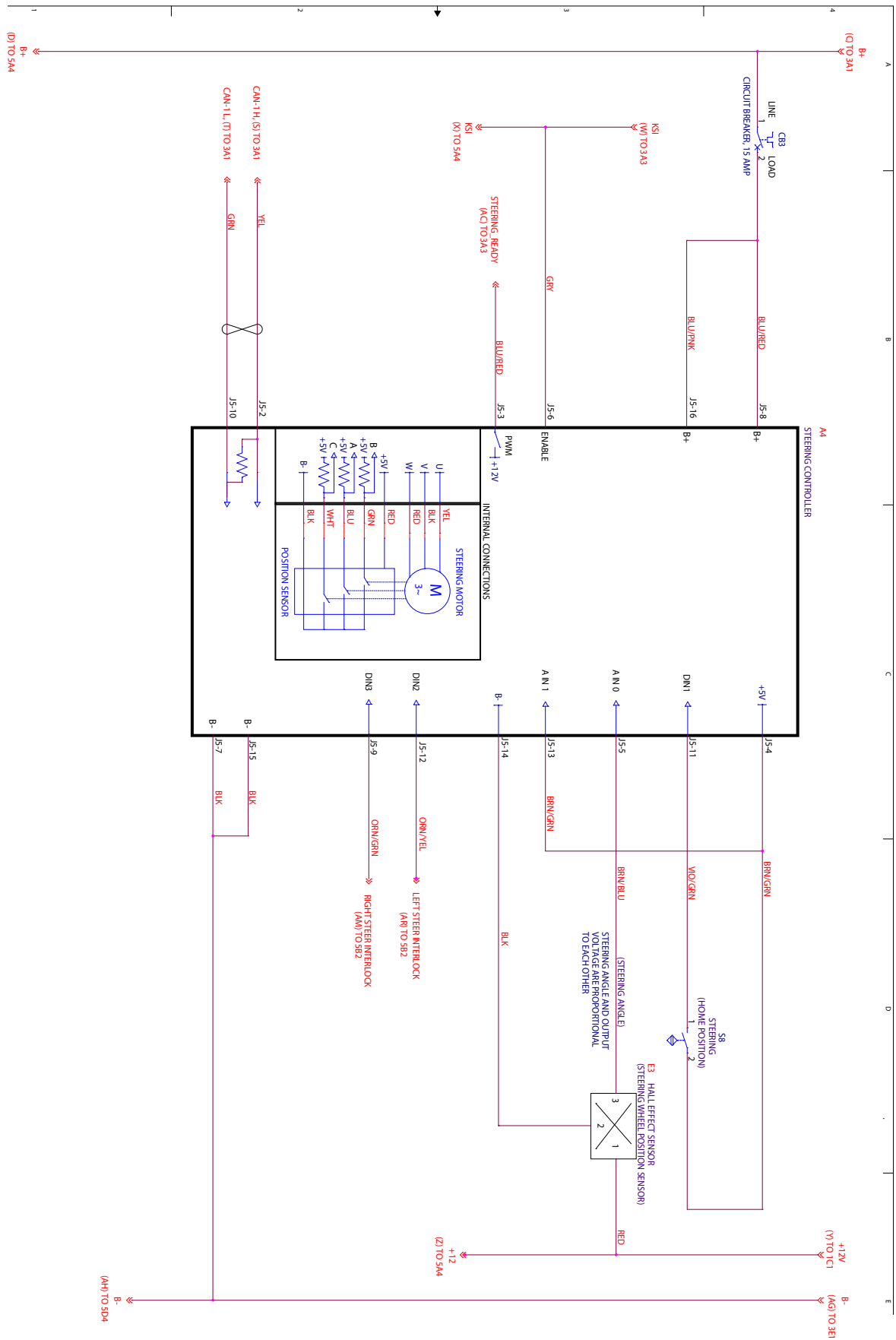
Sheet 2, Power Module



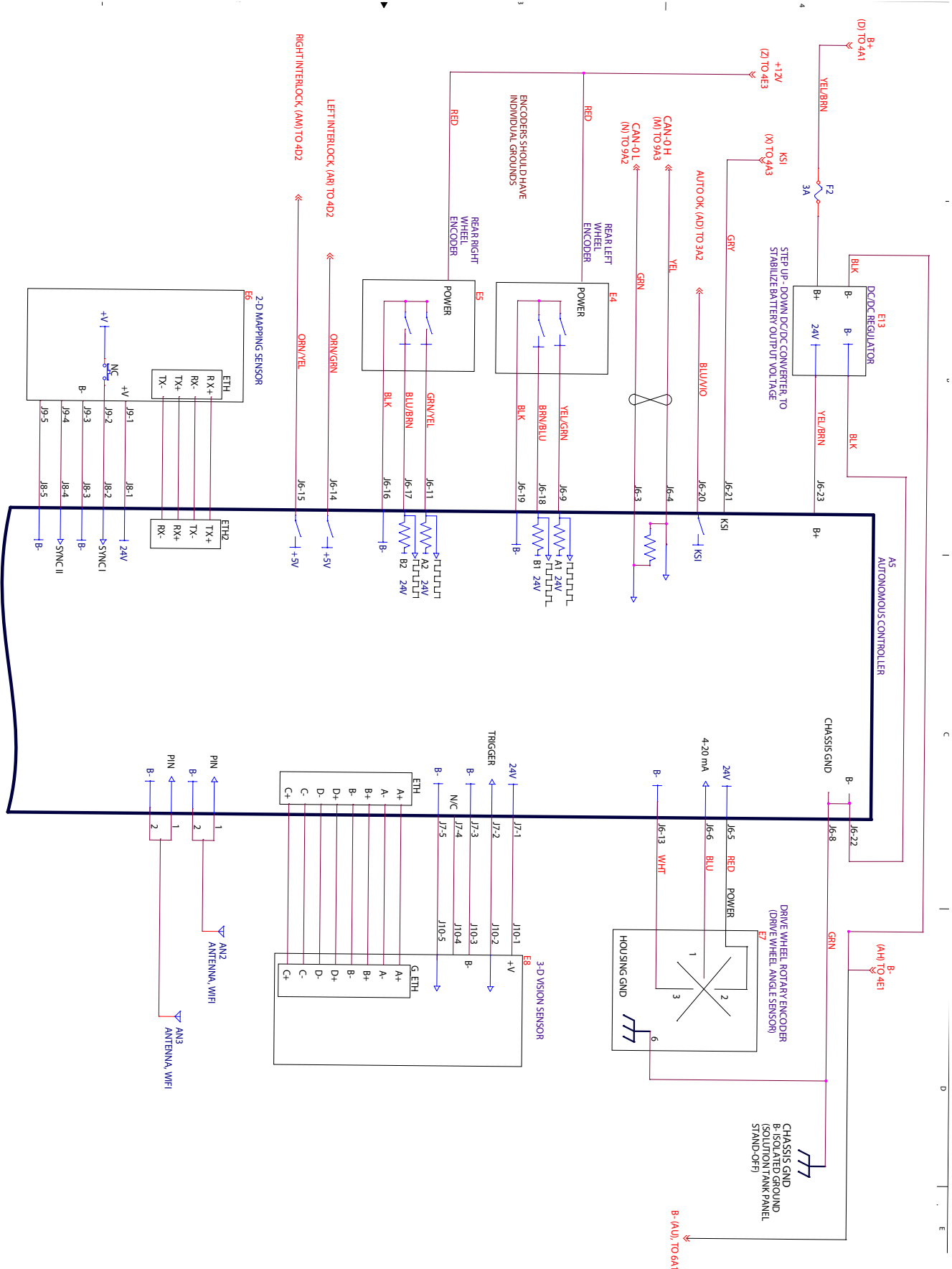
Sheet 3, Drive Controller



Sheet 4, Steering Controller



Sheet 5, Autonomy Controller



ITEMS NOT CONNECTED TO MAIN HARNESS

The diagram illustrates the electrical architecture of the AUTONOMOUS CONTROLLER, centered around a CHASSIS and connected to various external components.

Central Components

- CHASSIS:** The main hub for the system, featuring multiple J-Boxes (J11-1 to J13-5) and a CAN BUS.
- ETHERNET M12D RJ45 CABLE:** Connects the chassis to external networks.
- ETHERNET M12D:** Two ports for network communication.
- ETHERNET SAFETY LASER:** A critical safety component connected to the chassis.

Input/Output Modules

- IoT MODULE:** Manages network and power (PWR, GND, CAN H, CAN L) connections.
- TRUCK CLEAN MODULE:** Interfaces with various sensors (KEY, B+, B-, CAN H, CAN L).
- MULTICON ADAPTER HARNESS:** Connects to the TRUCK CLEAN MODULE.
- MULTICON TC1:** Another interface module for the truck clean system.

Sensors and Actuators

- REAR LH DROP-OFF SENSOR:** Monitors rear left drop-off status.
- FRONT LH DROP-OFF SENSOR:** Monitors front left drop-off status.
- REAR RH DROP-OFF SENSOR:** Monitors rear right drop-off status.
- FRONT RH DROP-OFF SENSOR:** Monitors front right drop-off status.
- 4-20mA A, B, C, D:** Analog sensors for various parameters.
- ARE ADDRESS A-I:** Addressable electronic components.
- LH PROTECTION ZONE 1 & 2:** Safety zones for the left side of the vehicle.
- RH PROTECTION ZONE 1 & 2:** Safety zones for the right side of the vehicle.

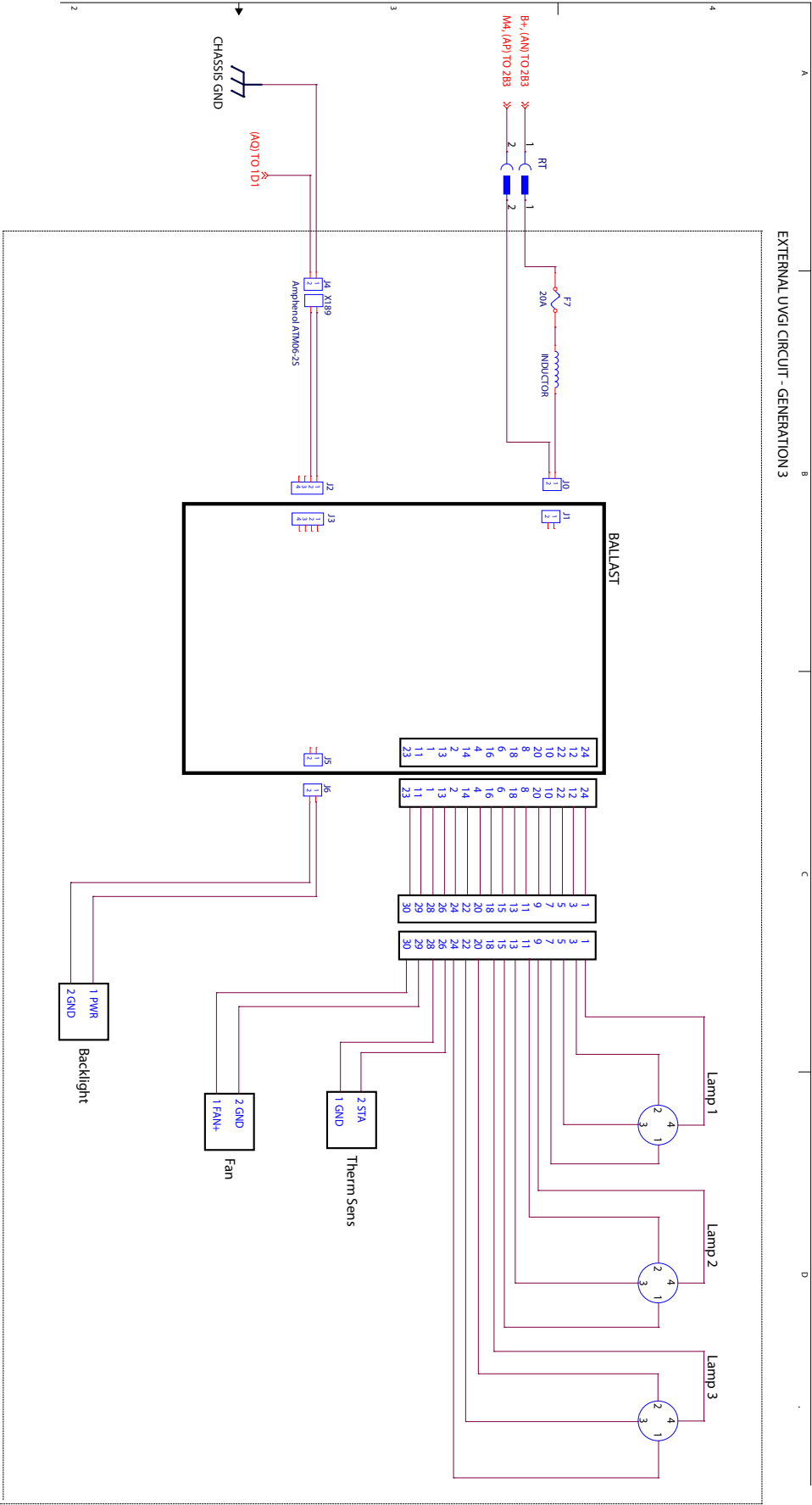
Wiring Details

- Power (PWR):** Connected to the IoT module and various sensors.
- Ground (GND):** Common ground for all components.
- CAN BUS:** Used for communication between the IoT module and other modules.
- ETHERNET:** RJ45 ports for network connectivity.
- SAFETY LASER:** Critical safety wiring ensuring proper operation.

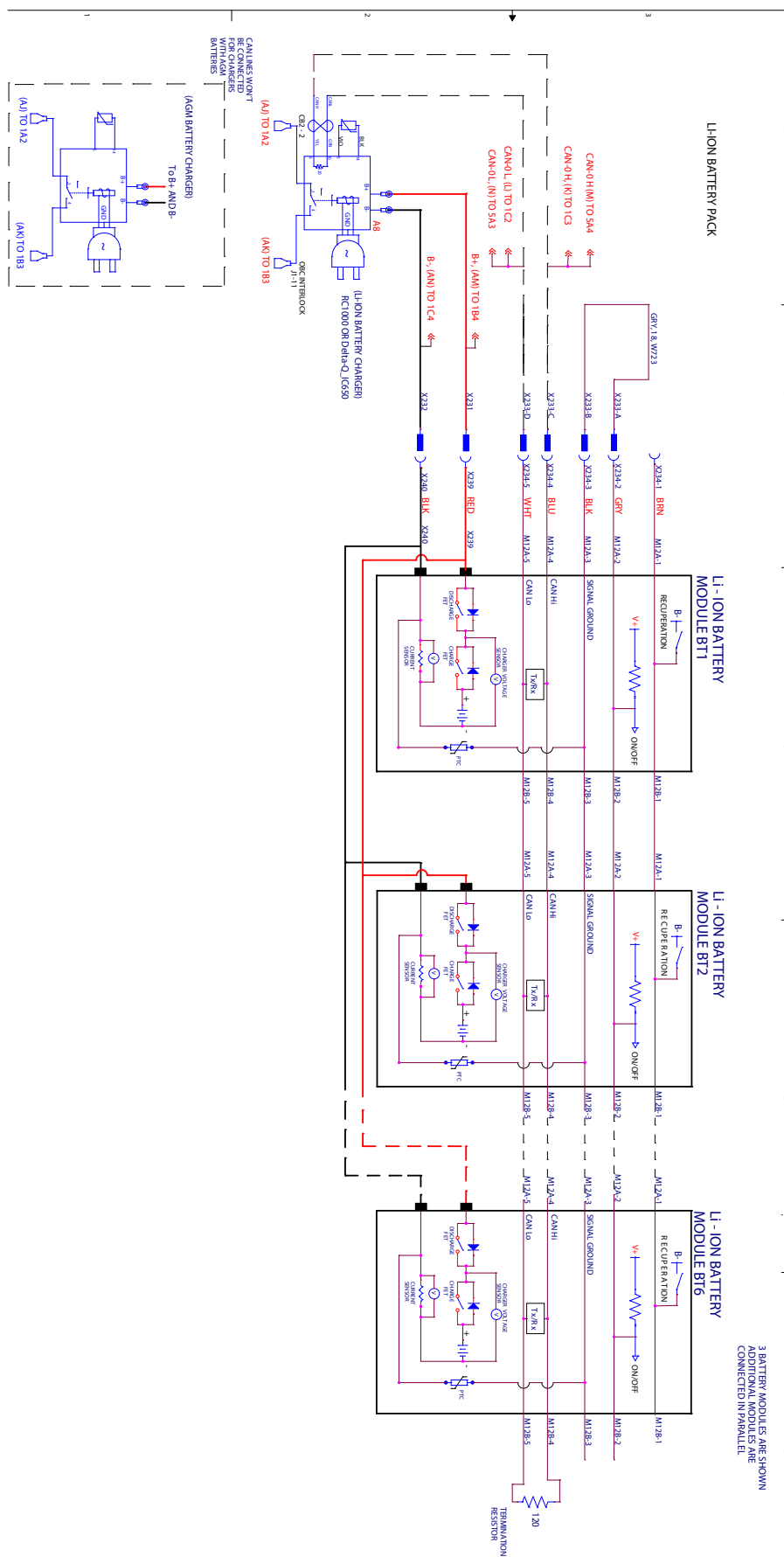
Legend:

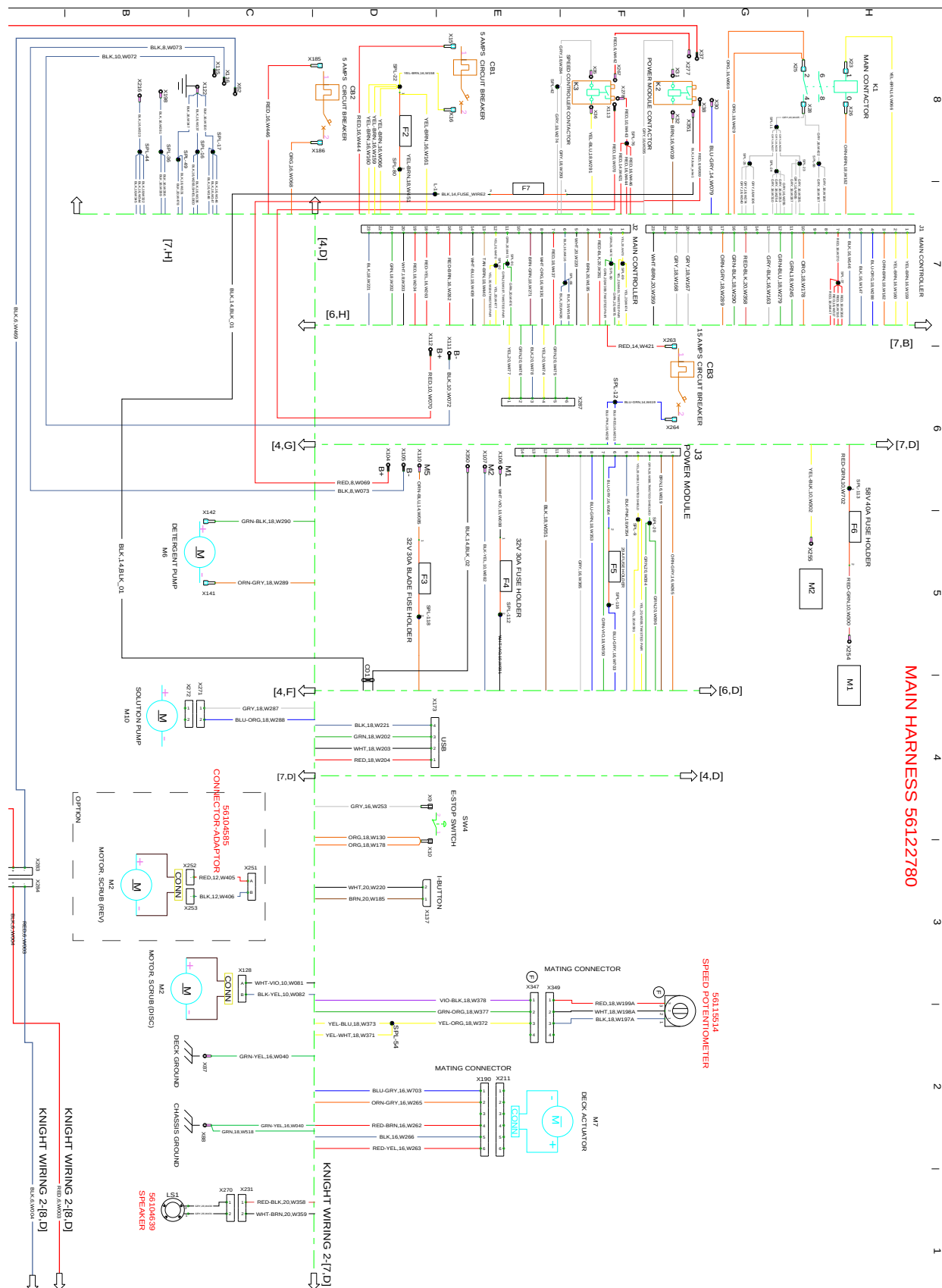
- TX+:** Transmitter Positive
- TX-:** Transmitter Negative
- RX+:** Receiver Positive
- RX-:** Receiver Negative
- BLK:** Black
- WHT:** White
- GRN:** Green
- YEL:** Yellow
- RED:** Red
- BLU:** Blue
- ORN:** Orange

Sheet 8, UVGI Option, Generation 3

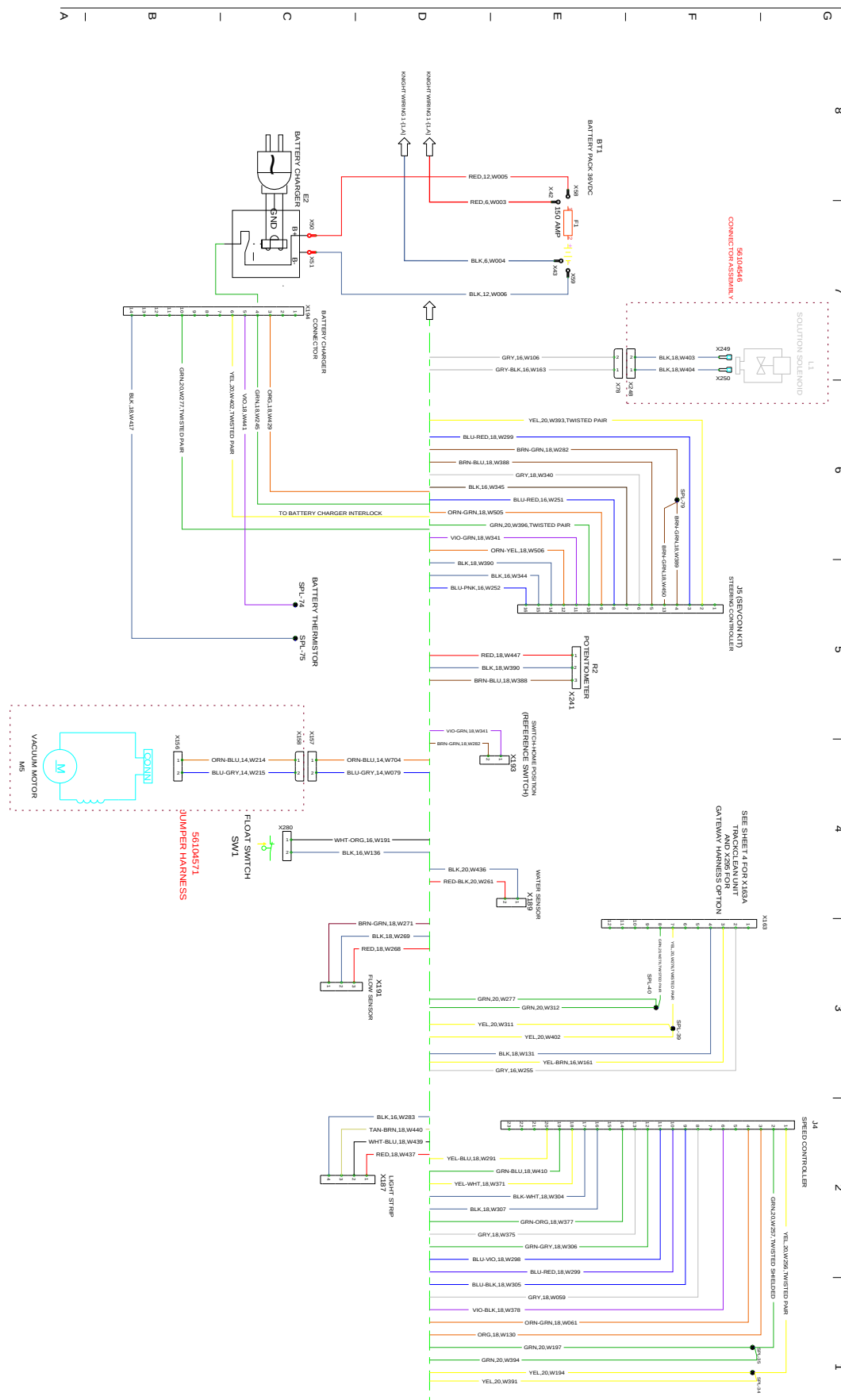


Sheet 9, Battery Connection Options

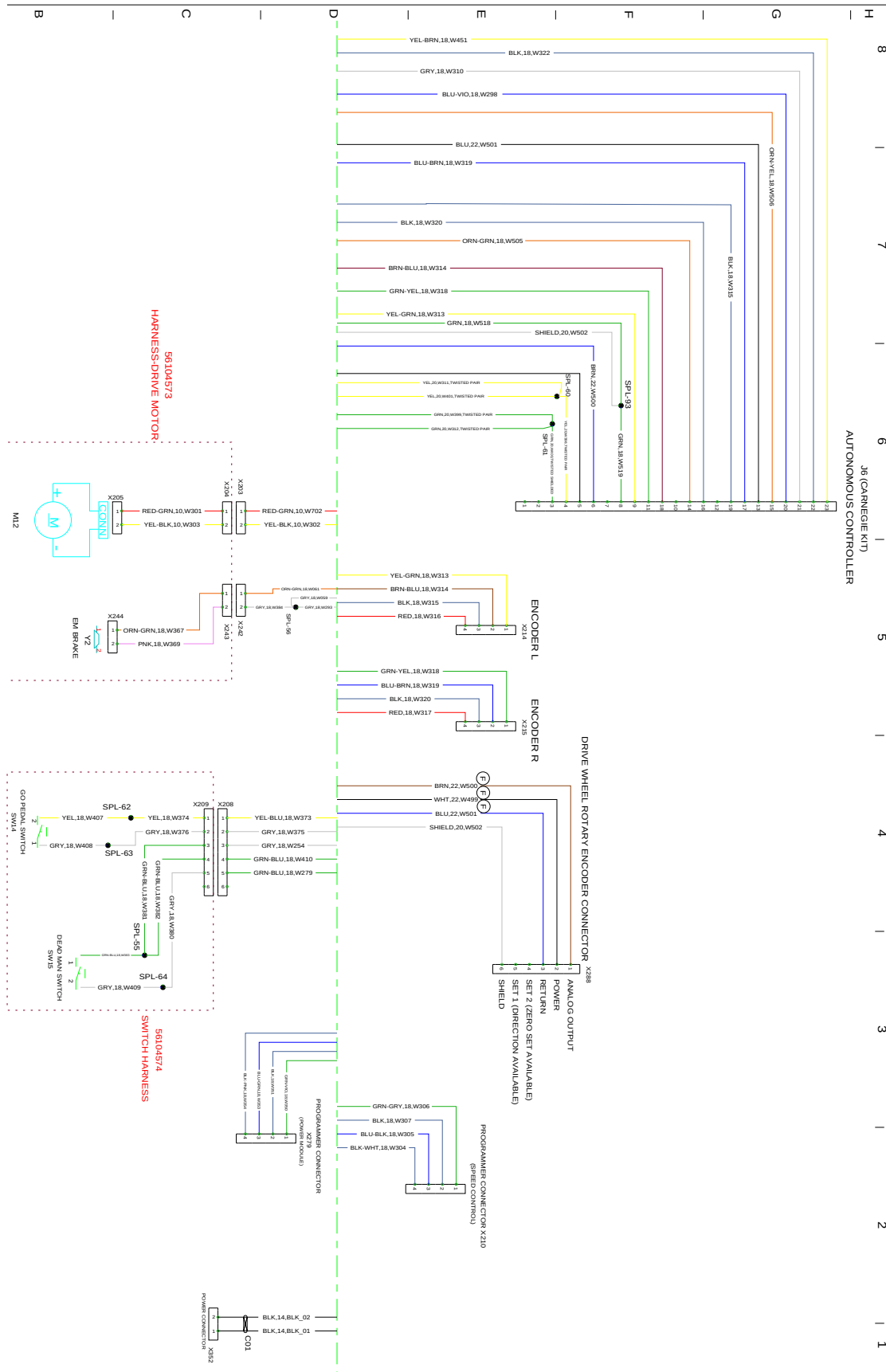


56104984, Rev F, for Legacy Models

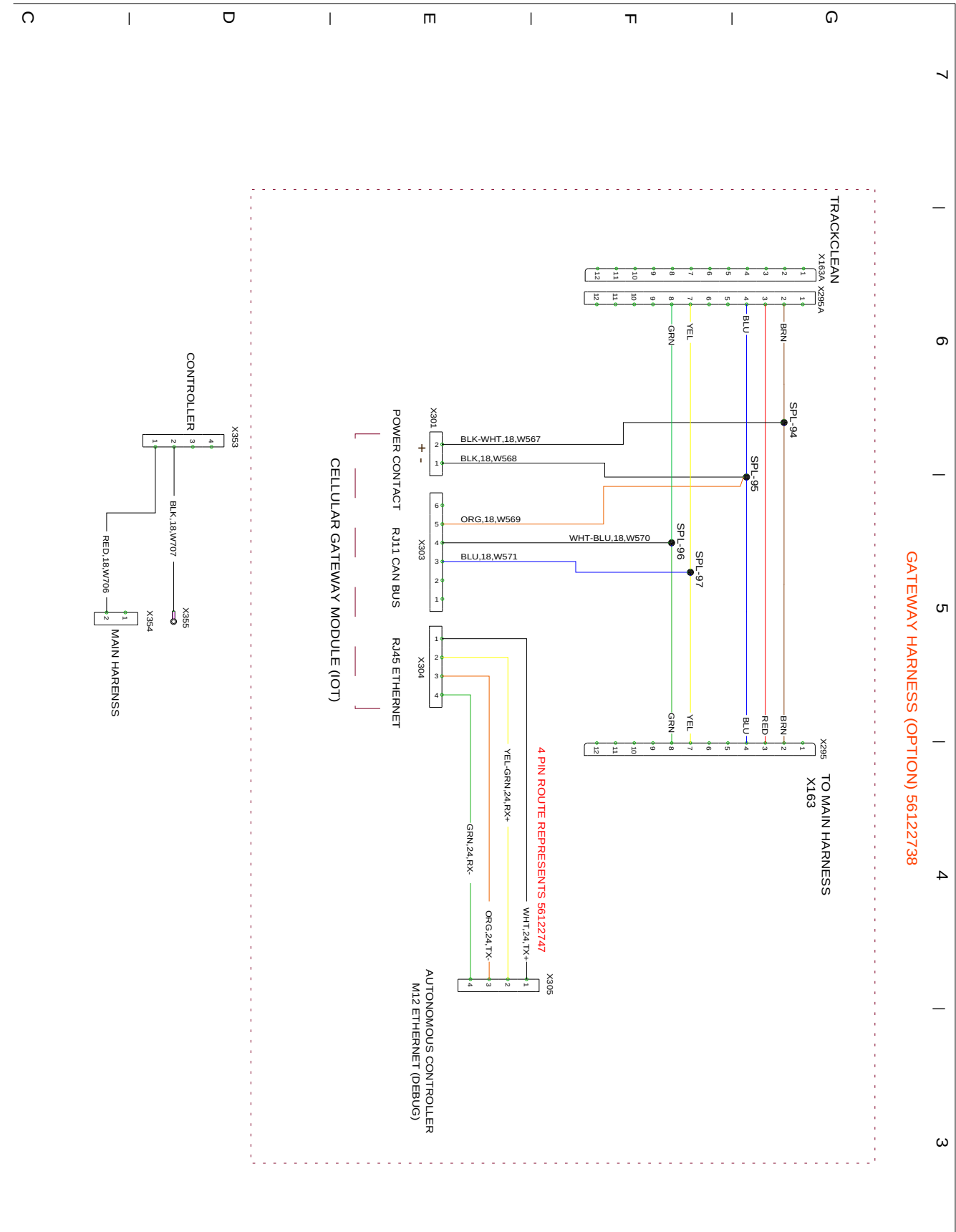
56104984, Rev F, Sheet 2



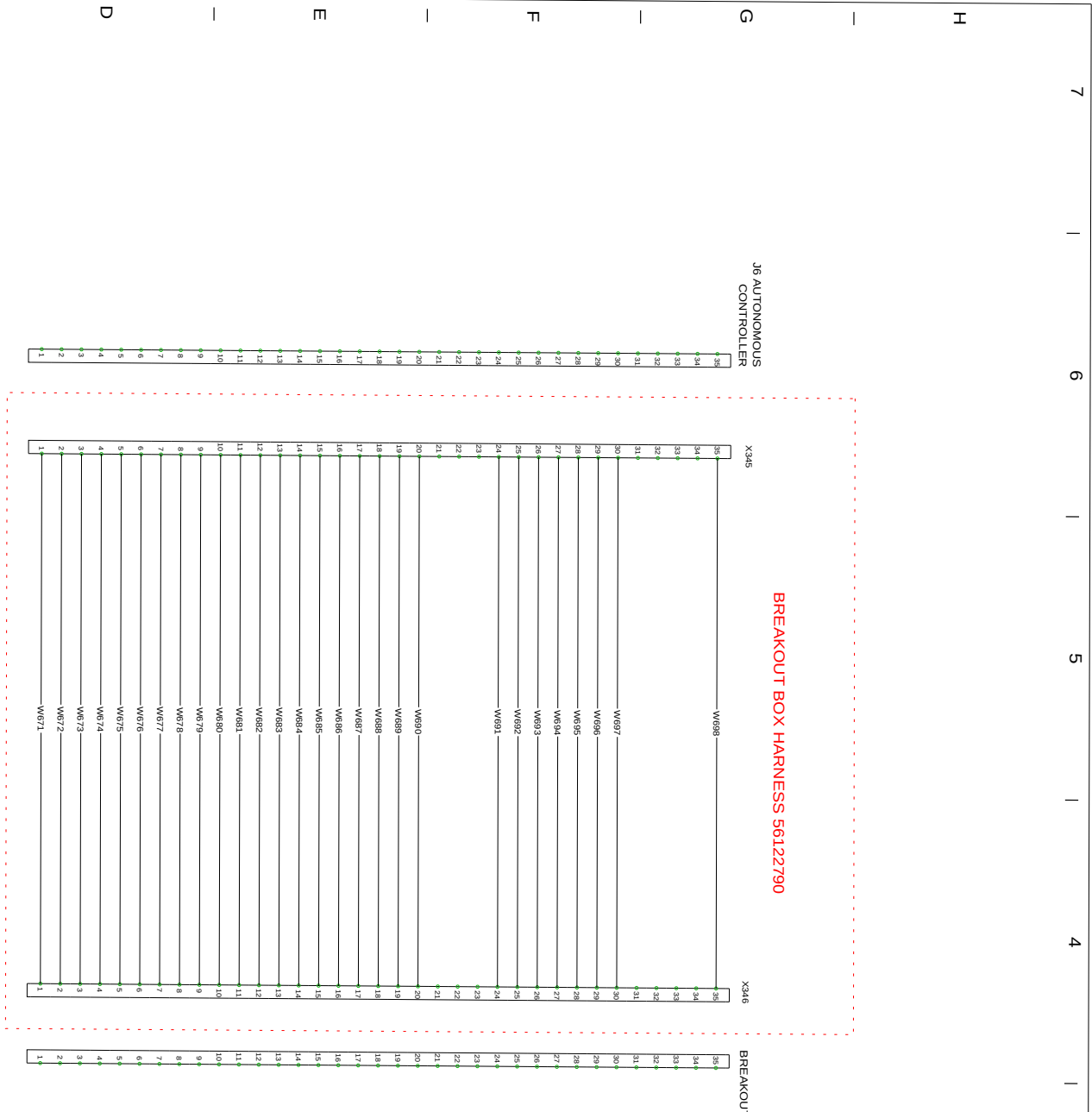
56104984, Rev F, Sheet 3



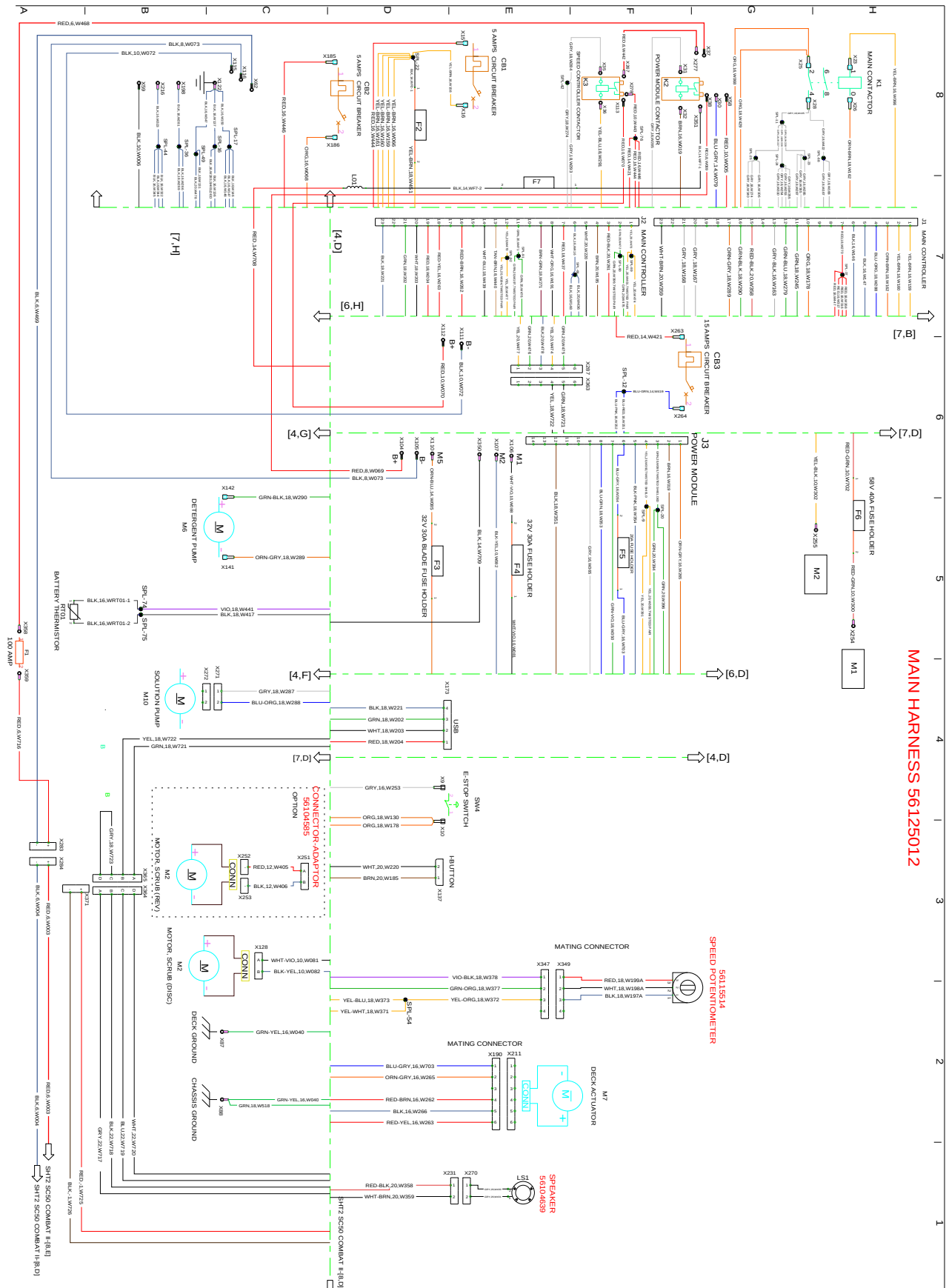
56104984, Rev F, Sheet 4



56104984, Rev F, Sheet 5



MAIN HARNESS 56125012



56104546 CONNECTOR ASSEMBLY

SOLUTION SCENARIO

LEGEND:

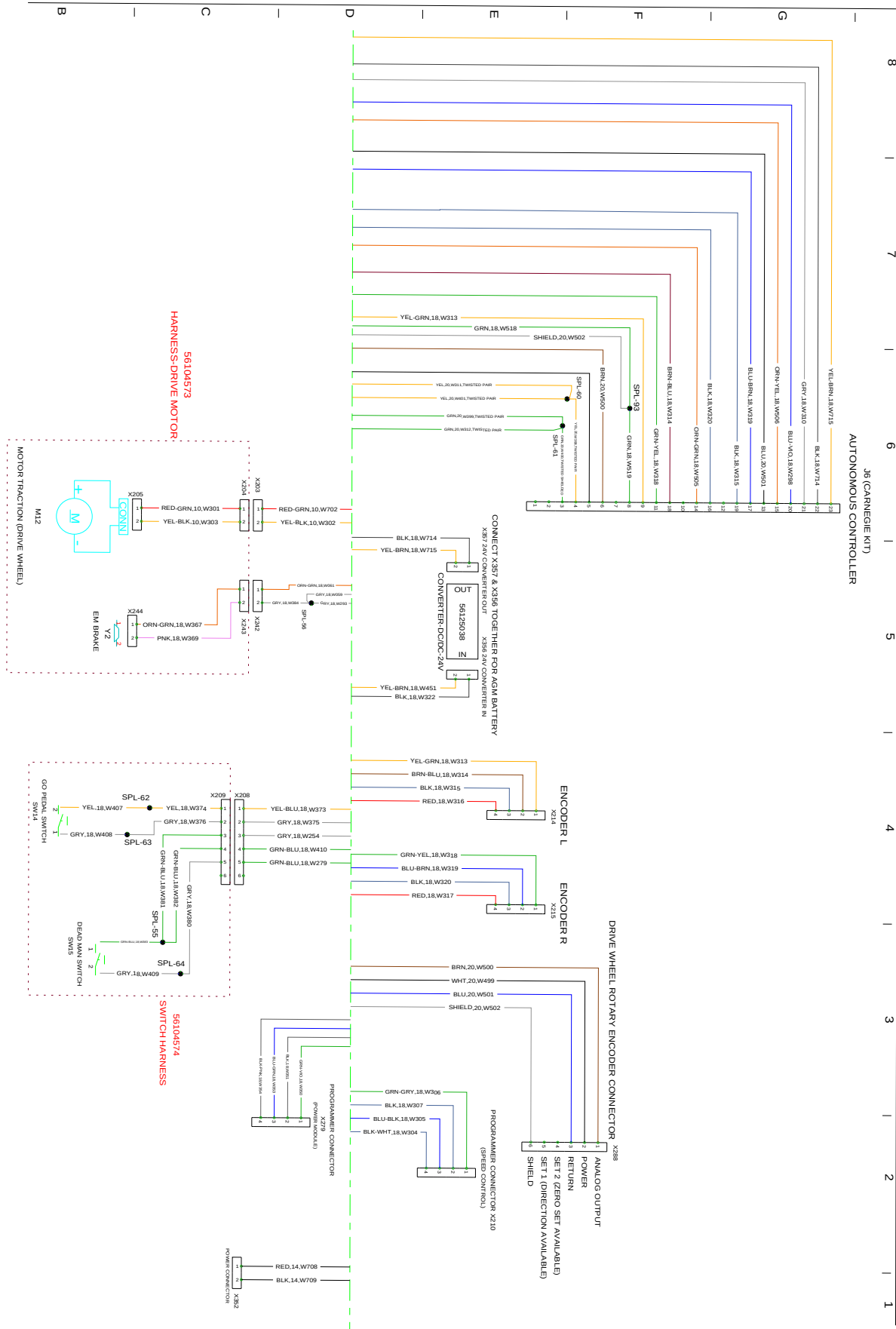
- XTN: BLK.6.W77
- XTN: RED.6.W73
- XTN: RED.6.W73
- XTN: RED.6.W73

COMPONENTS AND CONNECTIONS:

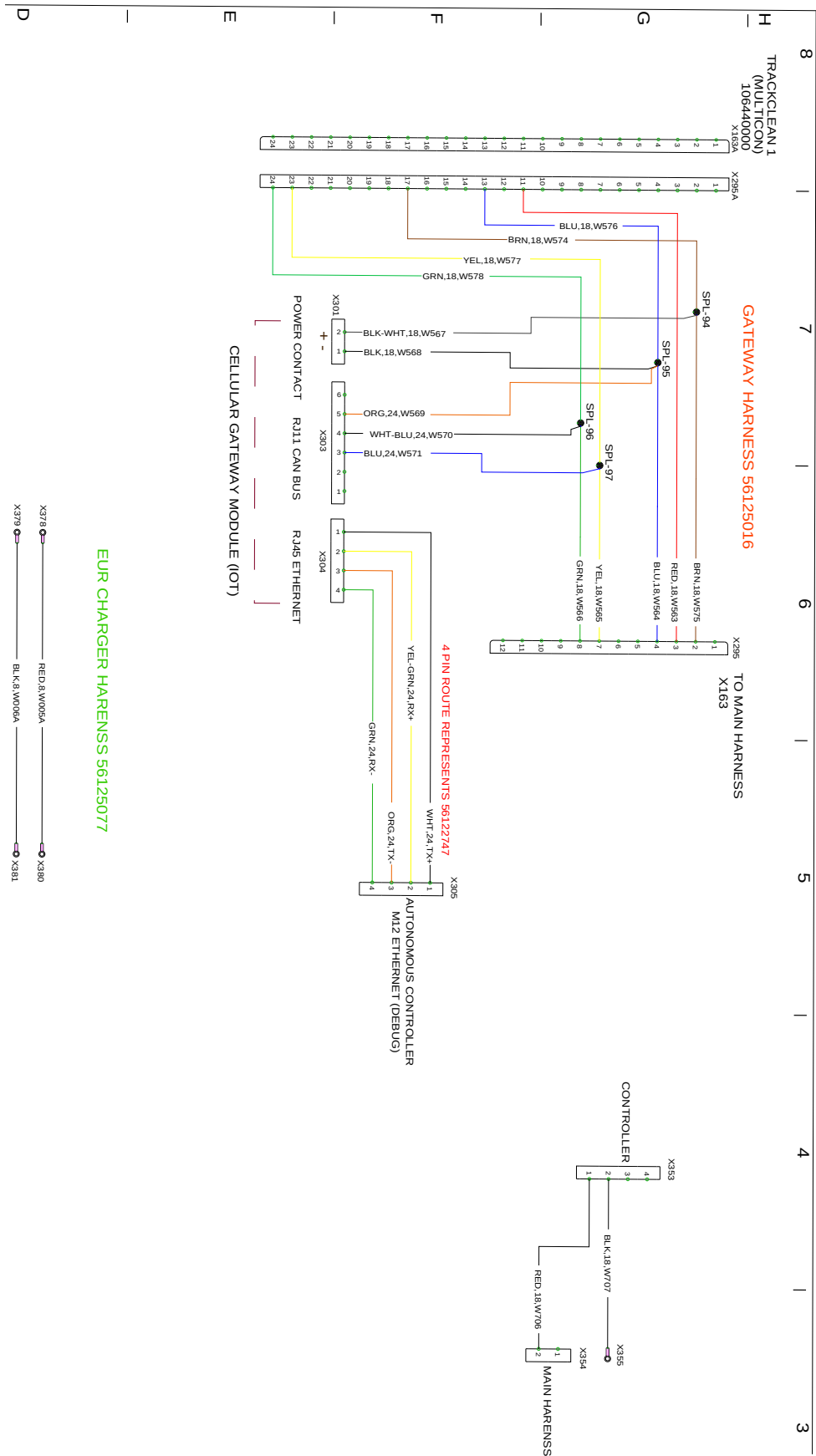
- BATTERY PACK 24VDC:**
 - BT1.U: BLK.1.W726, GRY.22.W717, BLK.22.W718, BLU.22.W719, WHT.22.W720
 - BT1.L: RED.6.W003, BLK.6.W004
- BATTERY CHARGER:**
 - RC1000: BLK.10.W005, RED.10.W006, BLK.10.W008
- STERNING CONTROLLER:**
 - XTN: BLK.18.W403, BLK.18.W404, BLK.18.W405
 - XTN: GRY.18.W340, BLK.18.W345, BLU.18.W251, ORN.18.W341, CRN.18.W506, BLK.18.W390, BLU.18.W388, BRN.18.W282, BRN.18.W388, BLU.18.W299, YEL.20.W393, TWISTED PAIR
- POTENTIOMETER:**
 - XTN: RED.18.W447, BLK.18.W390, BRN.18.W388
- WATER SENSOR:**
 - XTN: RED.18.W447, BLK.18.W390, BRN.18.W388
- FLUID SENSOR:**
 - XTN: BRN.18.W271, BLK.18.W269, RED.18.W268
- LIGHT STRIP:**
 - XTN: RED.18.W437, WHT.18.W439, TAN.18.W434, BLK.16.W283
- 56104571 JUMPER HARNESS:**
 - XTN: ORN.18.W214, BLU.18.W215, BLU.18.W216, WHT.18.W191, BLK.16.W136
- 56104546 CONNECTOR ASSEMBLY:**
 - XTN: BLK.18.W403, BLK.18.W404, BLK.18.W405, GRY.18.W340, BLK.18.W345, BLU.18.W251, ORN.18.W341, CRN.18.W506, BLK.18.W390, BLU.18.W388, BRN.18.W282, BRN.18.W388, BLU.18.W299, YEL.20.W393, TWISTED PAIR

SEE SHEET 4 FOR XTNA, XTND AND XTDF FOR CATERWAY HARNESS

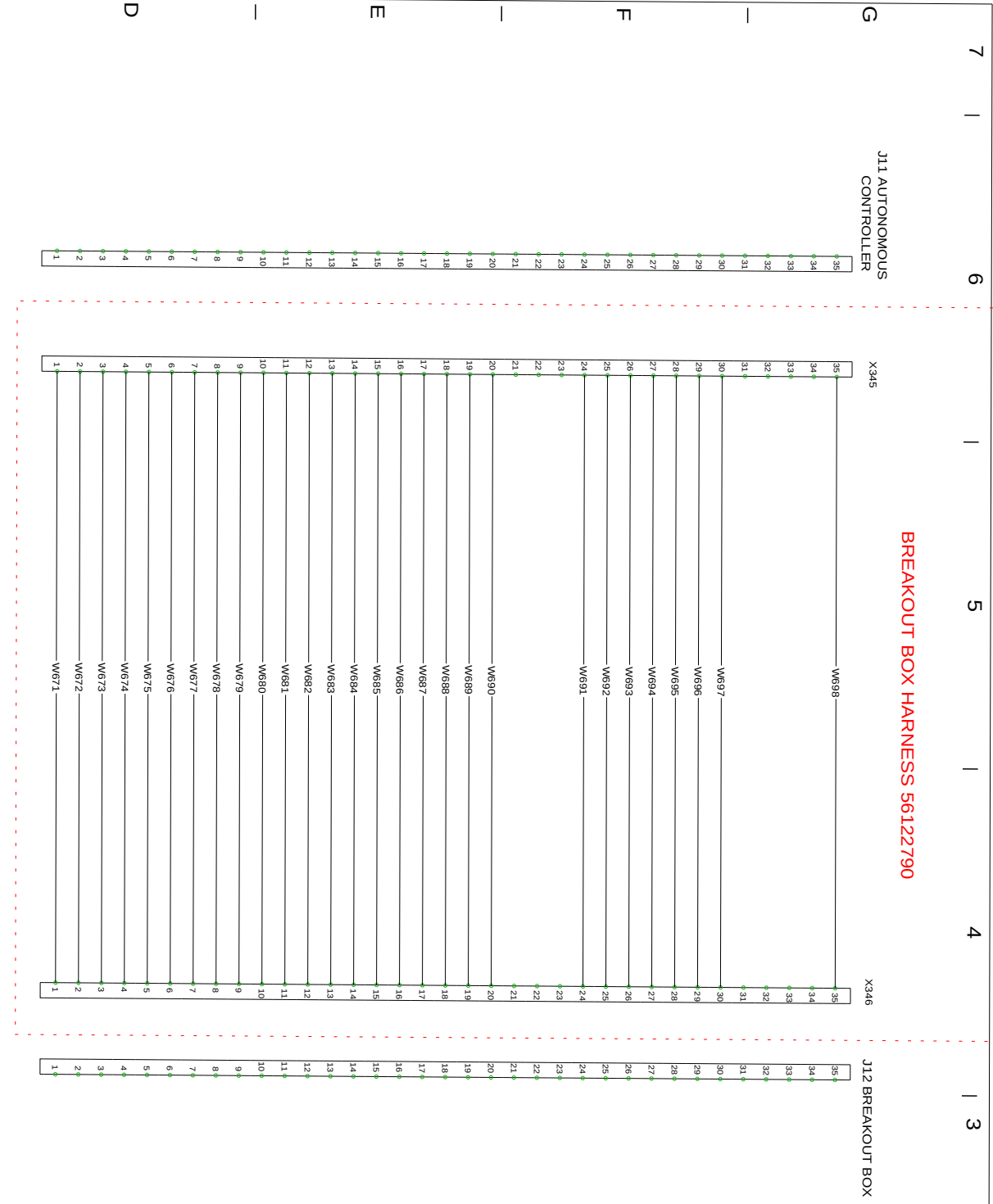
56104911, Rev. B, Sheet 3



56104911, Rev. B, Sheet 4

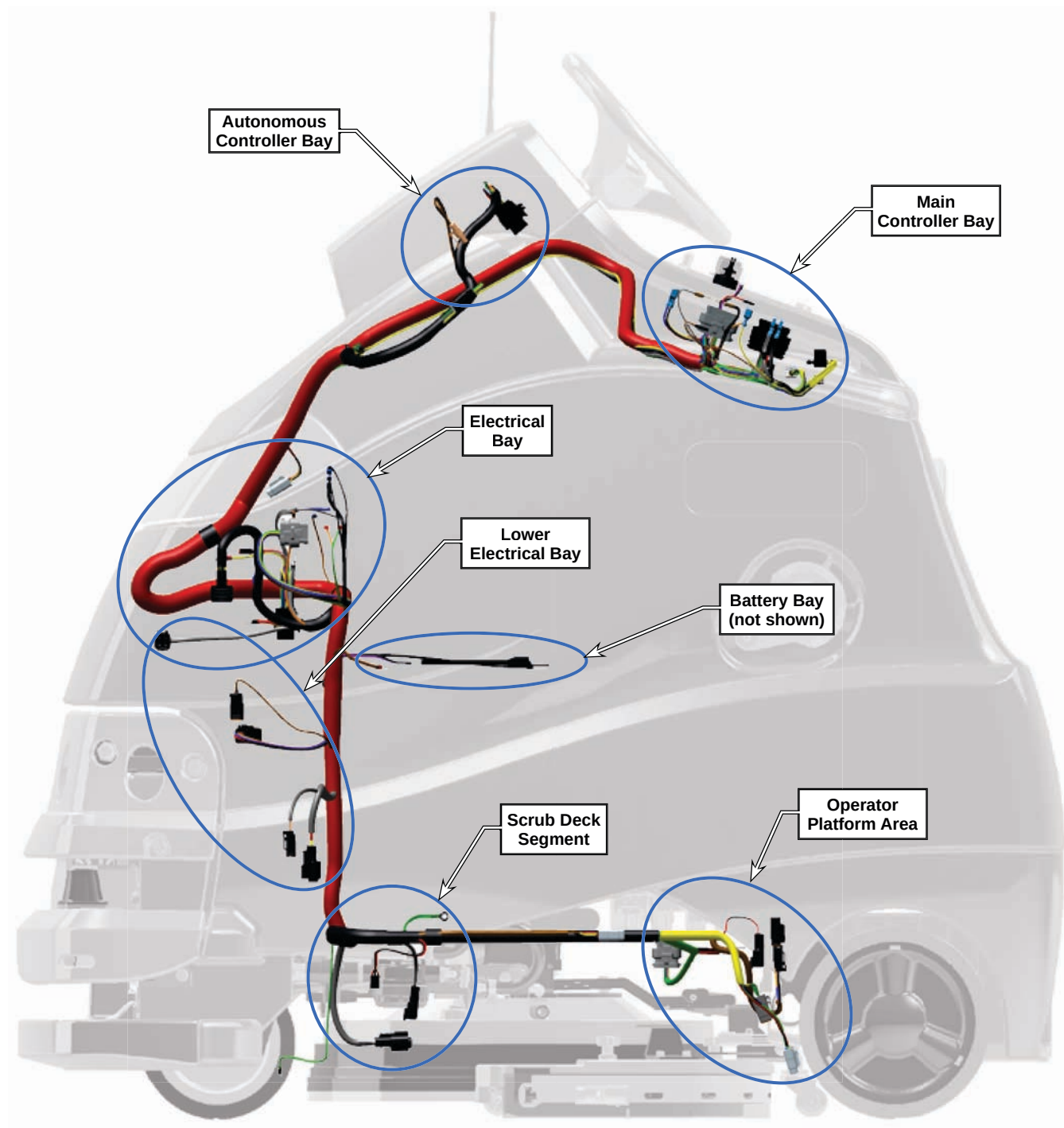


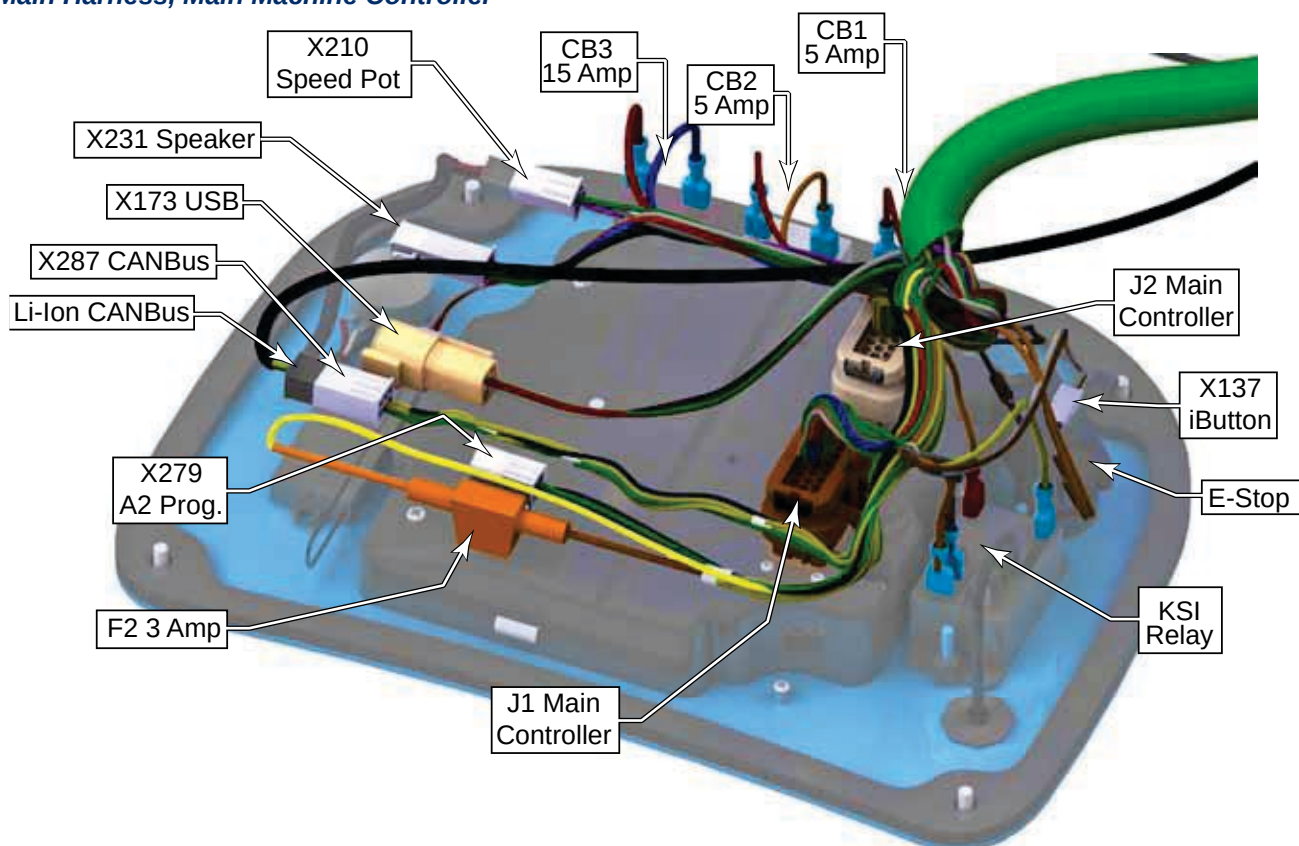
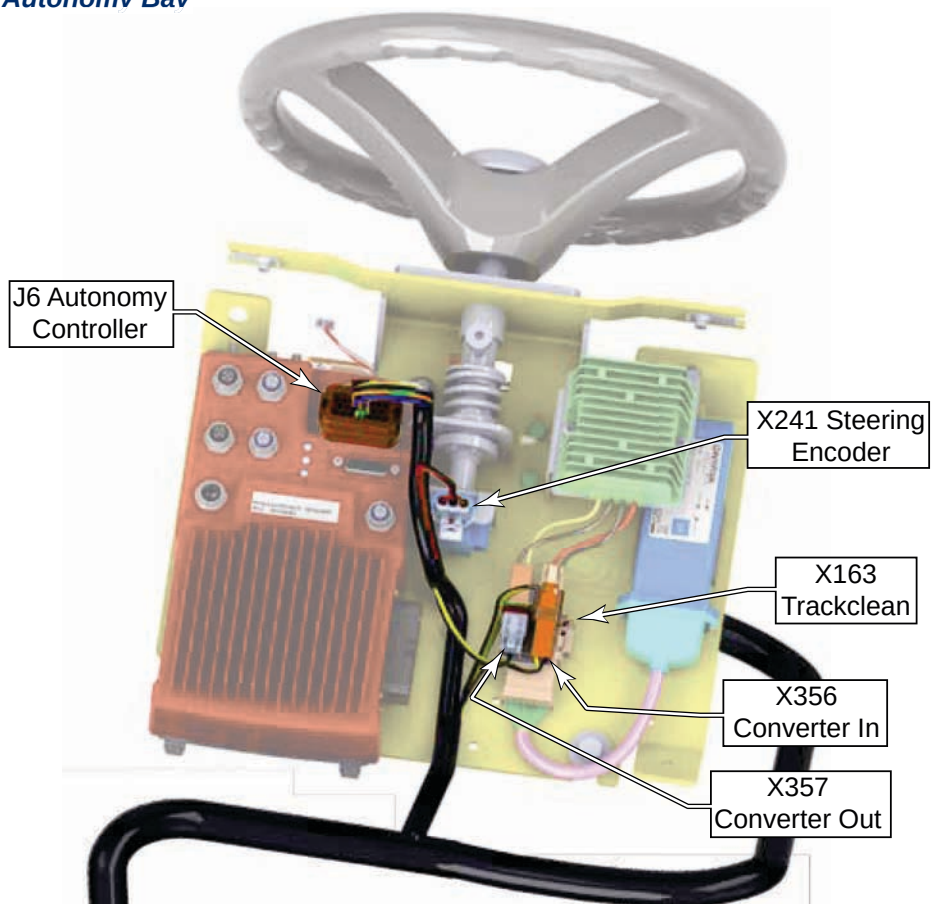
56104911, Rev. B, Sheet 5

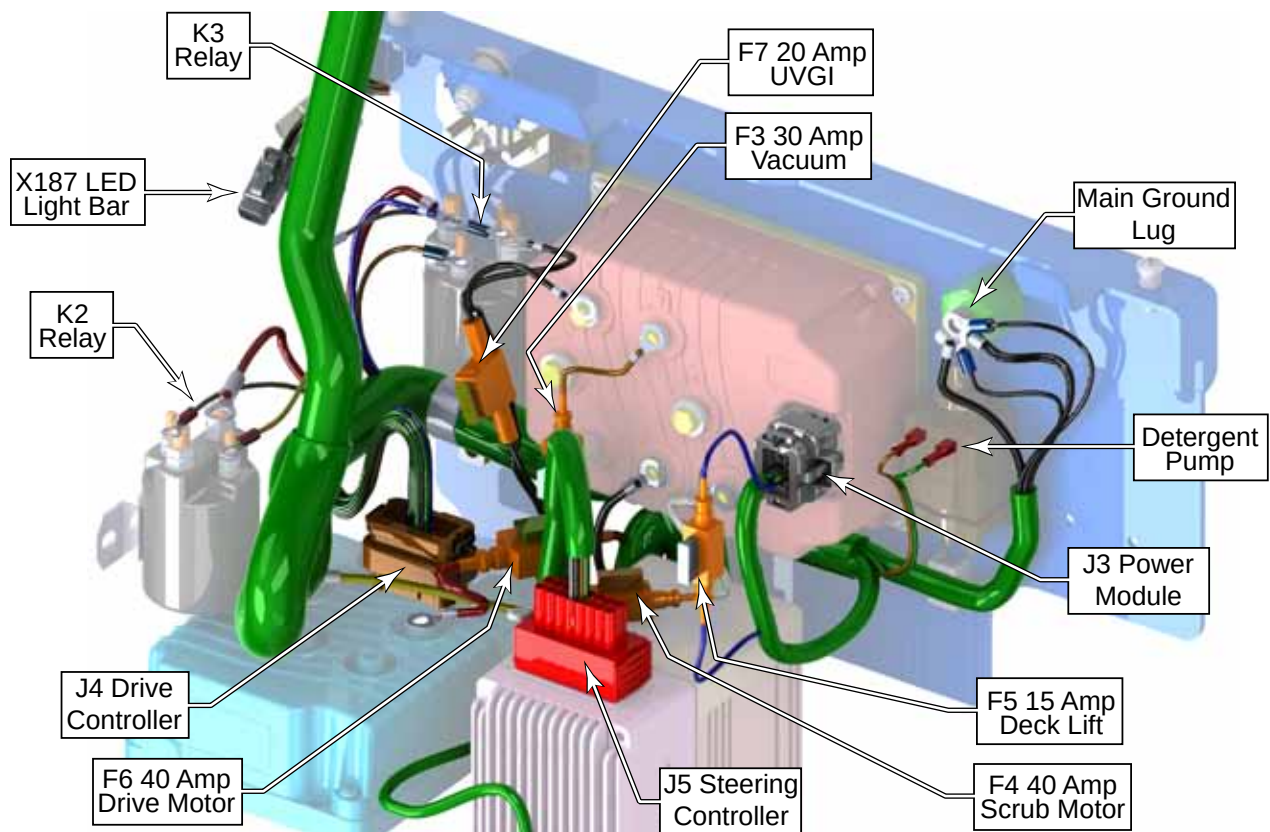
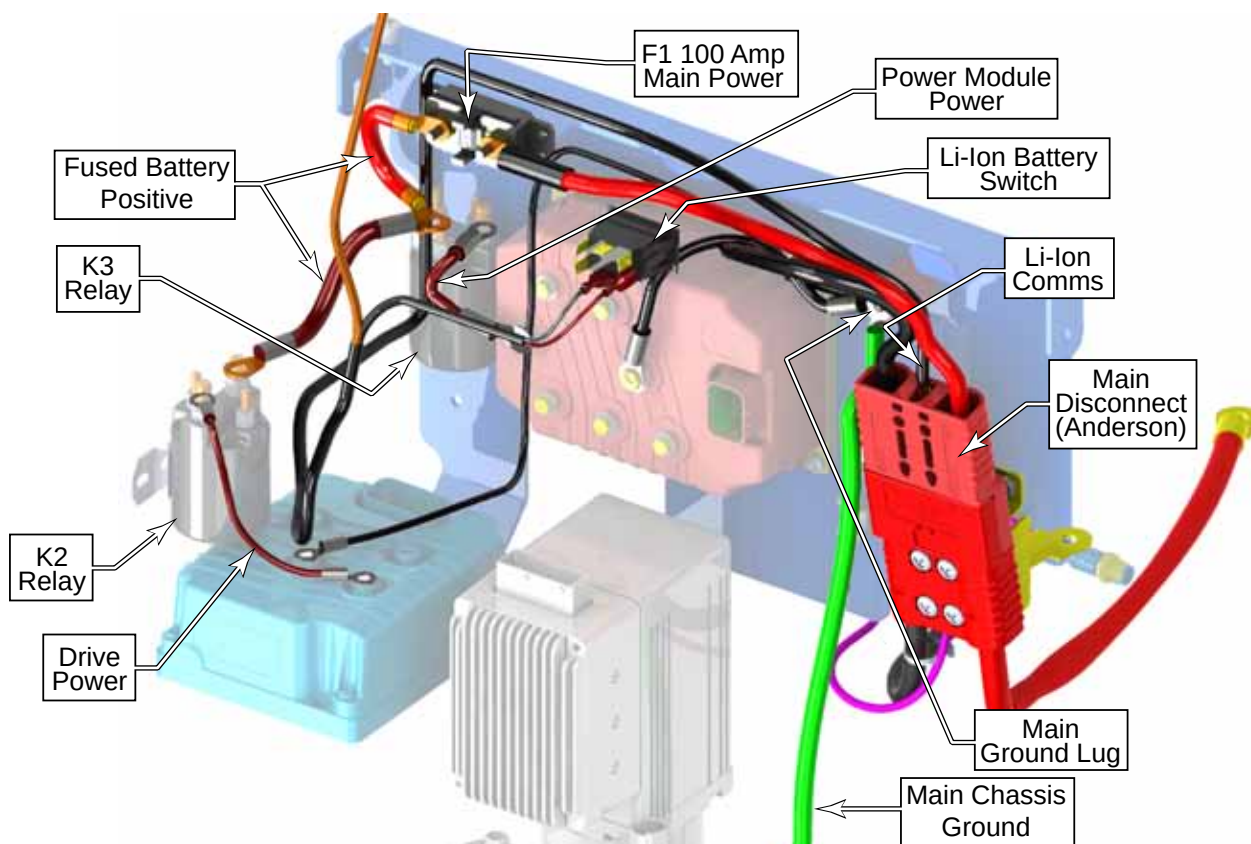


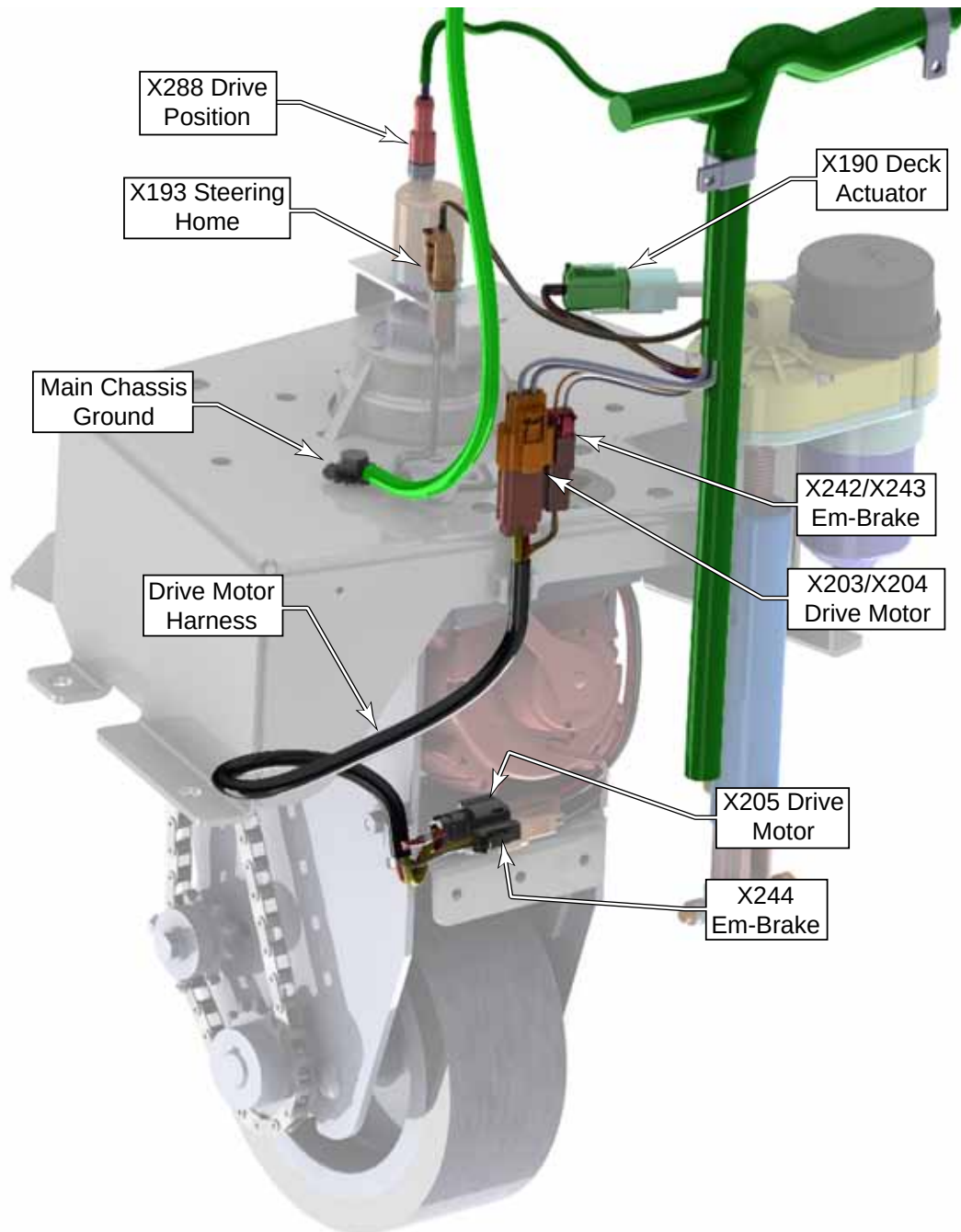
3D Harness Diagrams

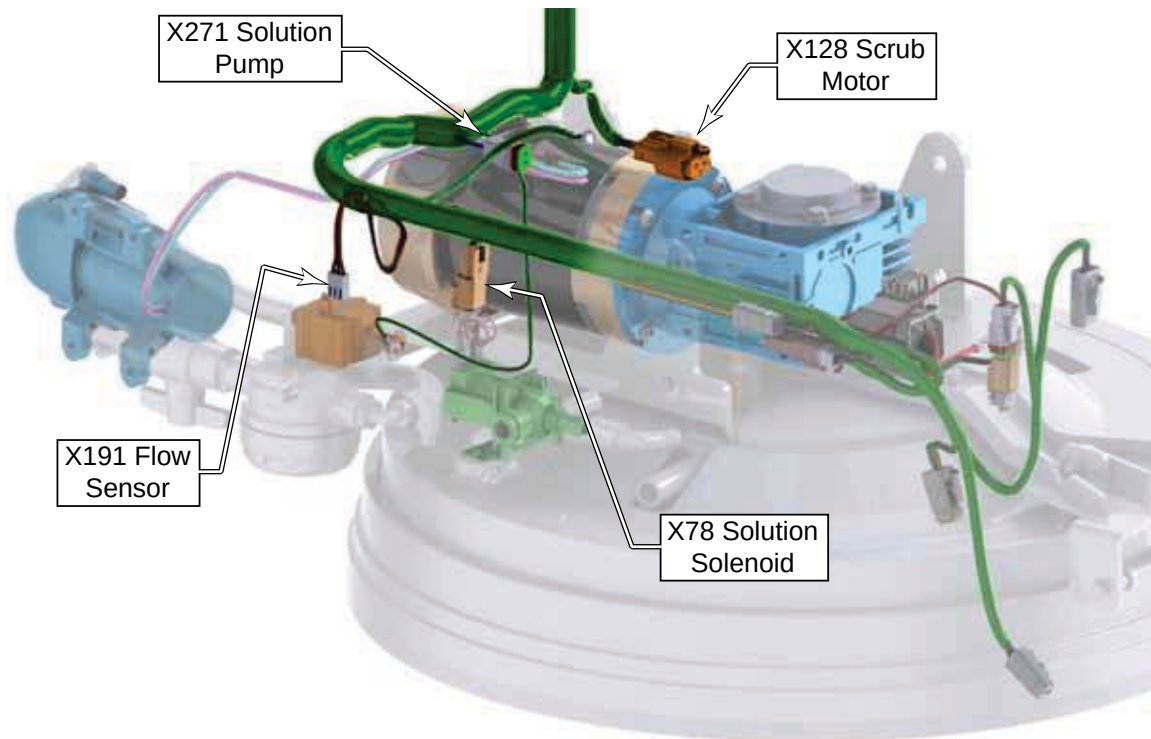
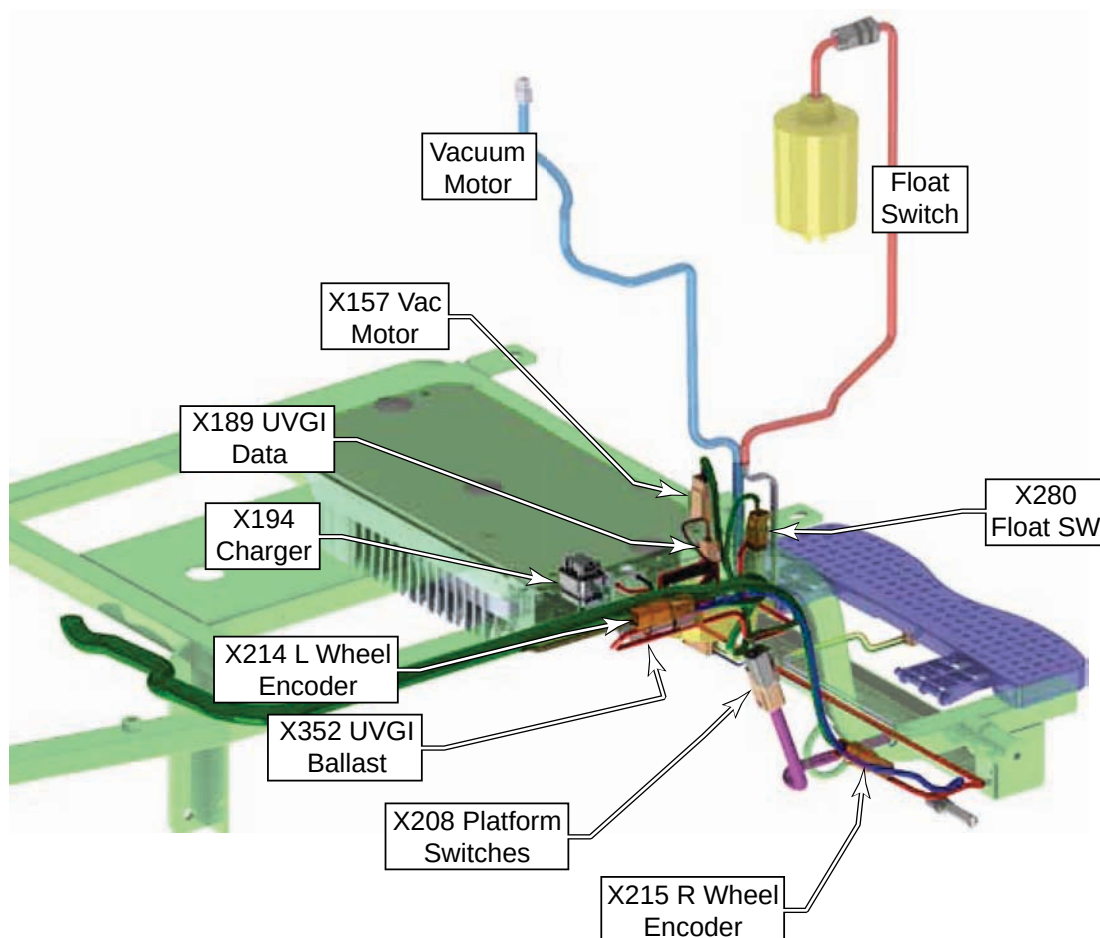
The following diagrams show the main electrical harness, autonomy harness, and connectors within the machine. This can be used in conjunction with the [“Electrical Connector Pin-Out Assignments”](#) on page 299 to identify where connectors are located and how they appear. Each of the highlighted sections of the harness in the diagram below is presented in greater detail in the subsequent images.

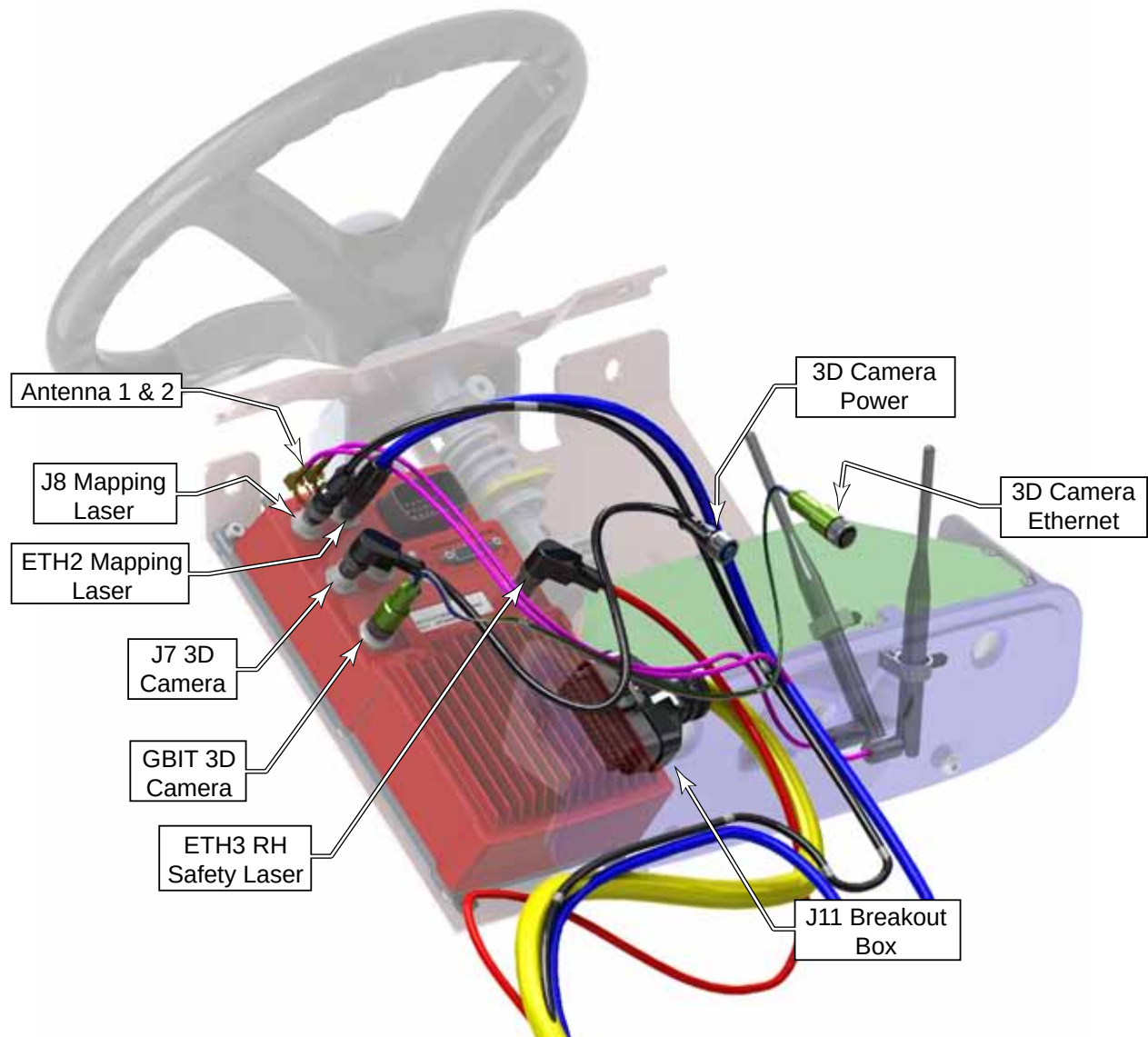


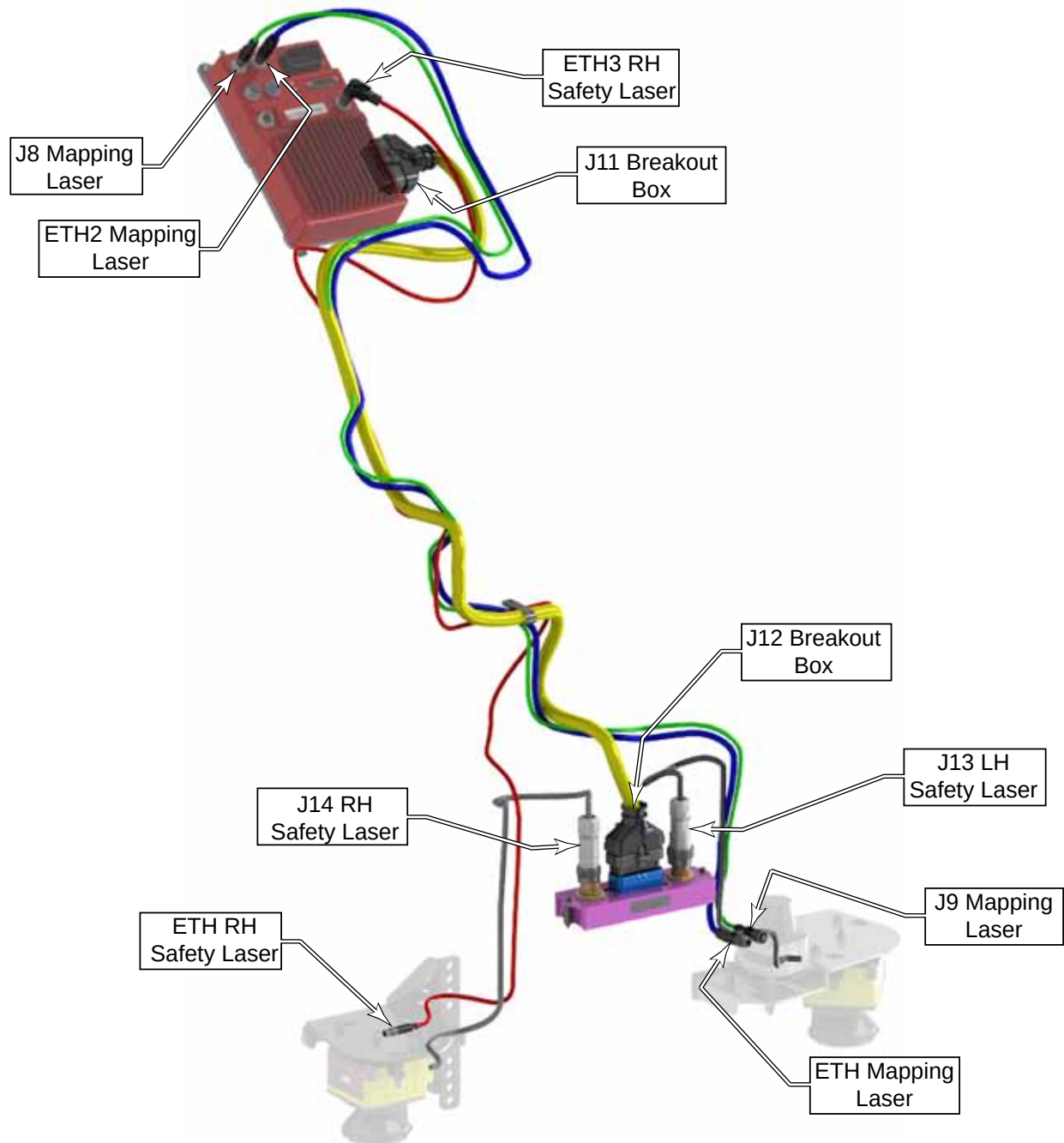
Main Harness, Main Machine Controller**Main Harness, Autonomy Bav**

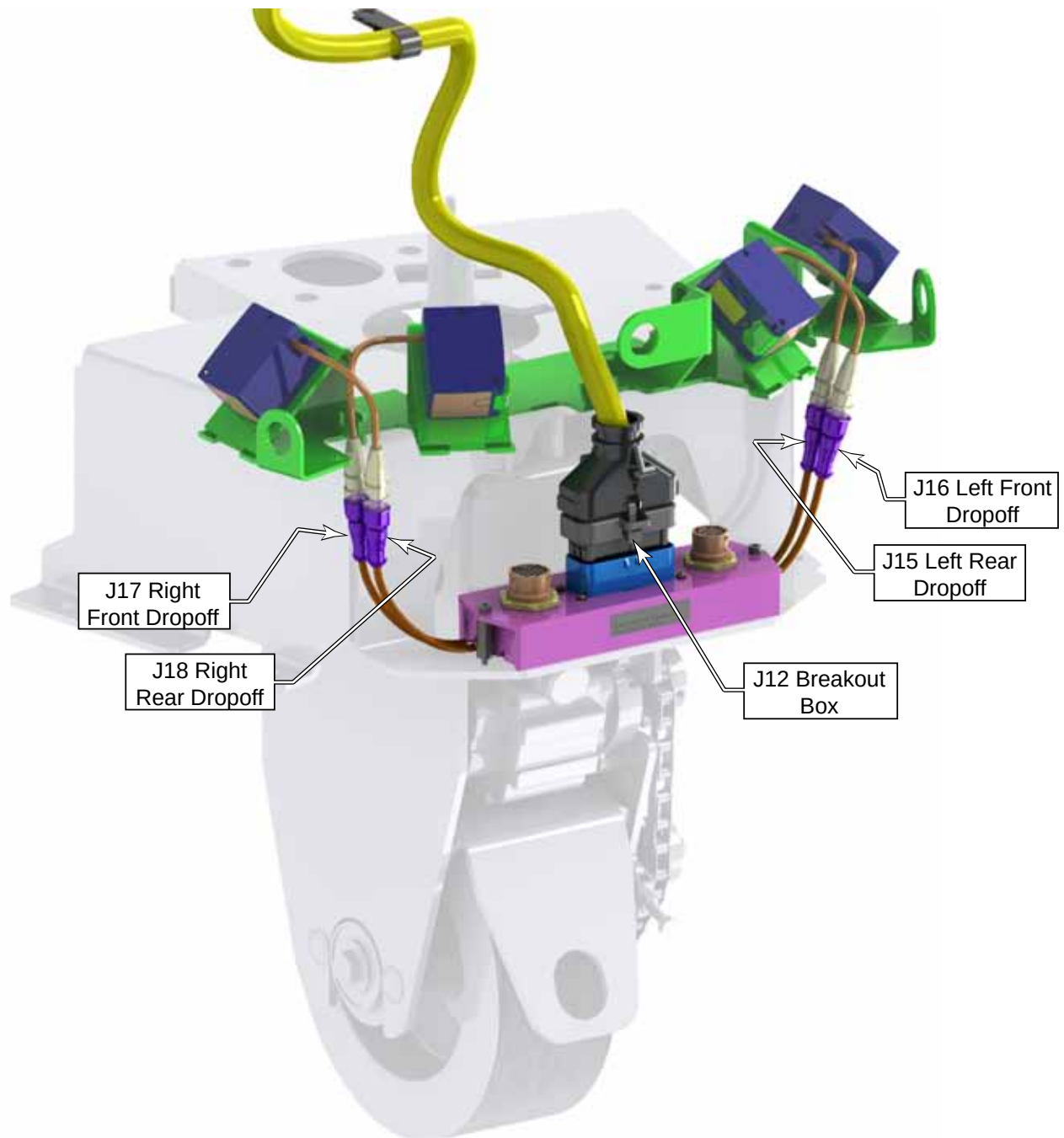
Main Harness, Electrical Bay**Power Connections, Electrical Bay**

Main Harness, Lower Electrical Bay

Main Harness, Scrub Deck**Main Harness, Rear Platform**

Autonomy Cables, Autonomy Bay

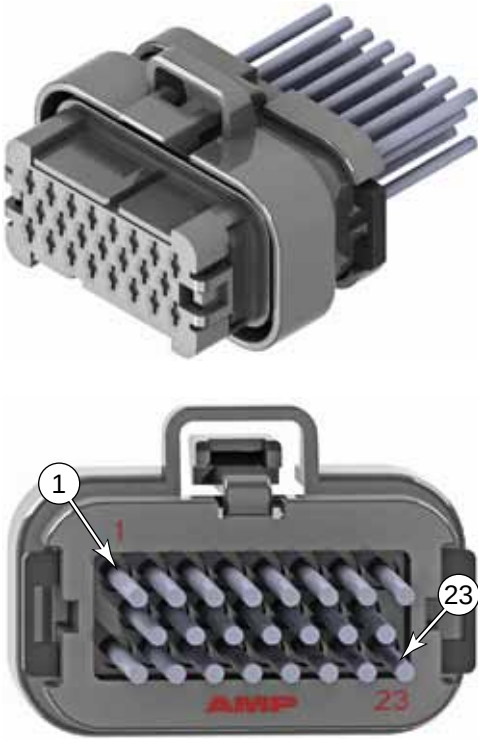
Autonomy Cables, Mapping and Safety Lasers

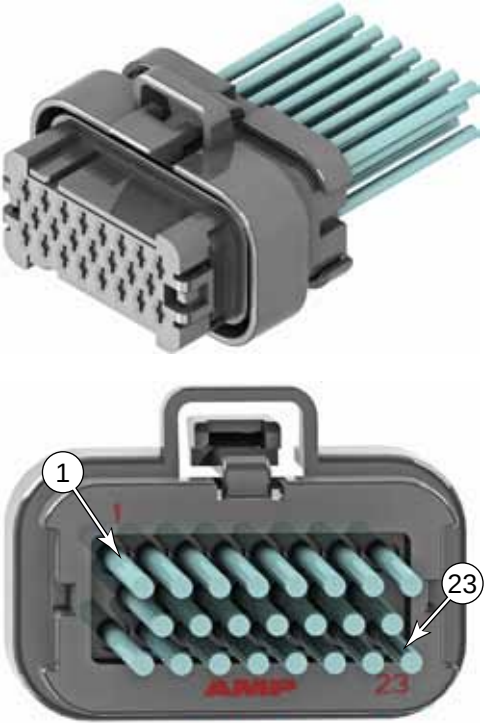
Autonomy Cables, Dropoff Sensors

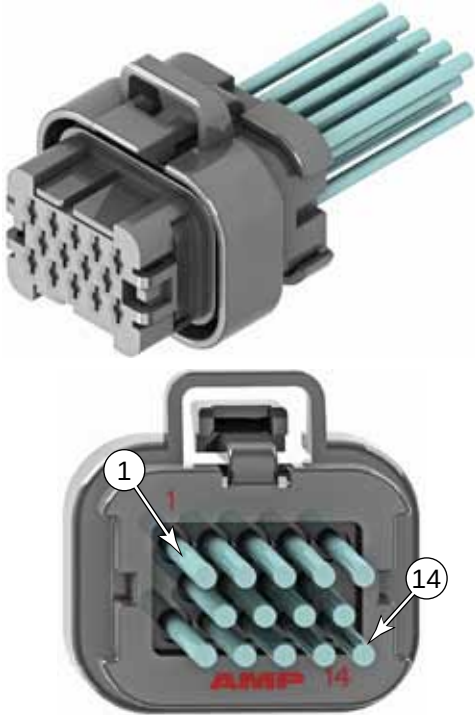
Electrical Connector Pin-Out Assignments

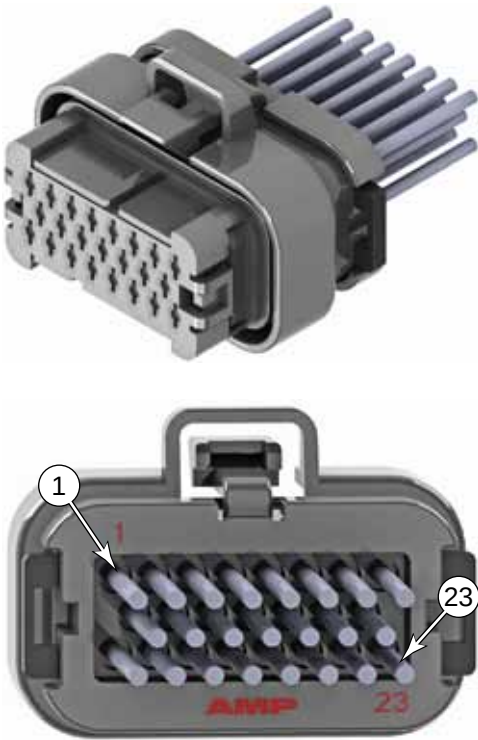
The machine uses a wide variety of electrical connectors, which vary depending on amperage passed, moisture encountered, and number of conductors present. Diagnosing machine problems, frequently involves examining the physical condition of the connectors, as well as the electrical signals passing through them.

The following tables list the individual connector pin-out assignments. The tables include connector illustrations to help you identify the various connectors on the machine. The connector pin-out information is organized by connector ID in alphabetical order.

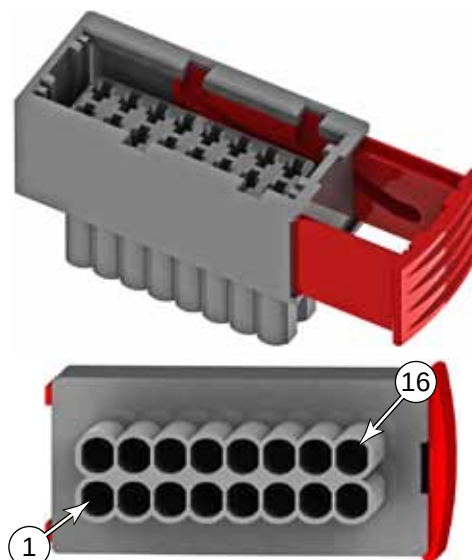
J1		Main Machine Controller		770680-1
Pin#	Wire	Color	Function	770680-1 and 770680-4 are nearly the same, except they have different keying to prevent mis-connection. 
1	W159	YEL-BRN	Battery+	
2	W160	YEL-BRN	Battery+	
3	W162	ORN-BRN	KSI Coil Out	
4	W288	BLU-ORN	Solution Pump PWM Out	
5	W147	BLK	Battery-	
6	W146	BLK	Battery-	
7	W270	RED	12V Power Out	
8				
9				
10	W178	ORN	E-Stop In	
11	W245	GRN	Charger Interlock In	
12	W279	GRN-BLU	Operator Presence In	
13	W163	GRY-BLK	Solution Solenoid Out	
14				
15	W358	RED-BLK	Speaker+ Out	
16	W290	GRN-BLK	Detergent Pump Bi-Directional Out	
17	W289	ORN-GRY	Detergent Pump Bi-Directional Out	
18				
19				
20	W167	GRY	KSI In	
21	W168	GRY	KSI in	
22				
23	W359	WHT-BRN	Speaker- Out	

J2		Main Machine Controller		770680-4
Pin#	Wire	Color	Function	770680-1 and 770680-4 are nearly the same, except they have different keying to prevent mis-connection. 
1	W473	YEL	CAN0 H	
2	W472	GRN	CAN0 L	
3	W261	RED-BLK	(Future) Water Sensor+	
4	W185	BRN	Smart Key B-	
5	W220	WHT	Smart Key Signal (+3.3V)	
6	W416	BLK	Battery-	
7	W437	RED	Light Strip +5V	
8	W191	WHT-ORN	Float Switch In	
9	W271	BRN-GRN	Flow Sensor In	
10				
11	W471	GRN	CAN1 L	
12	W470	YEL	CAN1 H	
13	W440	TAN-BRN	Light Strip Data Out	
14	W439	WHT-BLU	Light Strip Clock Out	
15				
16	W262	RED-BRN	Deck Actuator Position 1 In	
17				
18	W263	RED-YEL	Deck Actuator Position 2 In	
19	W204	RED	USB VBUS	
20	W203	WHT	USB DM	
21	W202	GRN	USB DP	
22				
23	W221	BLK	USB GND	

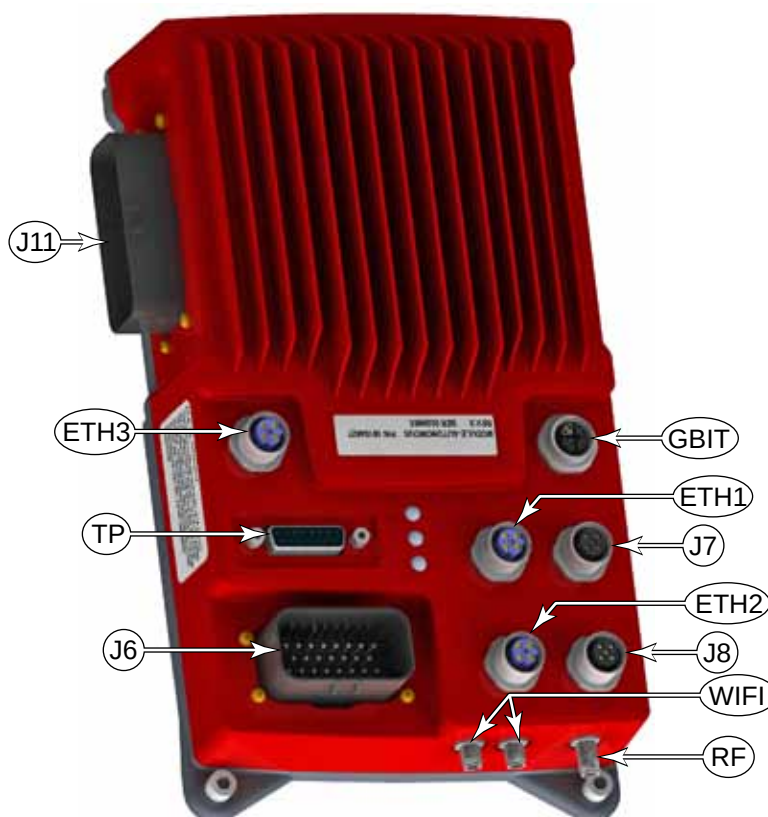
J3		Power Module		776273-1
Pin#	Wire	Color	Function	
1	W265	ORN-GRY	Deck Actuator Out 1 +/-	
2	W019	BRN	K2 Relay Coil Out	
3	W395	GRN	CAN1 L	
4	W392	YEL	CAN1 H	
5	W354	BLK-PNK	Curtis Prog +15V Out	
6	W264	BLU-GRY	Deck Actuator Out 2 +/-	
7	W350	GRN-VIO	Curtis Prog Serial Rx	
8	W353	BLU-GRN	Curtis Prog Serial Tx	
9	W365	GRY	KSI In	
10				
11				
12	W351	BLK	Curtis Prog Gnd Out	
13				
14				

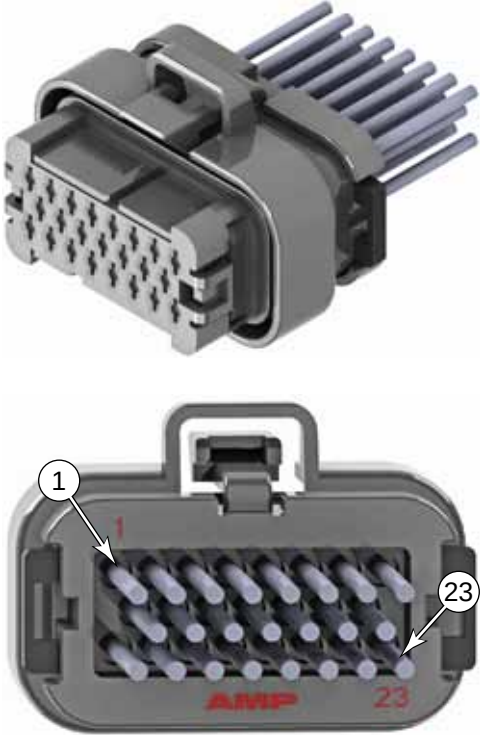
J4		Drive Controller		770680-1
Pin#	Wire	Color	Function	
1	W256	YEL	CAN1 H	
2	W257	GRN	CAN1 L	
3	W130	ORN	E-Stop In	
4	W061	ORN-GRN	EM Brake Out	
5				
6	W378	VIO-BLK	Speed Pot Gnd Out	
7				
8	W059	GRY	KSI In	
9	W305	BLU-BLK	Curtis Prog Tx	
10	W299	BLU-RED	Steering Ready In	
11	W298	BLU-VIO	Auto OK In	
12	W306	GRN-GRY	Curtis Prog Rx	
13	W375	GRY	Go Pedal Switch In	
14	W377	GRN-ORN	Speed Limit Pot In	
15				
16	W307	BLK	Curtis Prog GND	
17	W304	BLK-WHT	Curtis Prog +17V	
18	W371	YEL-WHT	Speed and Go Pdl +5V Out	
19	W410	GRN-BLU	Operator Presence In	
20	W291	YEL-BLU	K3 Relay Coil Out	
21				
22				
23				

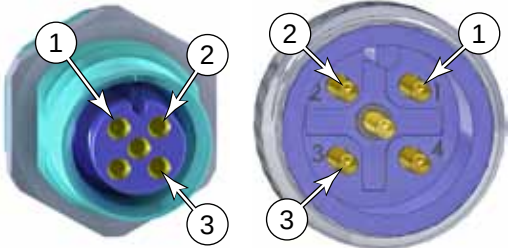
J5		Steering Controller		963217-1
Pin#	Wire	Color	Function	
1				
2	W393	YEL	CAN1 H	
3	W299	BLU-RED	Steering Ready (PWM) Out	
4	W389	BRN-GRN	+5V Sensor Supply Out	
5	W388	BRN-BLU	Steering Angle Sensor In	
6	W340	GRY	KSI In	
7	W345	BLK	Battery-	
8	W251	BLU-RED	Battery+	
9	W505	ORN-GRN	Right Steer Interlock	
10	W396	GRN	CAN1 L	
11	W341	VIO-GRN	Steering Home Sensor In	
12	W506	ORN-YEL	Left Steer Interlock	
13	W450	BRN-GRN	Analog 1 In (+5V)	
14	W390	BLK	Sensor Ground	
15	W344	BLK	Battery-	
16	W252	BLU-PNK	Battery+	

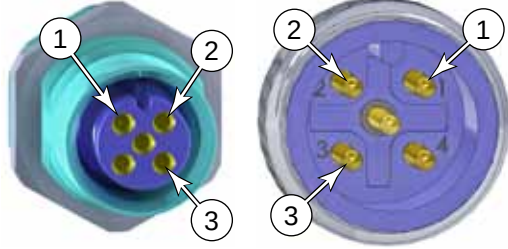


Autonomous Module	
Connector	Description
J6	Main Machine Harness
J7	3D Camera Power
J8	Map Laser Power
J11	Breakout Box
Eth1	Not Used
Eth2	Map Laser Data
Eth3	IOT Module
Gbit	3D Camera Data
WiFi	Antenna
WiFi	Antenna
RF	Antenna
TP	Engineering Test Port

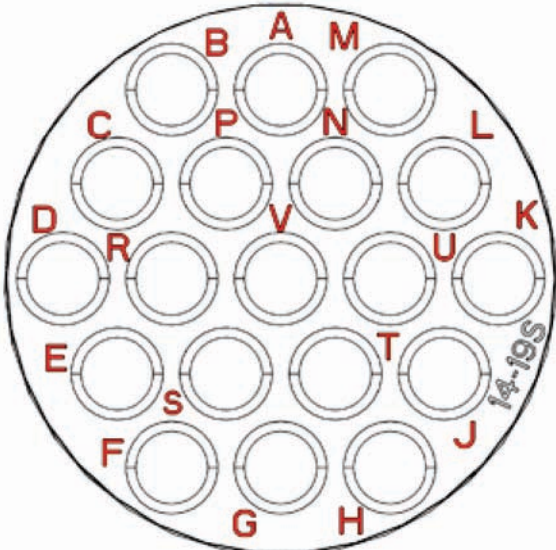


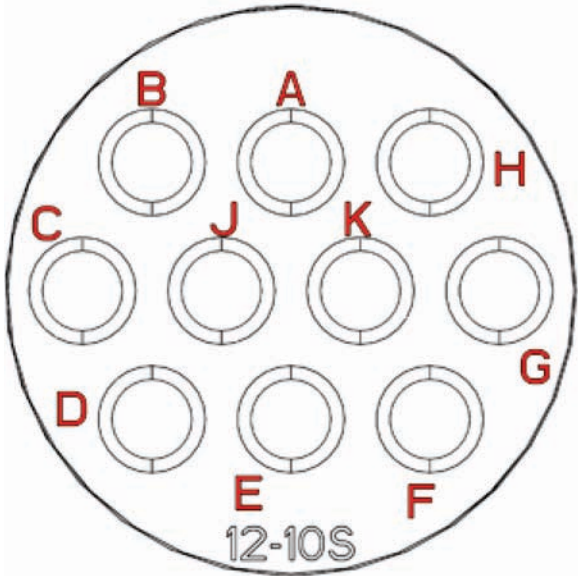
J6		Autonomy Controller		770680-1
Pin#	Wire	Color	Function	
1				
2				
3	W400	GRN	CAN0 L	
4	W398	YEL	CAN0 H	
5	W499	RED	+24V Sensor Supply Out	
6	W500	BLU	Drive Position Sensor In	
7				
8	W519	GRN	Chassis Ground (Not Battery)	
9	W313	YEL-GRN	Left Wheel Encoder A	
10				
11	W318	GRN-YEL	Right Wheel Encoder A	
12				
13	W501	WHT	Drive Position Sensor GND Out	
14	W505	ORN-GRN	Left Steer Interlock Out	
15	W506	ORN-YEL	Right Steer Interlock Out	
16	W320	BLK	Right Wheel Encoder GND Out	
17	W319	BLU-BRN	Right Wheel Encoder B	
18	W314	BRN-BLU	Left Wheel Encoder B	
19	W315	BLK	Left Wheel Encoder GND Out	
20	W298	BLU-VIO	Auto OK Out	
21	W310	GRY	KSI In	
22	W714	BLK	Regulated B-	
23	W451	YEL-BRN	Regulated B+	

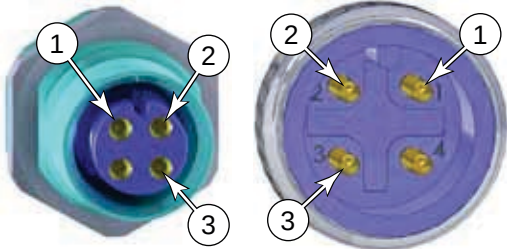
J7/J10		Multisense 3D Camera Power		
Pin#	Wire	Color	Function	
1			+24V	
2			Sync	
3			B-	
4			N/C	
5			B-	

J8/J9		Mapping Laser Power		
Pin#	Wire	Color	Function	
1			+24V	
2			Sync 1	
3			B-	
4			Sync 2	
5			B-	

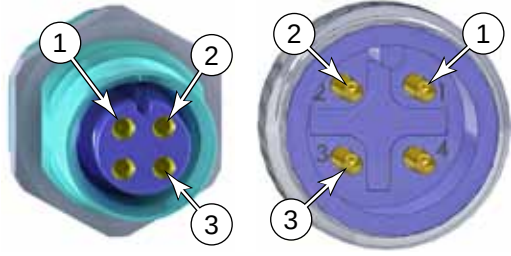
J11/J12		Autonomy Breakout Box		776164-1
Pin#	Wire	Color	Function	
1	W671		+24V	
2	W672		GND	
3	W673		Area Address A+	
4	W674		Area Address A-	
5	W675		Area Address B+	
6	W676		Area Address B-	
7	W677		Area Address C+	
8	W678		Area Address C-	
9	W679		Area Address D+	
10	W680		Area Address D-	
11	W681		Area Address E+	
12	W682		Area Address E-	
13	W683		Protection Zone A Interlock 1	
14	W684		Protection Zone A Interlock 2	
15	W685		Protection Zone A Warning 1	
16	W686		Protection Zone A Warning 2	
17	W687		Protection Zone B Interlock 1	
18	W688		Protection Zone B Interlock 2	
19	W689		Protection Zone B Warning 1	
20	W690		Protection Zone B Warning 2	
21				
22				
23				
24	W691		Ultrasonic LH (future)	
25	W692		Ultrasonic CTR (future)	
26	W693		Ultrasonic RH (future)	
27	W694		Drop Off Left-Rear	
28	W695		Drop Off Left Front	
29	W696		Drop Off Right Front	
30	W697		Drop Off Right Rear	
31				
32				
33				
34				
35	W698		Chassis Ground	

J13		Safety Laser, Master		RT0W71419SNH
Pin#	Wire	Color	Function	
A		BRN	+24V	
B		PUR	Area Address A+	
C		PUR/BLK	Area Address A-	
D		GRY	Area Address B+	
E		GRY/BLK	Area Address B-	
F		WHT	Area Address C+	
G		WHT/BLK	Area Address C-	
H		PNK	Area Address D+	
J		PNK/BLK	Area Address D-	
K		GRN	Area Address E+	
L		GRN/BLK	Area Address E-	
M		RED	Protection Zone A Interlock 1	
N		YEL	Protection Zone A Interlock 2	
P		RED/BLK	Protection Zone A Warning 1	
R		YEL/BLK	Protection Zone A Warning 2	
S		WHT/BLU	RS 485+	
T		WHT/RED	RS 485-	
U		BLK	Chassis Ground	
V		BLU	B-	
The pinout orientation is shown from the top-down view at the breakout box connector, which also coincides with the wire-side view of the cable connector. The cable connector is shown in exploded view, as disassembly would be required for back-probing cable connector. 				

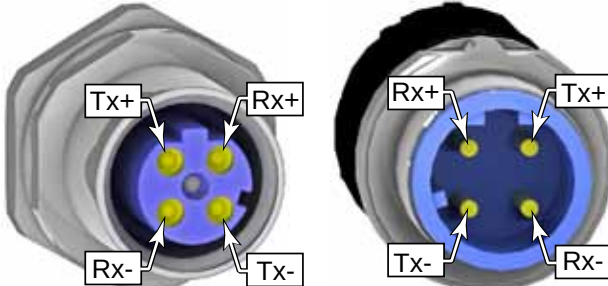
J14		Safety Laser, Slave		RT0W71210SNH
Pin#	Wire	Color	Function	
A		BRN	+24V	
B		RED	Protection Zone B Interlock 1	
C		YEL	Protection Zone B Interlock 2	
D		RED/BLK	Protection Zone B Warning 1	
E		BLU	B-	
F		YEL/BLK	Protection Zone B Warning 2	
G		WHT/BLU	RS 485+	
H		WHT/RED	RS 485-	
J		BLK	Chassis Ground	
The pinout orientation is shown from the top-down view at the breakout box connector, which also coincides with the wire-side view of the cable connector. The cable connector is shown in exploded view, as disassembly would be required for back-probing cable connector. 				

J15-18		Dropoff Sensors (4X)		
Pin#	Wire	Color	Function	
1			+24V	
2			Analog Data	
3			B-	
4			NC	

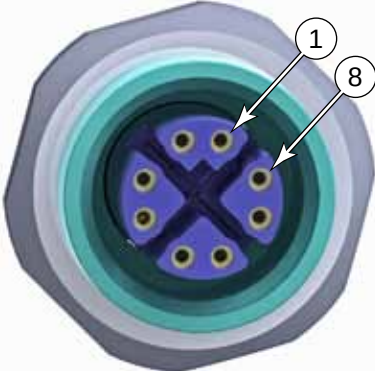
J19-21		(Future) Ultrasonic Personnel Sensors (3X)	
Pin#	Wire	Color	Function
1			+24V
2			Analog Data
3			B-
4			Sync



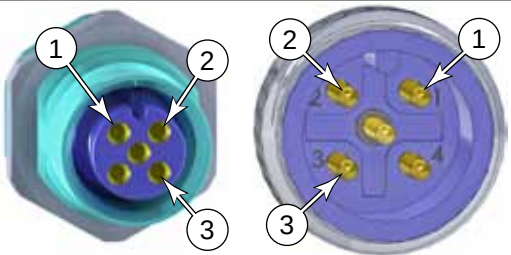
		Standard Ethernet	
Pin#	Wire	Color	Function
1			TX+
2			RX+
3			TX-
4			RX-

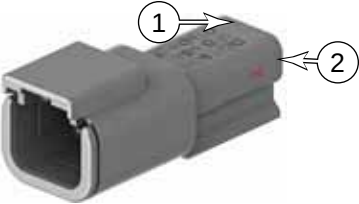


		Gigabit Ethernet	
Pin#	Wire	Color	Function
1			A+
2			A-
3			B+
4			B-
5			D+
6			D-
7			C-
8			C+



		Li-Ion Battery Comm	
Pin#	Wire	Color	Function
1			Recuperation
2			On/Off
3			Signal Ground
4			CAN-H
5			CAN-L

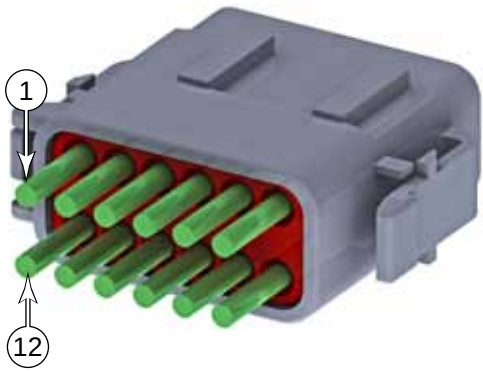


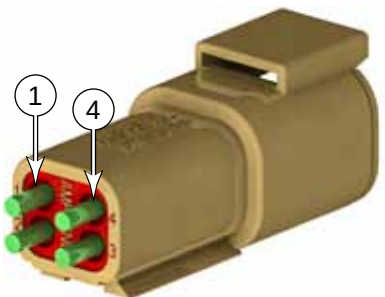
X78		Solution Solenoid		DTM04-2P
Pin#	Wire	Color	Function	
1	W163	GRY-BLK	Control (GND)	
2	W106	GRY	KSI (+24V)	

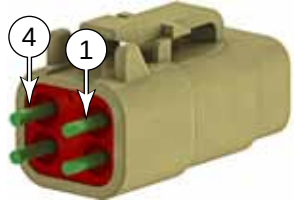
X128		Scrub Motor		19432-0013
Pin#	Wire	Color	Function	
1	W081	WHT-VIO	M1 PWM Control (B-)	
2	W082	BLK-YEL	M2 Fixed (B+)	

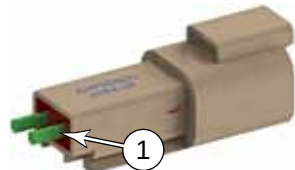
X137		Smart Key		43020-0201
Pin#	Wire	Color	Function	
1	W185	BRN	B-	
2	W220	WHT	Data (3.3V)	

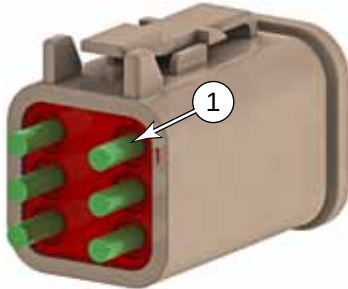
X157		Vacuum Motor Harness (Under Chassis)		ATP06-2S
Pin#	Wire	Color	Function	
1	W085	ORN-BLU	Control PWM (B-)	
2	W079	BLU-GRY	Battery+ (K2 Relay)	

X163		TrackClean		DTM06-12SA
Pin#	Wire	Color	Function	
1				
2	W255	GRY	KSI	
3	W161	YEL-BRN	Battery+	
4	W131	BLK	Battery-	
5				
6				
7	W276	YEL	CAN0 H	
8	W278	GRN	CAN0 L	
9				
10				
11				
12				

X173		USB Expansion		ATM04-4P
Pin#	Wire	Color	Function	
1	W204	RED	VBUS	
2	W203	WHT	DM	
3	W202	GRN	DP	
4	W221	BLK	GND	

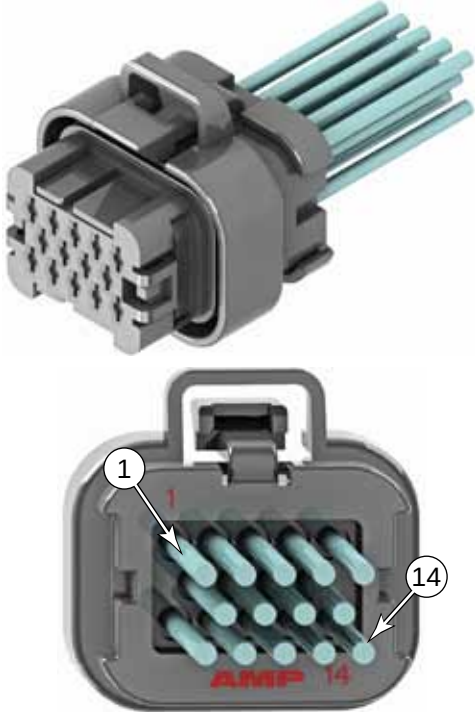
X187		Light Strip		DTM06-4S
Pin#	Wire	Color	Function	
1	W437	RED	+5V	
2	W439	WHT-BLU	SCLK (Serial Clock)	
3	W440	TAN-BRN	MOSI (Data)	
4	W283	BLK	Battery-	

X189		Water Sensor (Future)		ATM04-2P
Pin#	Wire	Color	Function	
1	W436	BLK	GND	
2	W261	RED-BLK	Signal (+3V)	

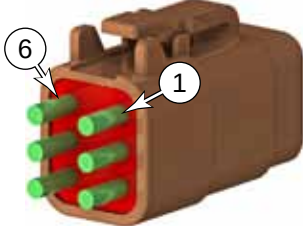
X190		Deck Actuator		DT06-6S
Pin#	Wire	Color	Function	
1	W264	BLU-GRY	Actuator 2 +/-	
2	W265	ORN-GRY	Actuator 1 +/-	
3				
4	W262	RED-BRN	Position 1	
5	W266	BLK	Battery-	
6	W263	RED-YEL	Position 2	

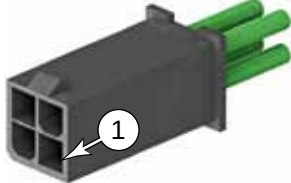
X191		Solution Flow Sensor		09-50-3031
Pin#	Wire	Color	Function	
1	W271	BRN-GRN	Data	
2	W269	BLK	Battery-	
3	W268	RED	+12V	

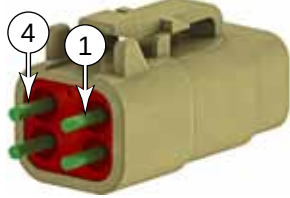
X193		Steering Home Sensor		AT06-2S
Pin#	Wire	Color	Function	
1	W341	VIO-GRN	Sensor Return	
2	W282	BRN-GRN	+5V	

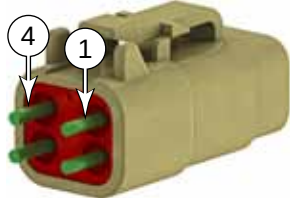
X194		Battery Charger		776273-1
Pin#	Wire	Color	Function	
1				
2				
3	W429	ORN	Bat+ (For Interlock Circuit)	
4	W245	GRN	Interlock Out	
5	W441	VIO	Battery Thermistor (temp sensor)	
6	W402	YEL	CAN0 H	
7				
8				
9				
10	W277	GRN	CAN0 L	
11				
12				
13				
14	W417	BLK	Battery Thermistor (temp sensor)	

X203		Traction Motor		19432-0013
Pin#	Wire	Color	Function	
1	W300	RED-GRN	M1 Bi-Directional PWM	
2	W302	YEL-BLK	M2 Bi-Directional PWM	

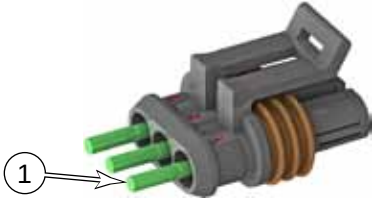
X208		Operator Platform Harness		DTM06-6S
Pin#	Wire	Color	Function	
1	W373	YEL-BLU	Go Pedal Return	
2	W375	GRY	KSI for Go Pedal	
3	W254	GRY	KSI for Operator Presence Switch	
4	W410	GRN-BLU	Operator Presence to Drive Controller	
5	W279	GRN-BLU	Operator presence to Main Machine Controller	
6				

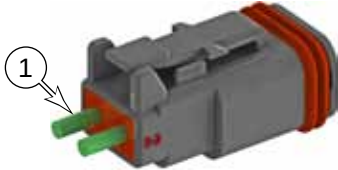
X210		Curtis Programmer (Traction)		39013049
Pin#	Wire	Color	Function	
1	W306	GRN-GRY	Data Rx	
2	W307	BLK	B-	
3	W305	BLU-BLK	Data Tx	
4	W304	BLK-WHT	+17V	

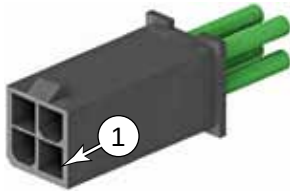
X214		Left Wheel Encoder		DTM06-4S
Pin#	Wire	Color	Function	
1	W313	YEL-GRN	Data Channel A	
2	W314	BRN-BLU	Data Channel B	
3	W315	BLK	B- from Autonomous Module	
4	W316	RED	+12V from Main Machine Controller	

X215		Right Wheel Encoder		DTM06-4S
Pin#	Wire	Color	Function	
1	W318	GRN-YEL	Data Channel A	
2	W319	BLU-BRN	Data Channel B	
3	W320	BLK	B- from Autonomous Module	
4	W317	RED	+12V from Main Machine Controller	

X231		Speaker		43025-0200
Pin#	Wire	Color	Function	
1	W358	RED-BLK	Speaker+	
2	W359	WHT-BRN	Speaker-	

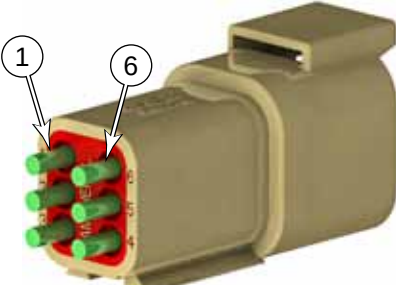
X241		Steering Encoder (Steering Wheel)		282087-1
Pin#	Wire	Color	Function	
1	W447	RED	+12V	
2	W390	BLK	GND	
3	W388	BRN-BLU	Analog Data	

X242		EM Brake		AT06-2S
Pin#	Wire	Color	Function	
1	W061	ORN-GRN	Control B-	
2	W384	GRY	KSI Power	

X279		Curtis Programmer (Power Module)		39013049
Pin#	Wire	Color	Function	
1	W350	GRN-VIO	Data Rx	
2	W351	BLK	B-	
3	W353	BLU-GRN	Data Tx	
4	W354	BLK-PNK	+15V	

X280		Recovery Float Switch		AT06-2S
Pin#	Wire	Color	Function	
1	W191	WHT-ORN	Switch Return	
2	W136	BLK	Battery-	

X287		CANBus Access Port		39-01-3069
Pin#	Wire	Color	Function	
1	W477	YEL	CAN0 H	
2	W476	GRN	CAN0 L	
3	W478	BLK	Battery-	
4	W474	YEL	CAN1 H	
5	W475	GRN	CAN1 L	
6				

X288		Drive Position Encoder		ATM04-6P
Pin#	Wire	Color	Function	
1	W500	BLU	Analog Data	
2	W499	RED	+5V	
3	W501	WHT	B-	
4				
5				
6	W502	SHIELD	Shield	

30 - Solution System

Functional Description

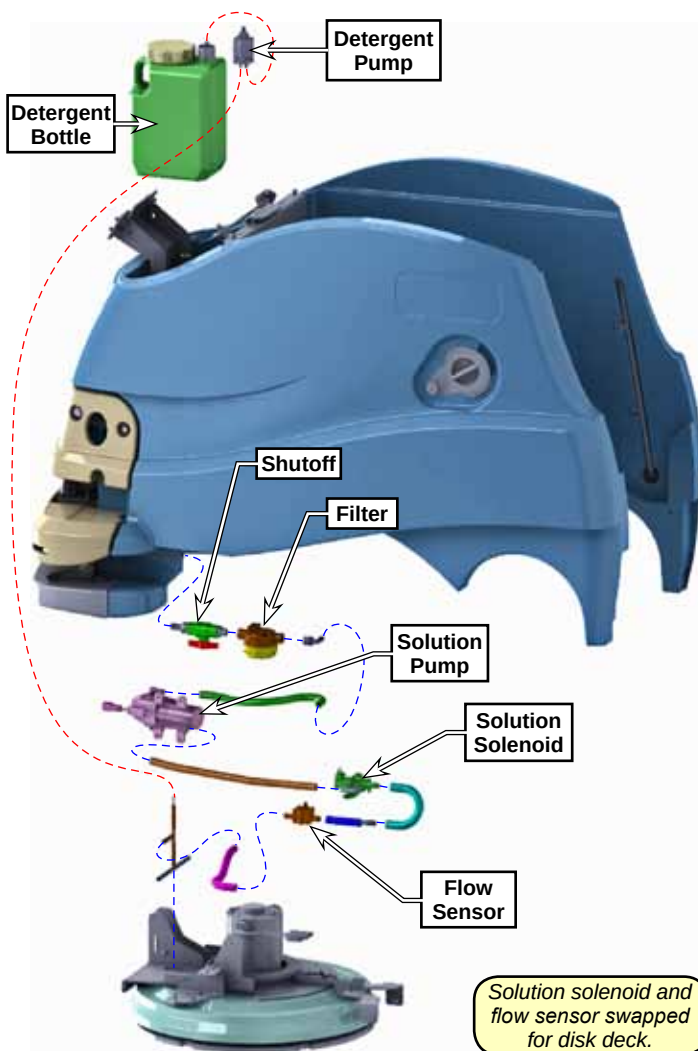
The Solution System uses a Proportional–Integral–Derivative (PID) feedback loop to regulate solution flow. A PID system continuously calculates an error value as the difference between a desired flow rate and the measured flow rate, and applies a correction based on proportional, integral, and derivative terms, which gives the control its name; PID.

Solution passes from the solution tank through a shutoff valve, and into the filter to ensure large particles don't clog the rest of the system. Even though gravity feed would be sufficient for a machine of this class, a solution pump is used in order to more accurately control the solution flow, regardless how much head pressure is in the solution tank as it empties.

The solution pump is PWM controlled from the Main Machine Controller, and the rate of power to the pump is determined by the PID feedback system and the flow sensor. The flow sensor is located downstream from the pump and provides the feedback necessary for the system to confirm the actual water flow.

The solution solenoid is an electromagnetic valve to turn the water flow on and off as needed.

The detergent pump is located near the top of the machine and injects small doses of detergent into the solution line proportional to the flow of the solution. The detergent pump is a solenoid actuated diaphragm with one-way valves to propel fluid with each actuation of the internal solenoid.

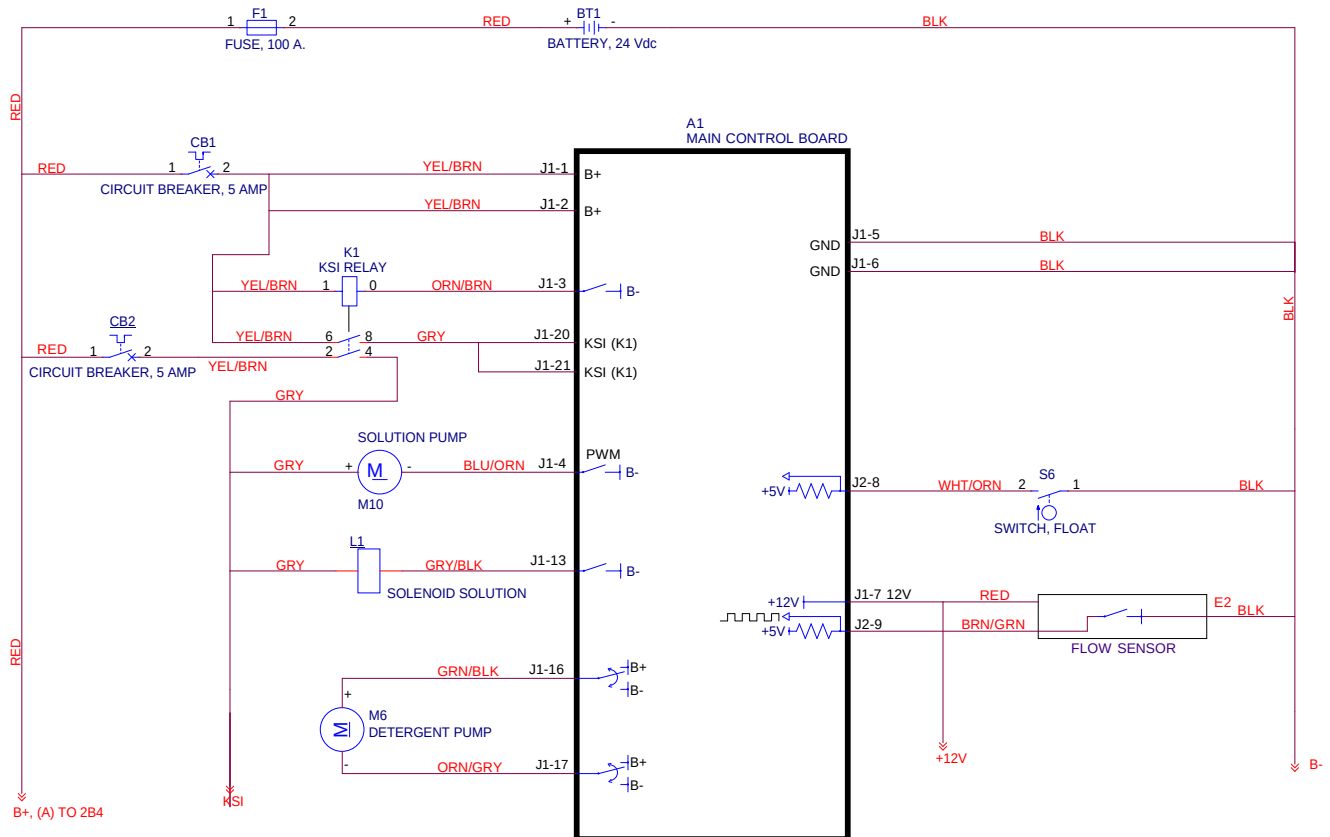


Circuit Description

All of the functions of the solution system are directly controlled by the Main Machine Controller (MMC). So the circuit descriptions are fairly straightforward, and all of the logic aspects are software driven. (The detergent pump is slightly more complex and is described on [page 317](#).)

The MMC controls when the KSI relay is closed. One pole from this relay supplies positive battery power into the MMC itself, and the other pole provides positive battery power to the solution solenoid and solution pump. This can be thought of as “enabling” those devices, with their final control driven by the MMC making the grounding connection.

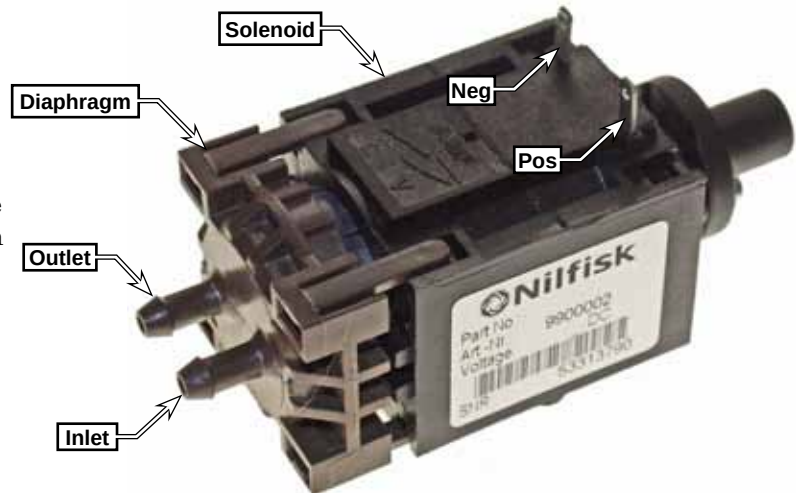
The flow meter is an electromechanical sensor that outputs a pulse train relative to the flow rate of the solution hose. Its internal electronics operate at 12 volts, which it receives from the MMC.



Detergent Pump

The detergent pump is a solenoid-driven diaphragm with one-way check valves. As the solenoid oscillates in and out, it drives a flexible diaphragm that draws fluid in during the retraction stroke, and drives fluid out during the compression stroke. The check valves allow fluid to enter only through the inlet port, and exit only through the outlet port.

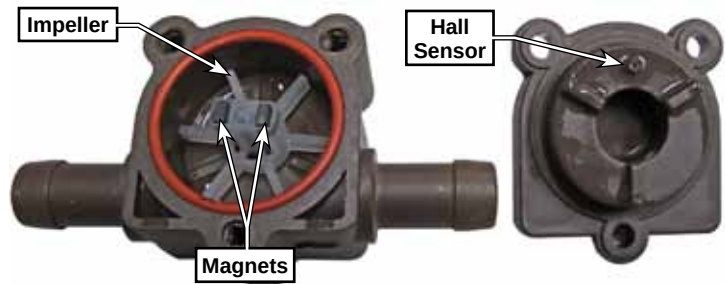
Unlike an AC solenoid that moves its plunger the same direction regardless of the electrical polarity, a DC solenoid changes its direction of travel depending on the electrical polarity of the coil. This is an important distinction because if the pump is driven with the wrong polarity, it will not pump liquid. However, the MMC powers the solution pump with an alternating DC voltage.



Solution Flow Meter

The solution flow meter provides feedback to the main machine controller regarding the actual solution flow to the scrub deck. As the solution flows from inlet to outlet, it causes an impeller to rotate. The hub of the impeller contains a pair of magnets. As the impeller rotates, these magnets pass below a hall effect sensor, which registers the movement.

The output of the flow meter is a square-wave signal of varying frequency, depending on the flow rate. In addition to monitoring the flow rate, the Main Machine Controller also uses the flow meter signal to determine when the solution tank is empty, as no flow will be reported.



Maintenance and Adjustments

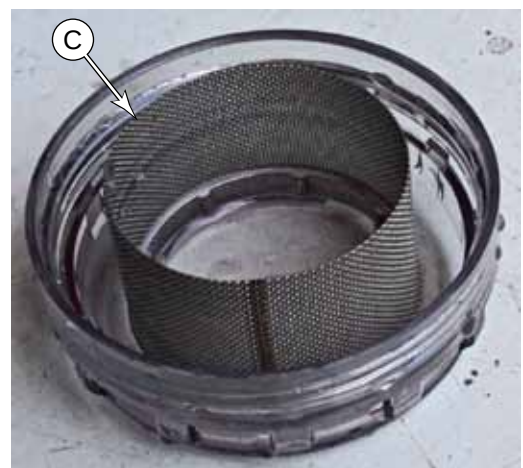
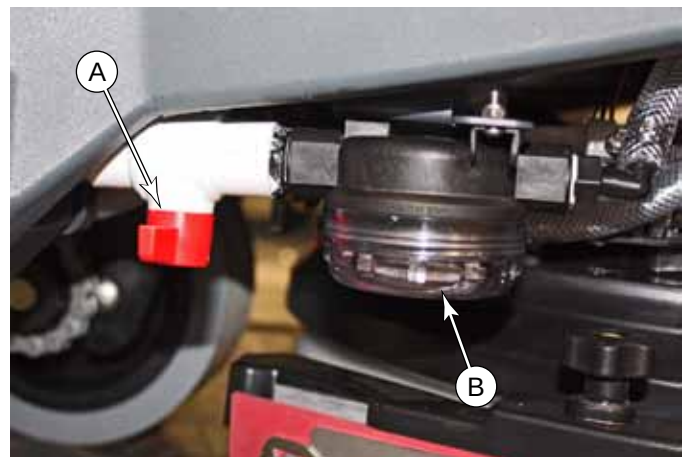
Draining the Solution Tank

There is a drain valve for the solution tank that is separate from the main solution flow plumbing. It is located on the right side of the machine. The valve is open when the handle is in the vertical position, and closed when in the horizontal position.



Cleaning the Solution Filter

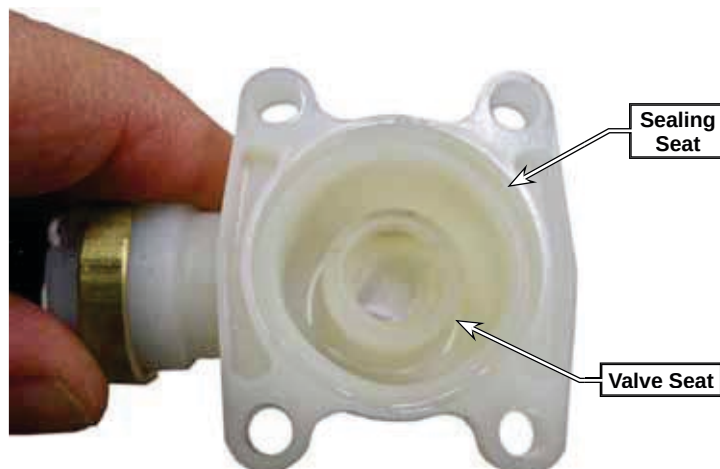
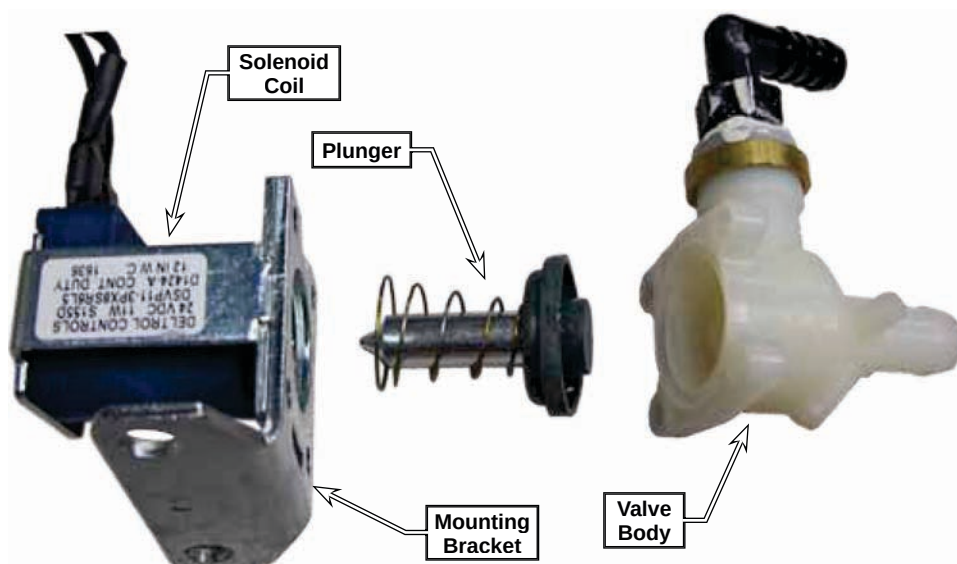
1. Shutoff the solution valve **(A)**.
2. Unscrew the solution filter **(B)**. There will likely still be some liquid in the line that will spill out.
3. Clean the filter bowl and screen **(C)**. Note that the screen is not removable from the bowl.



Clean and Inspect the Solution Solenoid

The solution solenoid should be periodically inspected for leaks or blockages. A machine stored for extended periods with solution in the lines may even develop a film-like obstruction in the solution system.

1. Close the solution shutoff valve.
2. Remove the solenoid from the scrub deck.
3. Remove the 4 screws that secure the solenoid valve body to the solenoid coil, and separate the valve, plunger, and coil.
4. Inspect the plunger shaft for corrosion, and the plunger head for cuts, tears, holes, and other damage. If damage is found, replace the solenoid.
5. Clean and inspect the valve body.
 - Rinse any debris from the valve body.
 - Inspect the sealing seat for nicks and causes of leaks.
 - Inspect the valve seat for nicks, burrs, and rough edges.



Removal and Installation

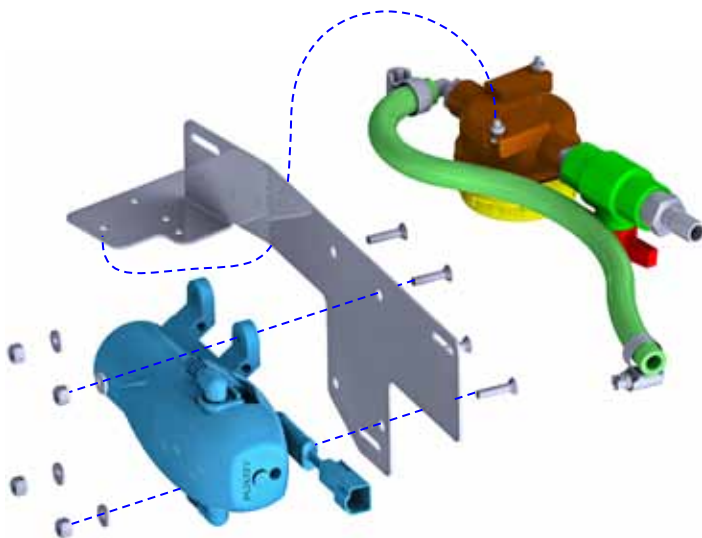
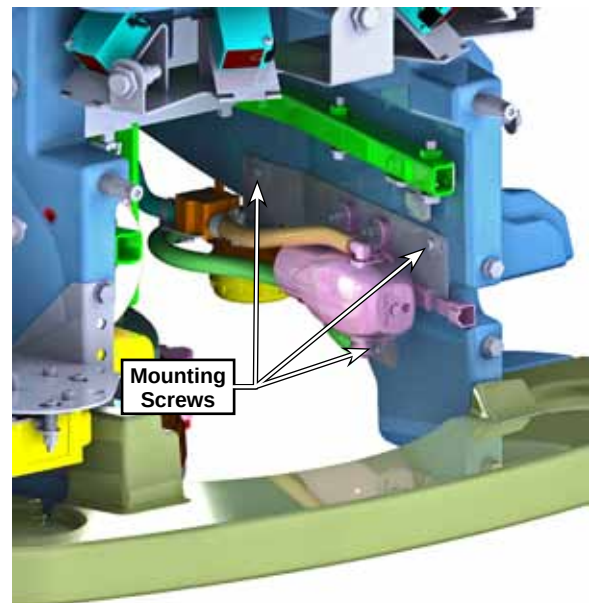
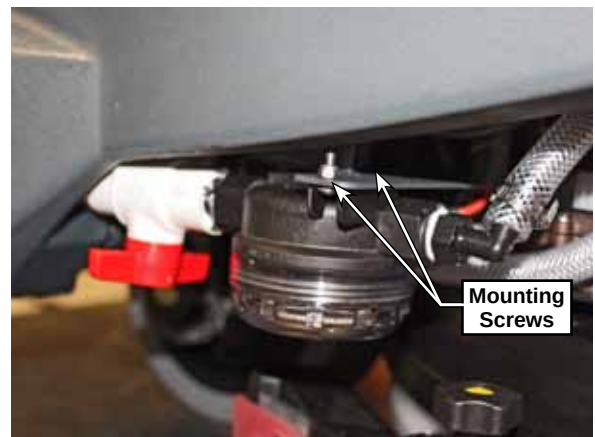
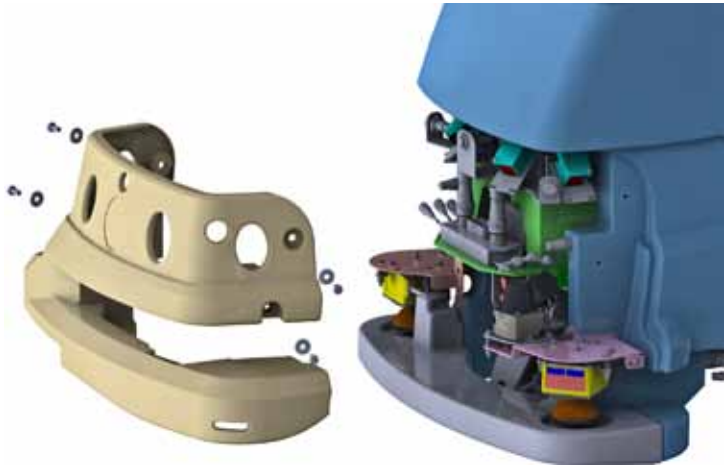
Solution Pump

1. Disconnect the main battery connector for safety while working near the drive system.
2. Remove the 4 screws and washers that secure the front nose to the recovery tank, and remove the front nose.
3. Rotate the drive system to the side, as necessary for easier access. (Drive system not shown for clarity.)
4. Turn off the solution valve.
5. Remove the incoming and outgoing solution lines from the solution pump.



Note: During disassembly, avoid allowing the solution pump mounting bracket from pressing down on the solution filter, as this may damage the plumbing connections.

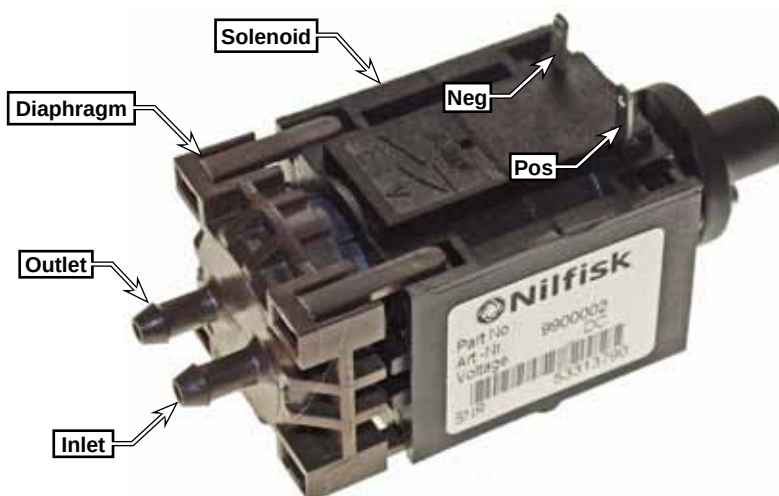
6. Remove the 2 screws and nuts that secure the solution filter to the same bracket that the solution pump is mounted to.
7. Remove any cable ties securing wiring or hoses to the pump mounting bracket.
8. While supporting the pump and bracket, remove the 3 screws and washers that secure the solution pump bracket to the solution tank.
9. Carefully slide the pump mounting bracket out from above the solution filter, and then remove the pump and bracket.
10. Remove the 4 screws, washers, and nuts that secure the pump to the bracket, and remove the pump.



Detergent Pump

Removal and replacement of the detergent pump is straightforward, however, it is important to check polarity of both fluid and electrical connections.

- Inlet tube from detergent bottle
- Outlet tube to scrub deck
- Positive = green/black
- Negative = orange/gray



Specifications

Component Specifications

Component	Specifications
Solution Solenoid Valve	Nominal Voltage – 24 VDC, 11 Watt
	Duty – Continuous
	Resistance – 55.5 Ohms $\pm 10\%$ @ 25° C
Solution Tank	Capacity – 12 gal. [45,4 l]

Nominal Solution Flow Rates

The nominal solution flow are listed in the following table. Note that these flow rates are based on a half-full solution tank.

Deck Type	Solution Setting	Nominal Flow Rate Gal/Min	Nominal Flow Rate L/Min
Disk Deck	Low	.140-.180	.53 - .68
	Medium	.300-.400	1.14 - 1.51
	High	.430-.570	1.63 - 2.16
Rev Deck	Low	.120-.150	.45 - .57
	Medium	.149-.209	.56 - .79
	High	.190-.270	.72 - 1.02

34-Scrub System

Functional Description

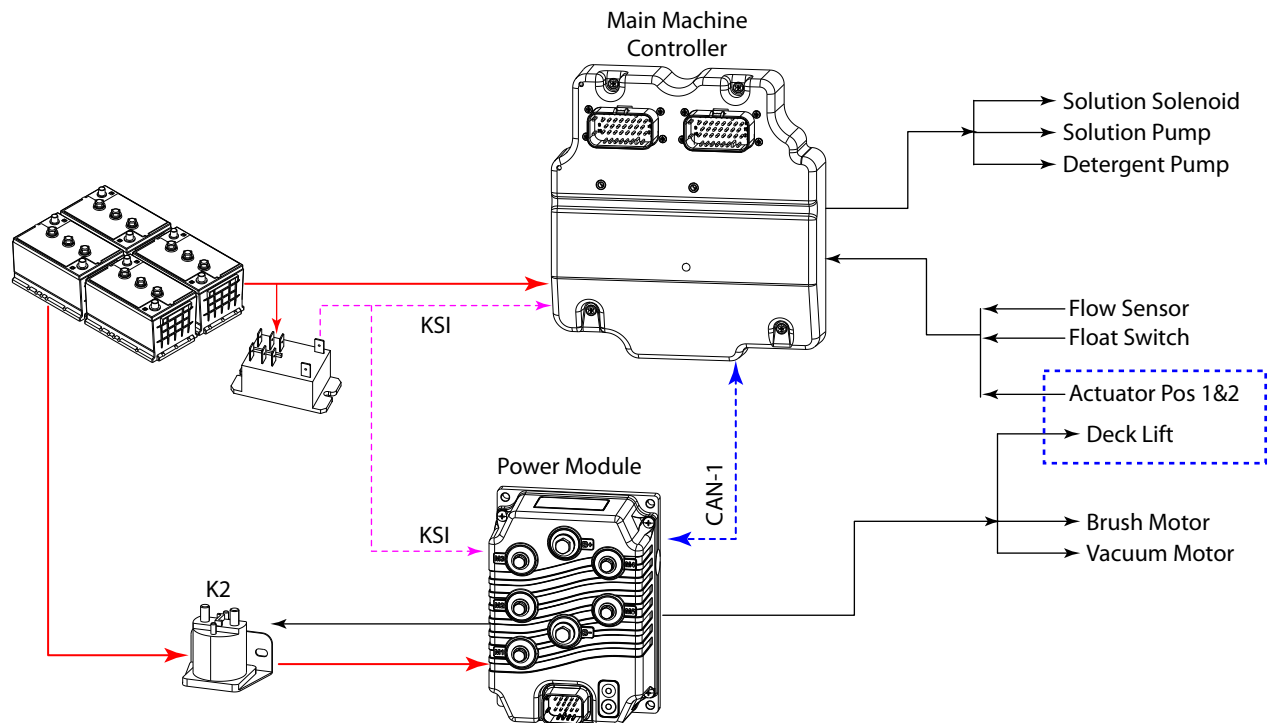
The scrub system consists of a circular scrub deck which is raised and lowered by an actuator, in conjunction with a parallelogram linkage to ensure the deck remains parallel to the floor surface. There are two classes of scrub deck available for the machine. The “Disc” deck uses a rotary motion of the scrub pad, while the “Rev” deck uses what’s termed a *Random Orbit* motion.

The deck lift actuator and brush motor are driven from the Power Module. The deck lift position sensors report position to the Main Machine Controller (MMC).

The scrub deck has four vertical positions:

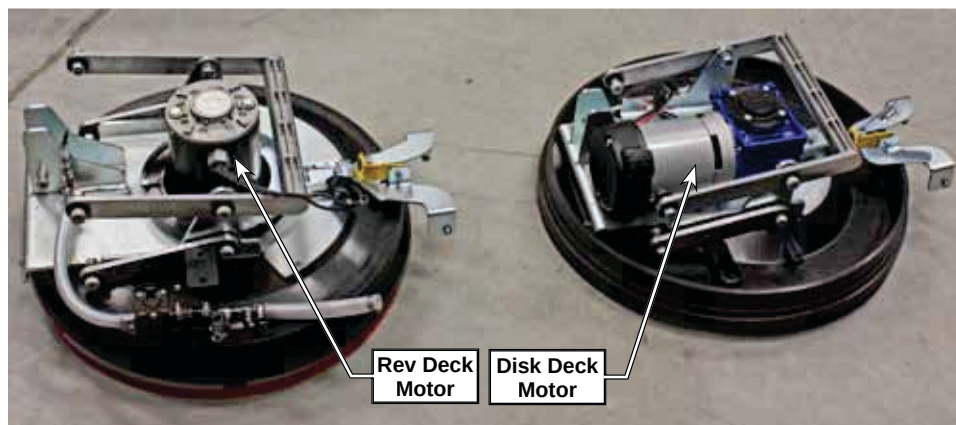
- The scrub deck is in the fully-retracted (up) position when the machine is in the transport mode (no scrubbing or vacuuming).
- The vacuum-only position lowers the scrub deck so the attached squeegee contacts the floor, but the brush/pad is raised slightly above the floor. This position is used for wet vacuuming of wastewater from the floor with no scrubbing.
- The “normal” scrub pressure position lowers the scrub deck so the brush/pad contacts the floor with normal scrub pressure.
- The “extra” scrub pressure position lowers the scrub deck to its extension limit so the brush/pad contacts the floor with greater than normal scrub pressure.

Functional Diagram

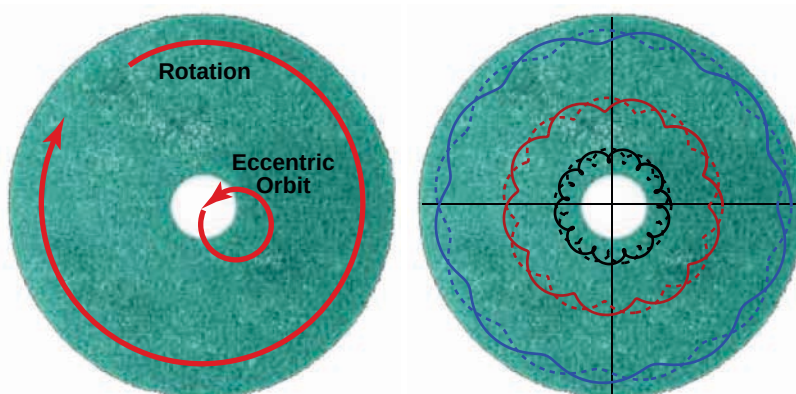


Deck Types

The disc deck provides a uniform rotational movement of the scrub pad. The disc deck is identified by the horizontal mounting of the brush motor. The motor's output shaft connects to the brush pad via a right-angle reduction gearbox. The gearbox increases the motor's output torque to better drive the pad.



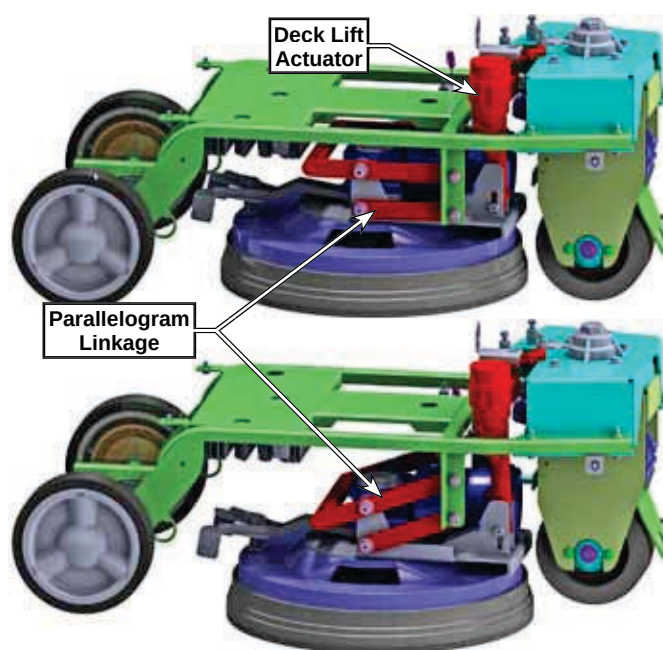
The Rev deck produces a dual-action motion, frequently referred to as *Random Orbital*. The motor's output shaft is connected to an eccentric cam, which causes the pad to oscillate in small circles, which is referred to as the orbit. However, this eccentric cam is connected to the pad via a bearing, which allows the pad to freewheel rotate. These two motions combine to produce what is called an *epicycloid* motion (shown to the far right).



Rev Deck Pad Motion

Deck Lift Actuator

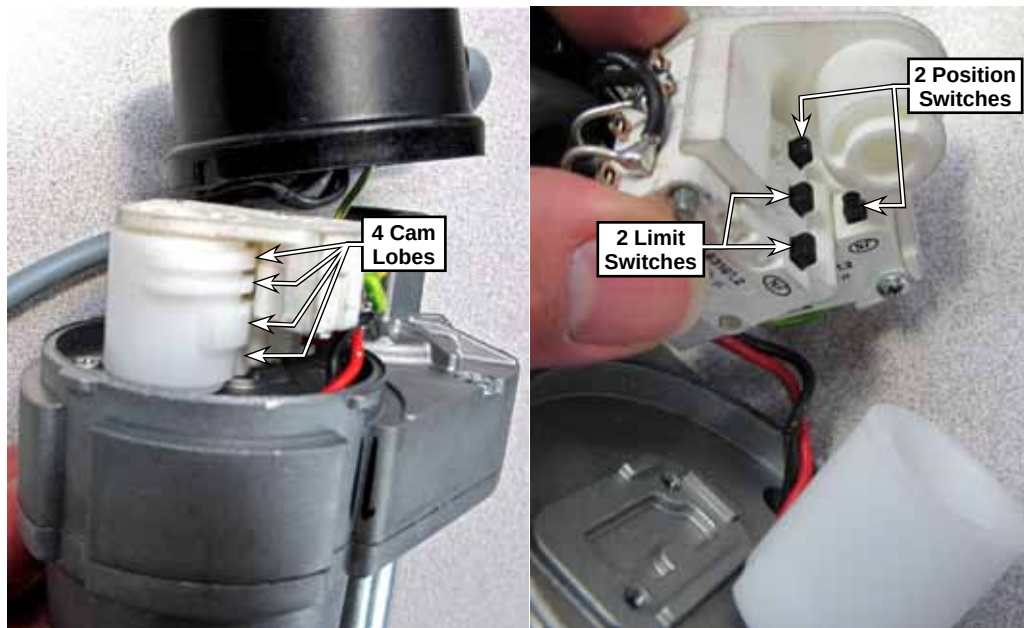
The scrub deck is raised and lowered with a leadscrew actuator, and a set of parallelogram linkage bars keep the deck oriented parallel to the floor. The concept of a parallelogram is that regardless of the angle between adjacent sides, the opposing sides will always remain parallel with one another. This is important for the scrub deck, to ensure that it applies even pressure to the floor, no matter the height, including when only the squeegee is in contact with the floor.



The deck lift actuator has 2 internal limit switches plus 2 informational, position switches inside the gear housing. All 4 switches are actuated by a 4-lobe cam that represents the full lineal travel of the leadscrew nut. The cam is gear-reduced to make less than a single rotation for the dozens of rotations for the full travel of the leadscrew and leadscrew nut.

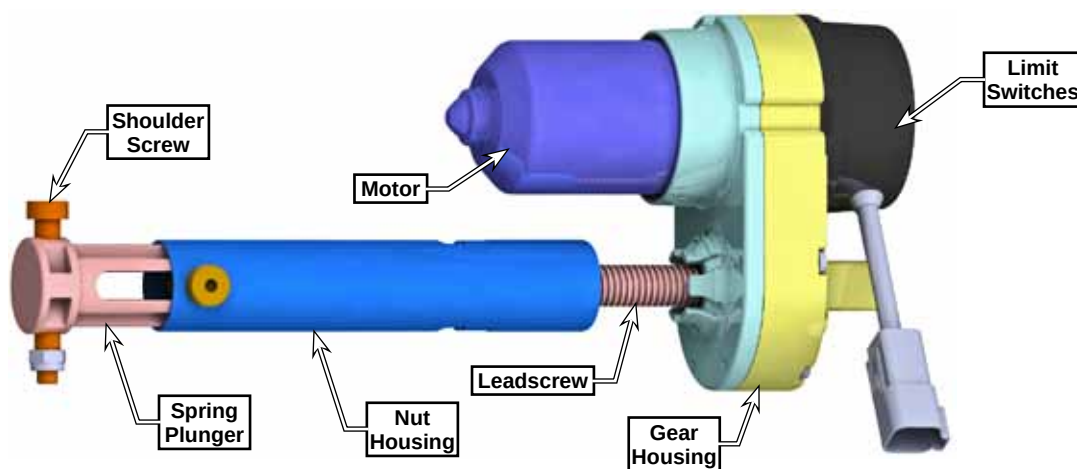
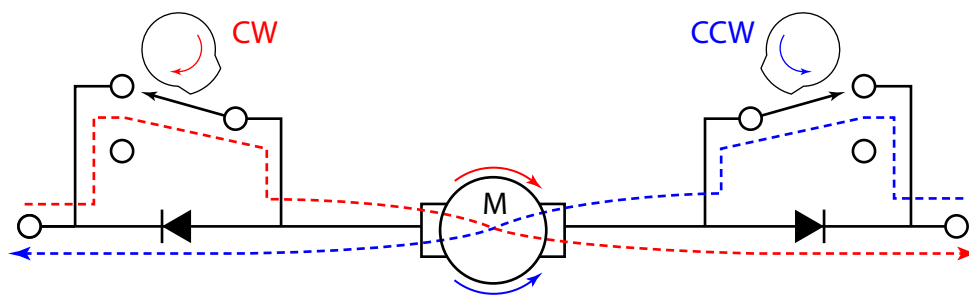
The 2 position switches don't directly control the actuator, but instead notify the Main Machine Controller that the actuator has reached the *Squeegee down* and *Deck Down* positions. The controller decides whether the actuator should be stopped or continue on to another height position.

The 2 limit switches directly control the operation of the actuator's motor, and prevent the actuator from operating beyond its upper and lower limit positions. An interesting aspect about these switches is that they are polarized, and impact the electrical circuit only for one electrical polarity. Each switch has a diode connected in parallel across the switch contacts, which electrically bypasses the switch for one polarity, but not the other.



When the actuator motor is being driven toward a limit switch, the switch opens, and interrupts power to the motor in that direction. However, when motor polarity is reversed, the diode conducts, and the motor is permitted to be driven away from that limit position.

Note: In the event of a diode failure, the motor would operate normally until it reached that limit, and then it would be completely disabled.

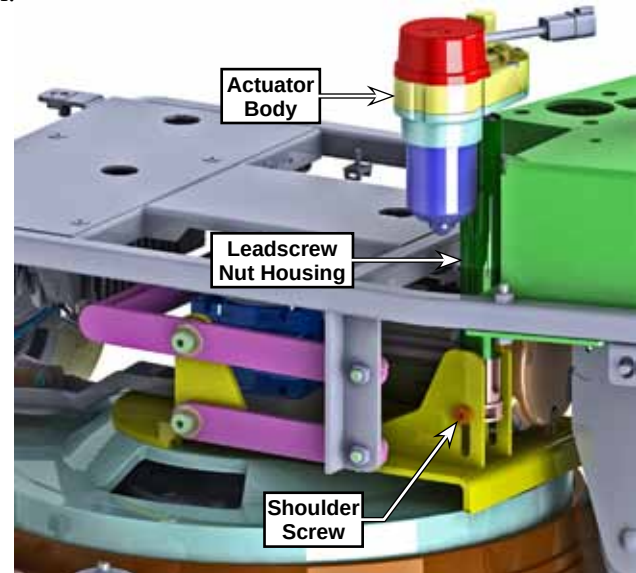


Maintenance and Adjustment

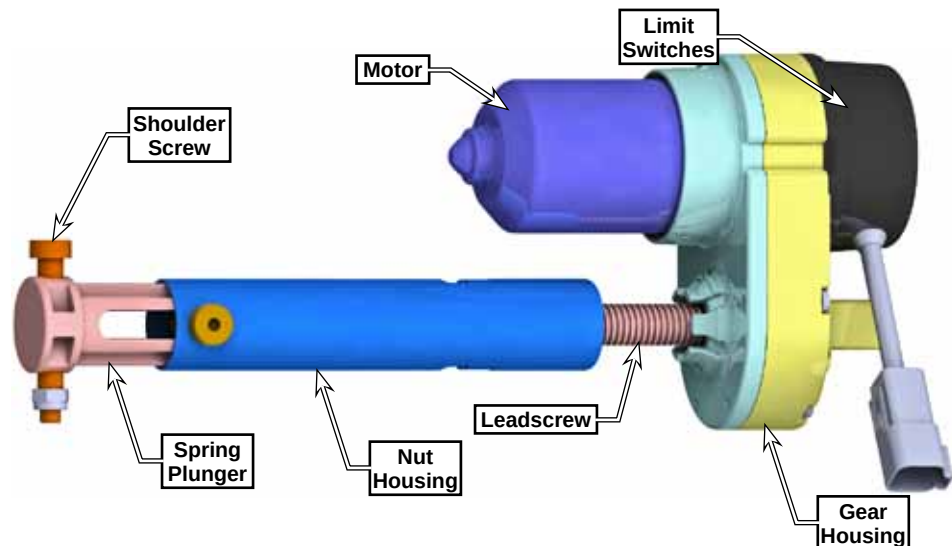
Scrub Deck Actuator Adjustment

The scrub deck actuator adjustment sets the position of the top of the nut housing when the actuator motor reaches the retracted limit. This represents a home-position, and all other extension positions are referenced from this home position. However, because the vacuum-only scrub deck position has the narrowest target range, it is used to verify the setting for the home position.

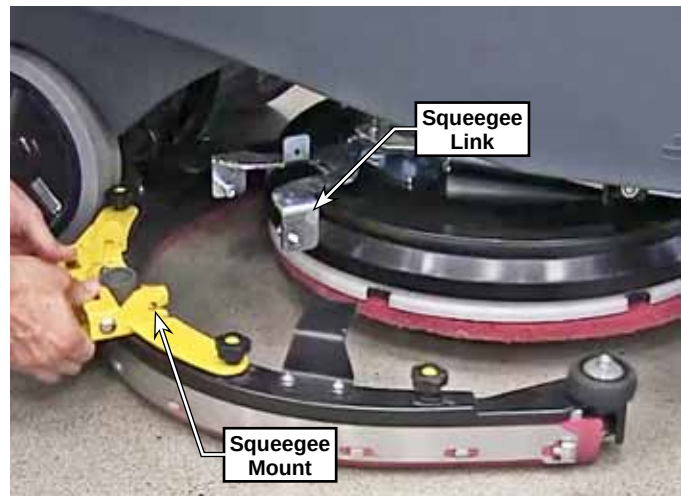
1. Remove the shoulder screw and nyloc nut that secures the bottom of the actuator to the scrub deck.
2. Drive the actuator motor to the up (fully retracted) position using service test mode or a jumper to the batteries.
 - When the nut housing gets close to the gear housing, allow the nut housing to turn a few times to ensure it will not bottom out against the gear housing.
3. Wait until the motor stops running due to the travel limit switch opening.
4. Manually rotate the nut housing toward the gear housing until it bottoms out, then unscrew the nut housing at least 1-1/2 turns, but no more than 2 turns, in order to align the mounting hole (shoulder screw) with the scrub deck.



5. Taking care to not rotate the nut housing, reattach the actuator to the scrub deck.



6. Remove the squeegee assembly from the scrub deck (squeegee link).
7. Rotate the squeegee link so it is pointing toward the rear of the machine (normal position when driving straight).
8. Stand on the operator platform and power the machine with Service Mode access.
9. Press the vacuum button to command the scrub deck to lower to the vacuum-only position.

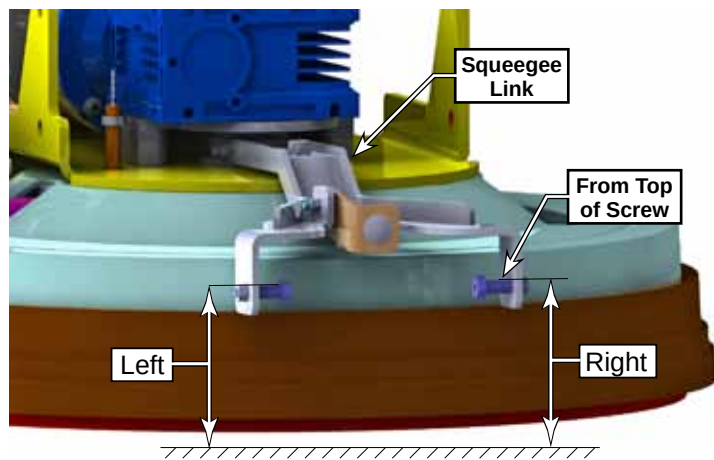


10. Measure the height of the squeegee pins (shoulder screws) from the floor.
 - Measure from the top of the shoulder, not the center.
 - Measure and record the height for both right and left shoulder screws.

11. If the two measurements are not the same, average the two.

$$\text{Average} = \frac{\text{Left} + \text{Right}}{2}$$

12. If the average of the heights is between 96 to 100 mm (3-3/4 to 3-15/16 inch), no further adjustments are necessary.



13. If the average of the heights is above or below the specified range, then adjust the nut housing as follows:

- a. Remove the shoulder screw connecting the actuator to the scrub deck.
- b. If the previous measurements were too low, “tighten” the nut housing to raise it.
 - Do not exceed 1-1/2 turns, or the nut housing will strike the gear housing at the home position.
 - Each 1/2-turn equals 2mm of travel.
- c. If the previous measurements were too high, “loosen” the nut housing to lower it.
 - Each 1/2-turn equals 2mm of travel.

14. Repeat steps 8 through 12 to verify the adjustment.

Troubleshooting

Most troubleshooting scenarios are error code driven. Refer to [Troubleshooting described on page 51](#) in the Controller chapter for error code tables. The scrub motor and deck actuator are controlled by the Power Module, which will report detectable errors such as motor shorts, open circuits, or overloads.

Uneven Cleaning Path

An uneven cleaning path typically indicates that the scrub deck is not applying equal down-pressure to all areas of the scrub deck. Depending on the type and severity, this may be more noticeable either in straight lines, sharp turns, or only standing still. A side-to-side imbalance would be more noticeable when driving in a straight line, while a front-to-rear imbalance would be more noticeable during sharp turns.

Because the deck lift actuator is acting on the right side of the scrub deck, there will be a slight increase in pressure on the right side of the deck, and this is normal. However, if there is an extreme difference between side-to-side or front-to-rear pressures, it is likely that the parallelogram linkage is slightly biased.

Causes

Minor skewing in the parallelogram linkage can be caused simply by the clearance between the pivot's shoulder screws and their respective holes. This can allow each pivot point in the parallelogram to be slightly off, and the linkage no longer perfectly parallel. If this is suspected, do the following:

1. Remove the scrubbing pad from the deck.
2. Manually lower the scrub deck to the floor, but with minimal down pressure.
3. Loosen all 8 pivot screws, and allow the scrub deck to rest naturally flat on the floor.
4. Retighten all 8 pivot screws.

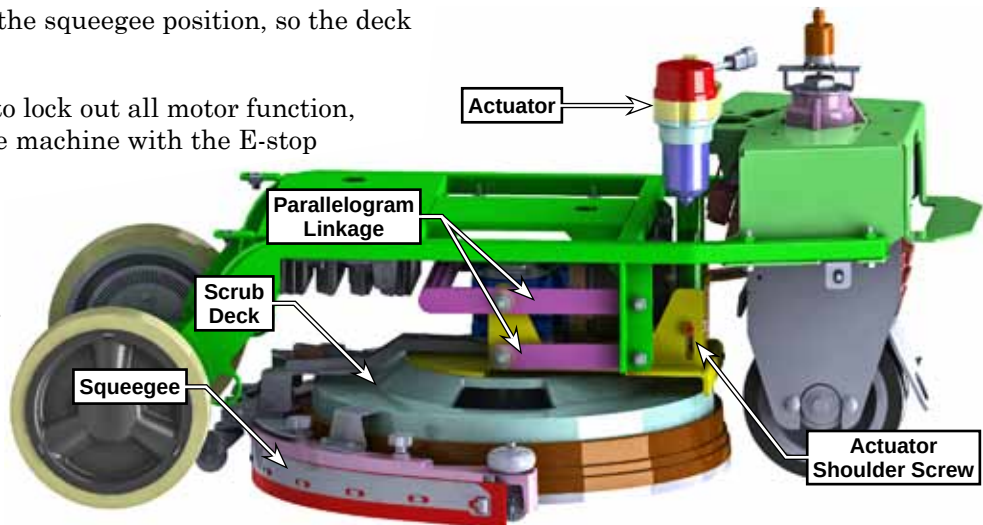
More significant skewing is likely the result of worn pivot bushings. While similar to the above, it can be more extreme due to greater clearances caused by wear.

1. Disassemble each of the 8 pivot points and examine the bushings, screws, and their clearance with the machine frame.
2. If any are found to be worn, replace them.
3. When reassembling the lift linkage, follow the procedure listed above with the scrub deck resting on the floor.

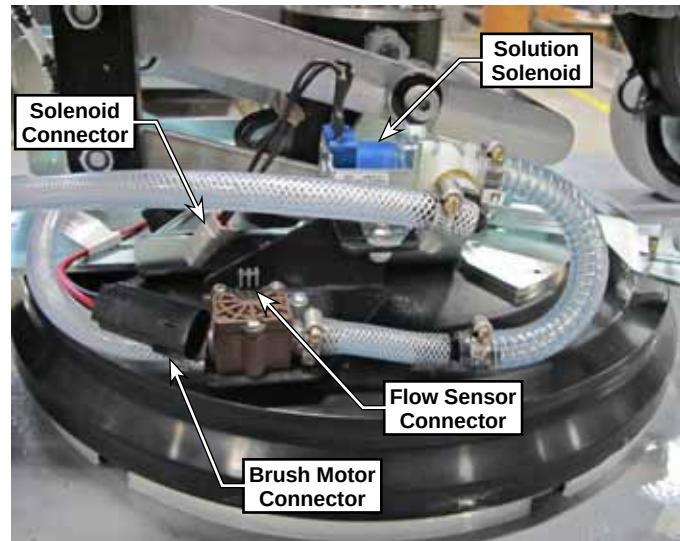
Removal and Installation

Scrub Deck

1. Drain both the recovery and solution tanks to reduce the weight of the machine.
2. Lower the scrub deck to the squeegee position, so the deck is slightly off the floor.
3. Press the E-stop switch to lock out all motor function, and then power down the machine with the E-stop depressed.
4. Wait for the Autonomous controller to power down (15 seconds after the dropoff sensors turn off), and then disconnect the main battery connector in the electrical bay.

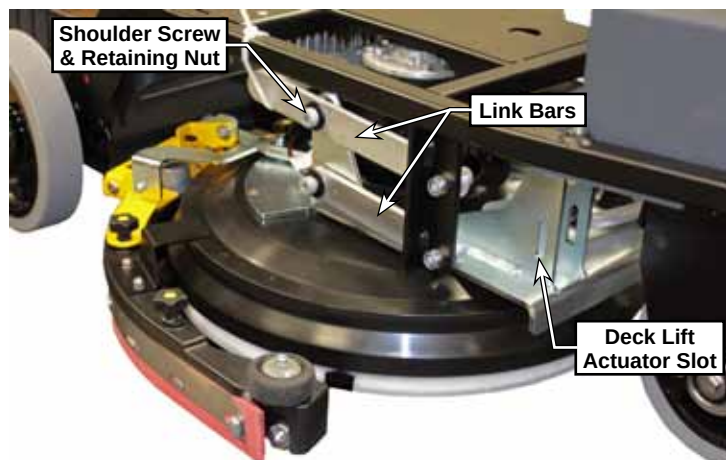


5. Disconnect the solution line from the solution solenoid, and the detergent hose from the solution fitting.
6. Disconnect the scrub brush motor, flow sensor, and solution solenoid.
7. Remove the Squeegee Assembly from the scrub deck.
8. Remove the shoulder screw and nut that attaches the deck lift actuator to the scrub deck.



Note: Make note of the rotational position of the actuator leadscrew housing (nut). Do not permit the housing to be rotated while the deck is disconnected.

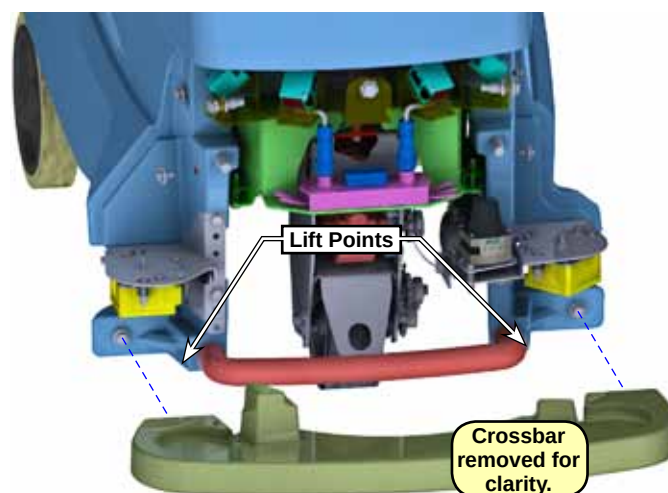
9. Remove the 4 shoulder screws and nuts that secure the parallelogram linkage to the scrub deck.



10. Chock the rear wheels to prevent the machine from moving.
11. Raise the front of the machine as necessary to slide the scrub deck out to the side.



Note: Lift the machine by the bottom of the recovery tank. Do not lift or support the machine by the crossbar. The crossbar is not designed to take the weight of the machine.

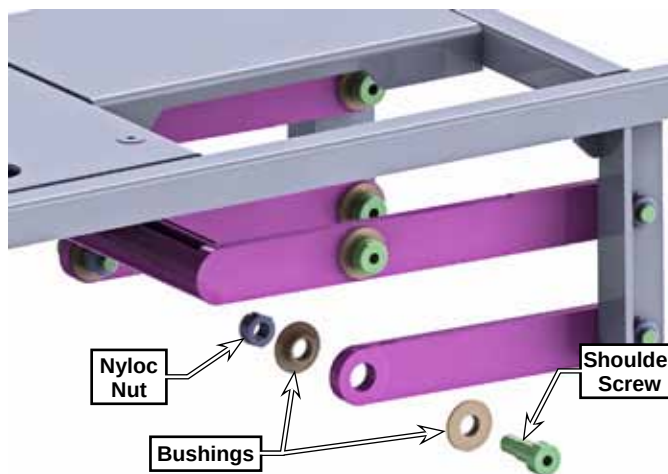


Replacement Notes



Note: If the deck lift actuator housing (leadscrew nut) was rotated while the deck was disconnected, then perform the [Scrub Deck Actuator Adjustment](#) described on page 325 before reassembling the machine.

1. Before inserting the scrub deck back under the machine, remove the scrub pad so that the deck will rest directly on the floor.
2. Insert the scrub deck back under the machine, and line up the parallel links with the deck.
3. If the machine was raised, lower it back down to resting on the floor.
4. Loosely install all 4 shoulder screws and nuts. Make sure the bushings are properly seated with their shank inside the bores of their link arms.
5. Make sure the scrub deck is resting flat on the floor, and the squeegee is not yet attached, nor the lift actuator.
6. Tighten all 4 shoulder screws, taking care to not apply any undue bias to the link arms in the process.
7. Reattach the deck lift actuator.
8. Reattach the squeegee.



CAUTION: Pinch hazard. Make sure personnel and tools are clear of the scrub deck before reconnecting the main battery disconnect. The scrub deck will be automatically raised when power is restored to the system.

9. Reconnect all fluid and electrical connections.
10. Reconnect the main battery disconnect, and release the E-stop switch.

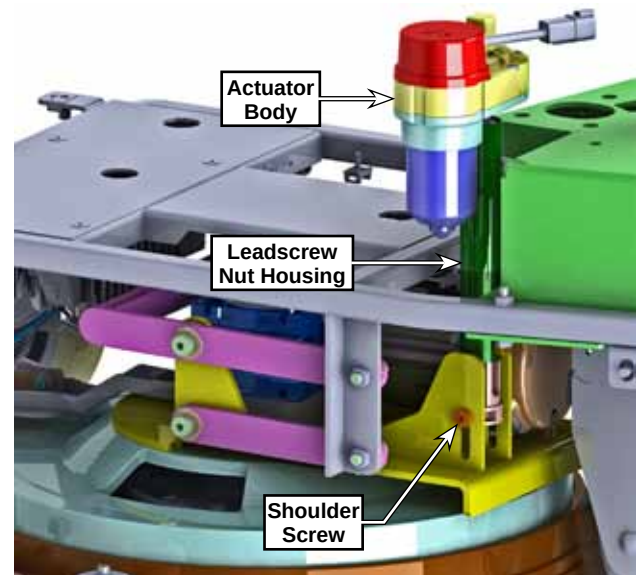
Scrub Deck Actuator Assembly

1. Drain the recovery tank.
2. Lower the scrub deck to the squeegee position, so the deck is slightly off the floor.
3. Press the E-stop switch to lock out all motor function, and then power down the machine with the E-stop depressed.
4. Wait for the Autonomous controller to power down (15 seconds after the dropoff sensors turn off), and then disconnect the main battery connector in the electrical bay.

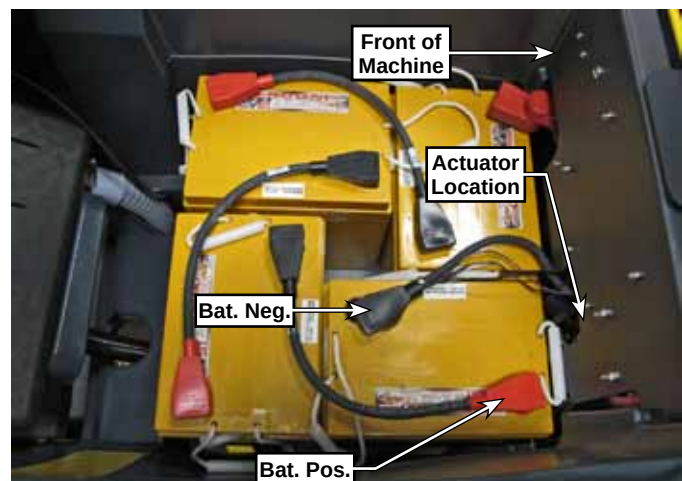


Note: If the actuator is non-functional, support the scrub deck from below to take the weight off while you disconnect the actuator in the steps below.

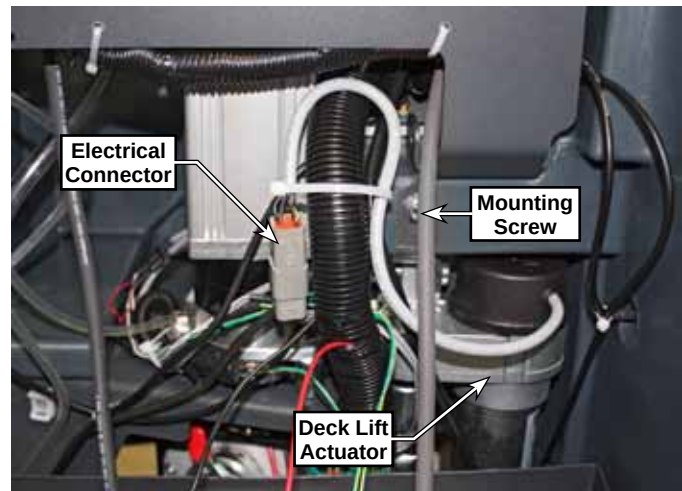
5. Remove the shoulder screw and nyloc nut that secures the bottom of the actuator to the scrub deck.
6. Using a cable tie, tape, or some other means, secure the leadscrew nut housing to the actuator body to prevent the nut housing from rotating while disconnected from the scrub deck.



7. Open the hood and recovery tank to access the battery bay.
8. Disconnect and remove the battery closest to the scrub deck actuator to get enough clearance to remove the actuator.



9. Disconnect the actuator electrical connector, and free up any necessary cable ties.
10. Remove the mounting screw that secures the actuator's mounting bracket to the solution tank, and remove the actuator up through the battery bay.



Replacement Notes



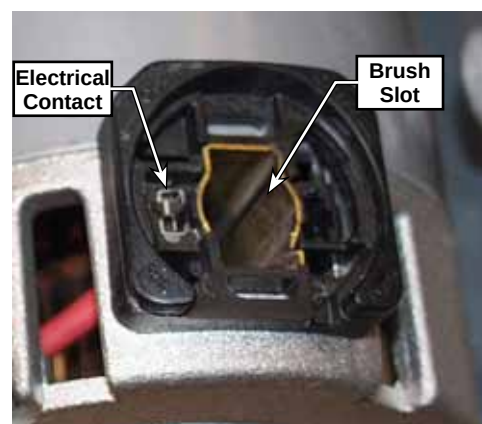
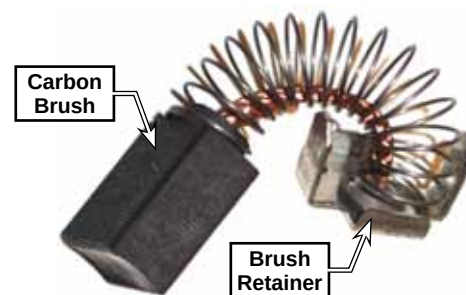
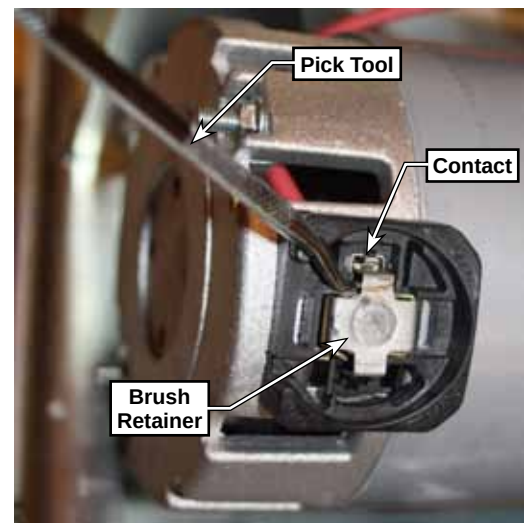
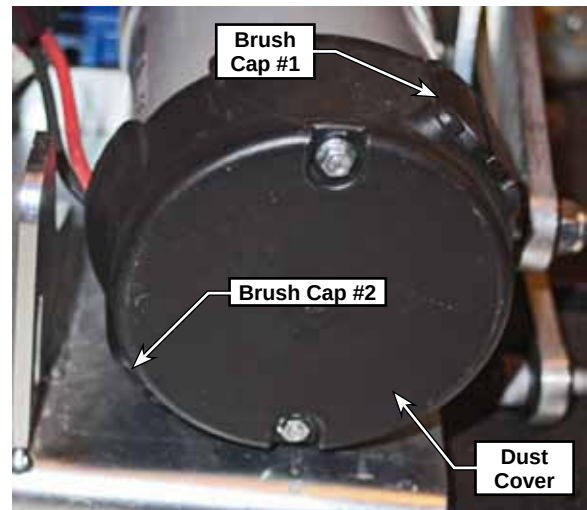
Note: If the deck lift actuator housing (leadscrew nut) was rotated while the deck was disconnected, then perform the [Scrub Deck Actuator Adjustment](#) described on page 325 before reassembling the machine.



CAUTION: Pinch hazard. Make sure personnel and tools are clear of the scrub deck before reconnecting the main battery disconnect. The scrub deck will be automatically raised when power is restored to the system.

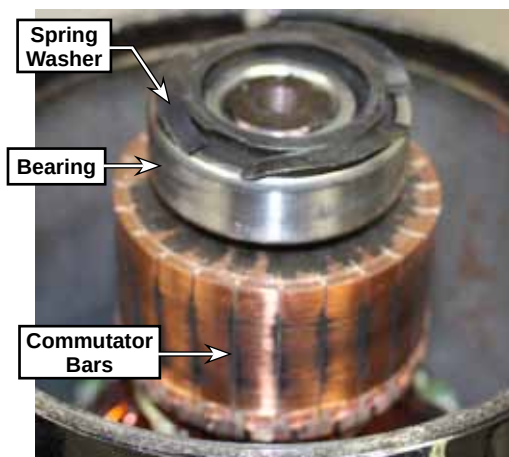
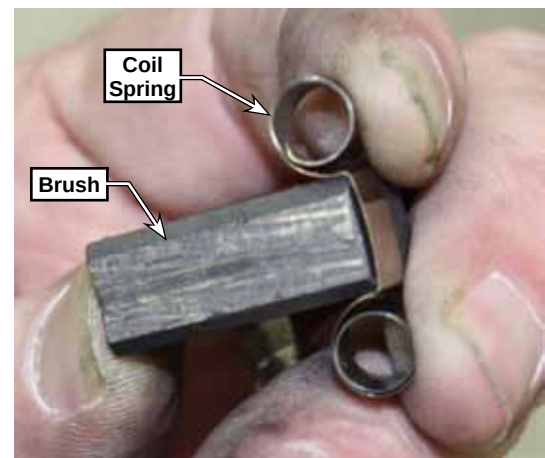
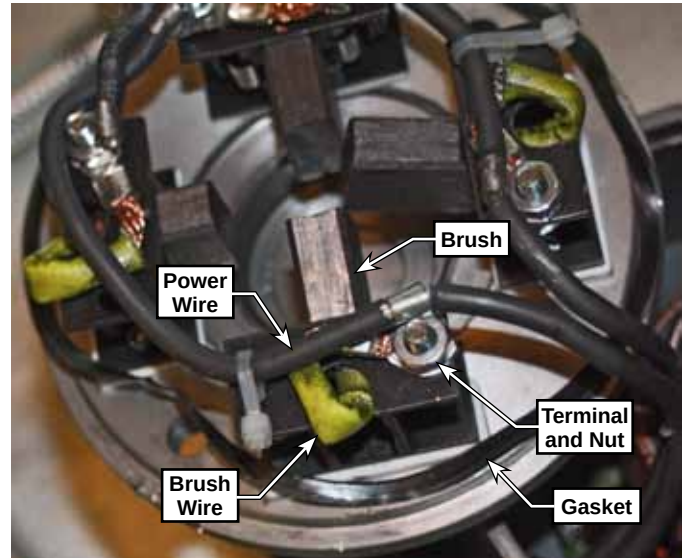
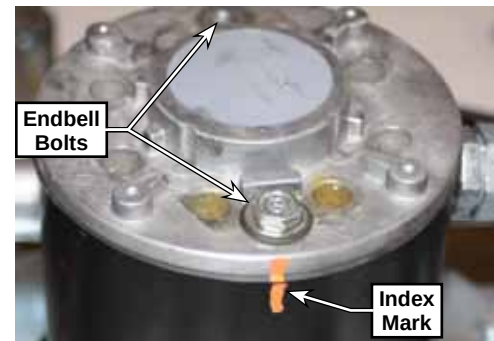
Motor Brushes (Disc Deck)

1. Remove the [Scrub Deck](#) described on page 328.
2. Rotate each of the 2 brush caps approximately 1/4-turn to unlock it, and remove the brush cap.
3. Using a small screwdriver or pick, gently pry up the brush retainer out of the electrical contact, and remove the brush from the motor.
4. Inspect the commutator bars for carbon build-up or damage.
 - a. Remove the 2 nuts that secure the dust cover to the end of the motor, and slide the cover off the motor.
 - b. If any commutator bars are damaged or missing, replace the motor.
 - c. If the commutator bars are blackened from arching, use fine emery cloth to polish the surface.
 - d. Replace the dust cover.
5. Slide the new brush into the slot, line up the retainer tab with the electrical terminal, and push the retainer into the terminal.
6. Replace the brush caps.
7. Reinstall the scrub deck.



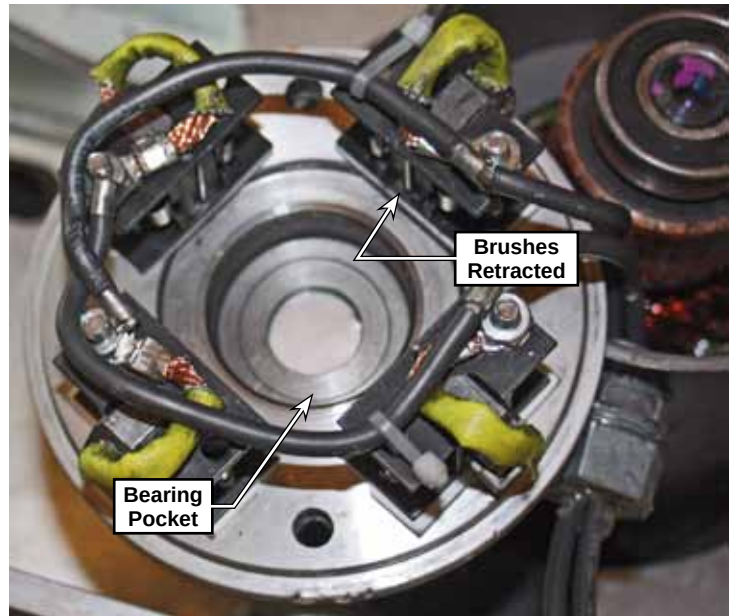
Motor Brushes (Rev Deck)

1. Remove the [Scrub Deck](#) described on page 328.
2. Using tape or marker, place an index mark on the motor and endbell for reassembly placement.
3. Remove the two long bolts that secure the endbell through the motor.
4. Evenly pry up the endbell off the motor.
 - Note that the end bell is a slip-fit press on the bearing, so it is important to lift it off evenly.
 - Take care to not damage the gasket between the endbell and motor housing.
 - Take care to not lose the spring washer from the top of the bearing.
5. One at a time, replace each of the 4 brushes.
 - a. Remove the nut securing the brush wire to the electrical terminal.
 - b. Lift off the power wire and brush wire from the terminal screw.
 - c. Slide the brush toward the center to remove it from the brush holder.
 - d. Make sure the coil spring is oriented as shown, and install the coil spring and new brush into the brush holder.
 - e. Reinstall the power wire and brush wire, and secure them with the retaining nut.
6. Inspect the commutator bars for carbon build-up or damage.
 - If any commutator bars are damaged or missing, replace the motor.
 - If the commutator bars are blackened from arcing, use fine emery cloth to polish the surface.

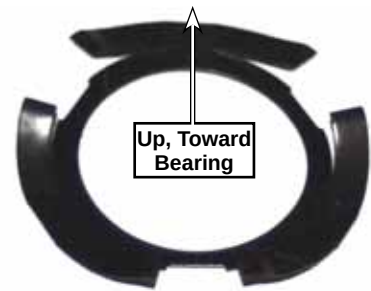


7. Retract all 4 brushes into their holder, and insert a pin or paper clip through the holes in the endbell to hold the brushes retracted.
8. Place the spring washer inside the bearing cup of the endbell, and use a strong magnet to hold it in place. The inner circular ring faces toward the endbell, and the outer spring tabs face toward the bearing.
9. Place the gasket around the flange of the endbell.

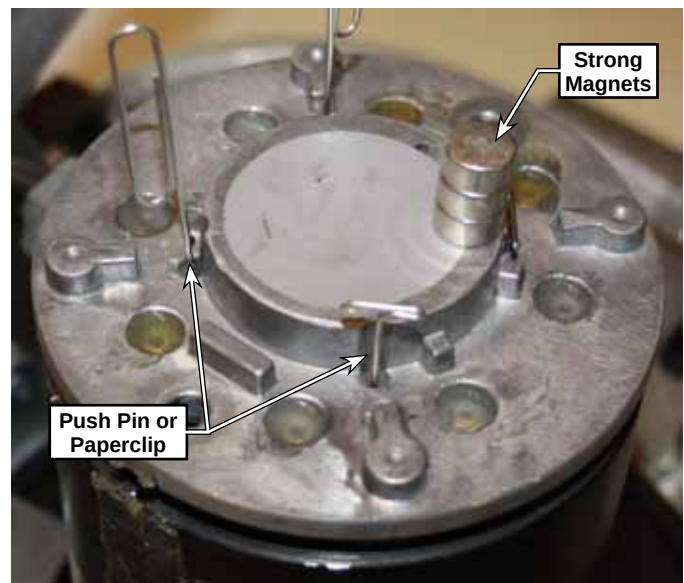
- Hint: If the gasket does not want to stay in place, wait until the endbell is almost fully seated over the motor, and then put the gasket in place between the endbell and motor housing. Make sure the gasket is not twisted.



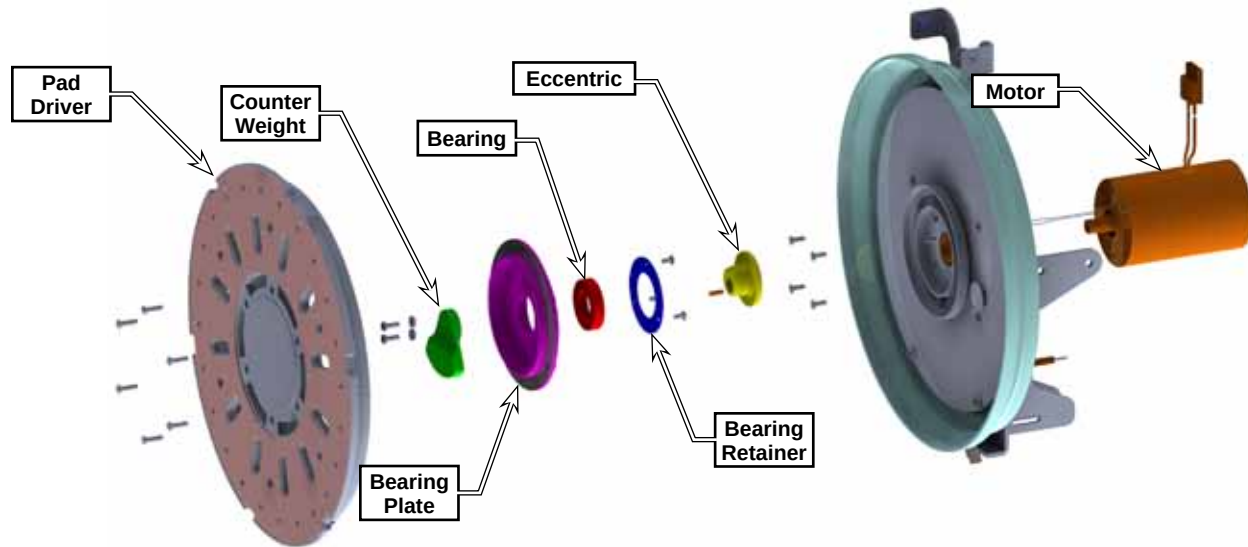
10. Line up the index mark on the endbell and motor housing, and begin seating the endbell over the shaft bearing.
 - If the outer edges of the brushes interfere with the motor housing, retract the pins/paperclips halfway out to allow the brushes to move inward slightly.
 - Once the brushes are at least 1/3 below the height of the motor housing, the pins may be removed.
 - Press the endbell down evenly over the bearing, without tilting it or skewing it.



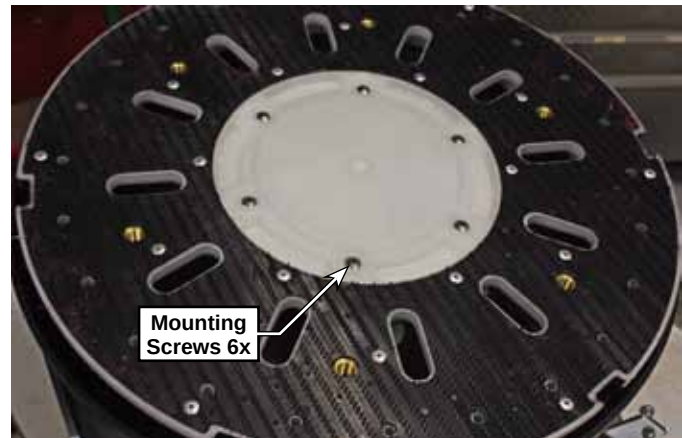
11. Remove the 4 pins/paperclips and the magnet.
12. Reinstall the 2 long bolts that secure the endbell.



Rev Deck Bearing and Motor



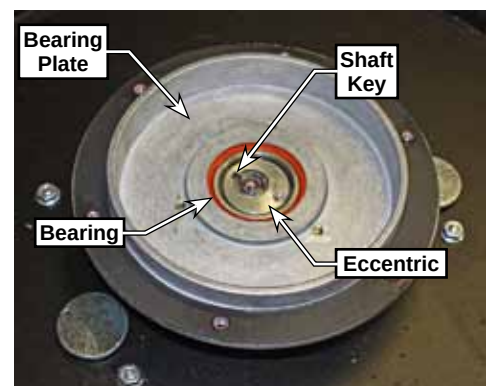
1. Remove the [Scrub Deck](#) described on page 328.
2. Remove the 6 screws that secure the pad driver to the bearing plate, and remove the pad driver.
 - During replacement, use Loctite 243 on the screws and torque them to 40 in-lb (4.5 Nm)



3. Remove the 2 screws that secure the counter weight to the motor shaft and to the eccentric, and remove the counter weight.
 - During replacement, use Loctite 243 on the screws and torque the screws to 62 in-lb (7 Nm).



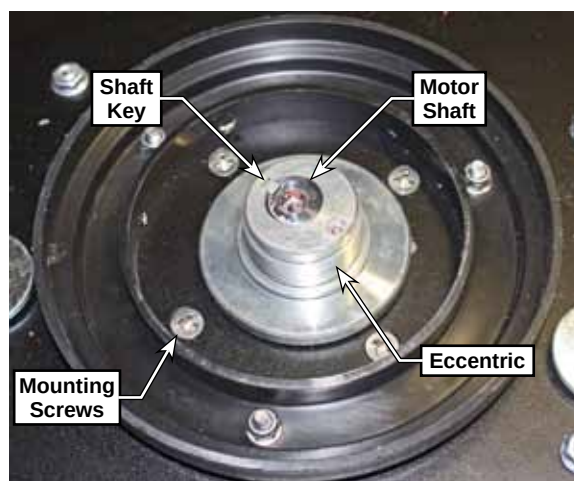
4. Remove the bearing plate (with bearing), the eccentric, and the shaft key.
 - During replacement, apply a small amount of anti-seize to the motor shaft before installing the eccentric.
 - Make sure the key is properly installed.



5. Turn the bearing plate over, remove the 3 screws that secure the bearing retainer to the bearing plate, and remove the retainer.
6. The bearing is a light press fit into the bearing plate. Press the bearing out to remove it.
 - During replacement, make sure to not skew the bearing while pressing it into the bearing plate.



7. Remove the 4 screws that secure the motor to the Rev Deck, and remove the motor.
 - During replacement, use Loctite 243 on the screws and torque them to 96 in-lb (10 Nm).
 - The motor wires should be exiting on the left side of the machine.



Specifications

Component	Specifications		
Brush Motor Amp Draw	Disc	13-17 AMPS	Red pad, sealed concrete floor, maximum pressure, high solution flow, stationary, 24±1 VDC, allow time for current to stabilize.
	Rev	13.5-20.5 AMPS	
Deck Actuator	Down Force	Normal: 75 ± 4 Lbs	
		Full: 88 ± 4 Lbs	
	Amp Draw	No Load: 1.8 Amps	
		Full Load: 7.0 Amps	

38-Squeegee System

Functional Description

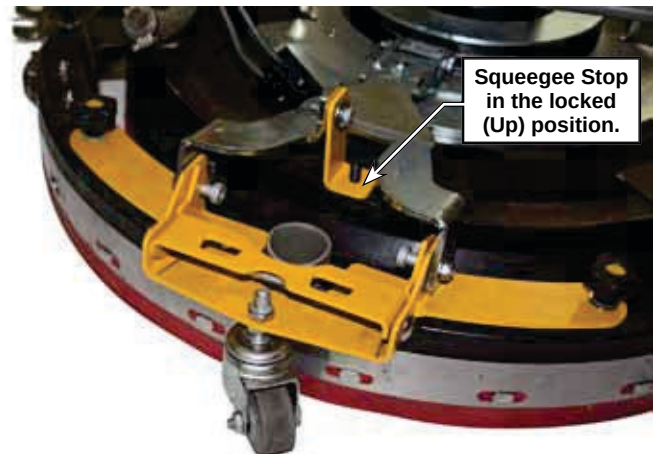
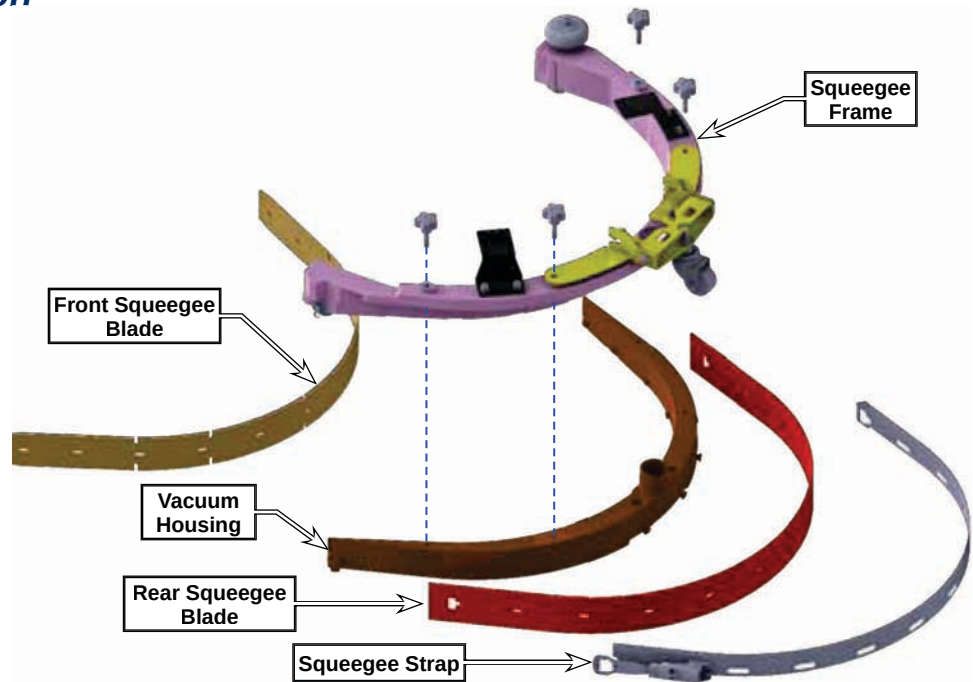
The squeegee assembly mounts directly to the scrub deck, and as such, does not require a separate lifting mechanism like many other systems. It also mounts concentric to the scrub deck, which results in better squeegee tracking during turns.

Friction between the squeegee and the floor causes the squeegee to always track behind the scrub deck, regardless of the direction the scrub deck is traveling, including during turns.

The squeegee can be used for 3 modes during cleaning operation: Scrub and

Squeegee, Squeegee Only, and Scrub Only. For squeegee-only operation, the scrub deck is raised slightly so that the squeegee remains in contact with the floor, but the scrub deck is just above the floor. In scrub-only operation, the squeegee stop is manually engaged to hold the squeegee off the floor.

As the machine travels forward, the squeegee blades deflect rearward (radially outward around the whole curve), which permits the squeegee blade to seal better against contours in the floor. The squeegee frame contains 3 wheels that prevent the squeegee frame from lowering too far as the squeegee blades deflect back. This determines the maximum deflection of the squeegee blade. The rear caster wheel can be adjusted up and down to align the front and rear squeegee blades parallel to the floor surface.



Maintenance and Adjustment

Squeegee Blade Replacement

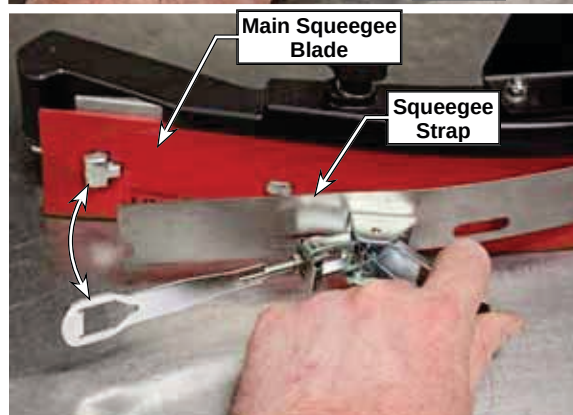
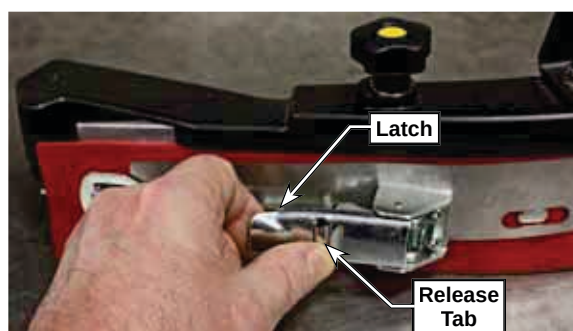
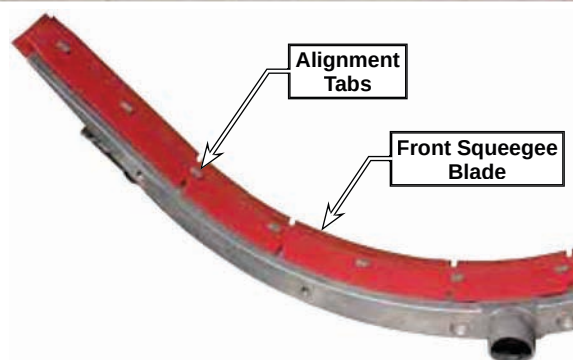
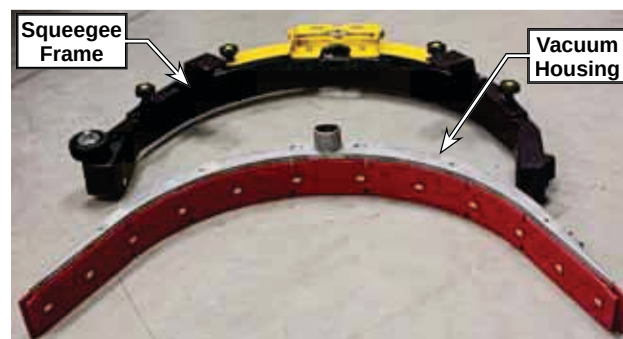
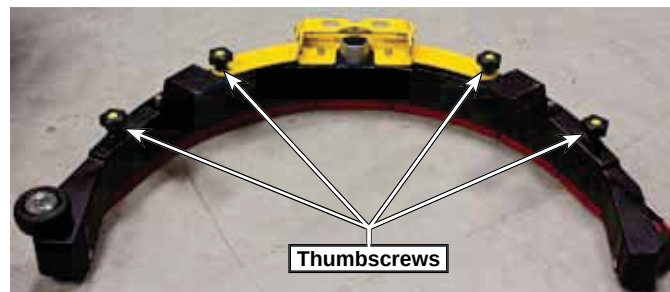
Each squeegee blade has 4 usable edges before the blade needs to be replaced. When an edge becomes worn, the blade can be rotated front-to-rear or top-to-bottom to expose a new, fresh edge to the lower-front position.

1. Remove the squeegee assembly from the machine.
2. Unscrew the 4 thumbscrews that secure the vacuum housing to the squeegee frame, and remove the vacuum housing.
3. Lift the front squeegee blade off the alignment tabs.
4. As appropriate, either replace the squeegee blade with new, or rotate the squeegee blade top-to-bottom or front-to-rear to present a new edge to the floor.
5. Install the squeegee blade onto the alignment tabs. Make sure the blade is straight and without ripples.
6. Reinstall the squeegee frame.



Note: It is best to have the squeegee frame installed when replacing the main squeegee blade, because the frame will act as a straightedge for positioning the squeegee blade onto the vacuum housing.

7. Press in on the release tab, and open the latch on the main squeegee blade strap.
8. Remove the strap, and remove the squeegee blade.
9. Inspect and clean the air channels in the vacuum housing. As necessary, you may remove the channel inserts for cleaning.
10. As appropriate, either replace the squeegee blade with new, or rotate the squeegee blade top-to-bottom or front-to-rear to present a new edge to the floor.
11. Install the squeegee blade onto the alignment tabs.
 - Bias the squeegee blade up against the squeegee frame to ensure the blade is straight and without ripples.
12. Reinstall the squeegee strap.



Troubleshooting

Problem	Cause	Comments
Poor water pick-up.	Vacuum Leak	• Inspect the seal on the recovery tank cover. Make sure the machine hood is closed completely, and straight. • Inspect the suction hose for tears and holes. • Inspect the squeegee blade edges for cuts or tears. • Inspect the drain hose for leaks or a loose cap.
	Poor Airflow	• Inspect and clean the recovery tank filter. • Inspect the suction hose for blockage. • Inspect and clean the air channels in the squeegee vacuum housing.
Streaks	Squeegee not in full contact with the floor	• Check the squeegee blade for nicks or tears. • Make sure the squeegee blade is installed straight, without ripples.

40-Recovery System

Functional Description

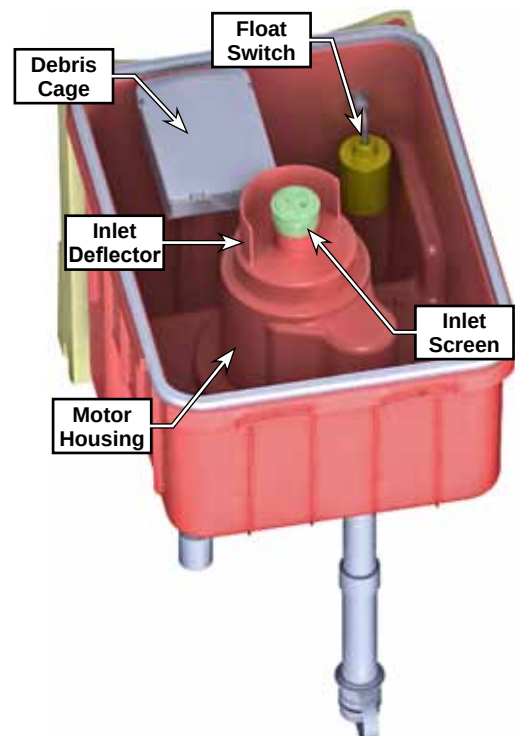
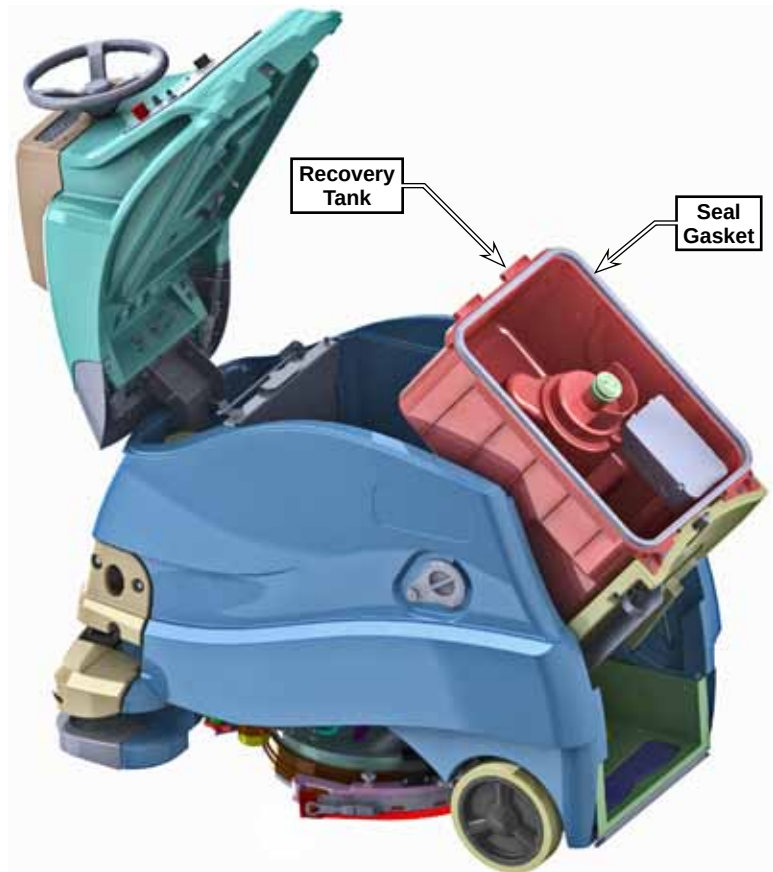
The Recovery System pulls the wastewater from the squeegee and directs it into the recovery tank. The 24-volt, three-stage electric vacuum motor creates a vacuum in the recovery tank with sufficient airflow to lift the fluids from the squeegee and into the vacuum hose, which then directs the water into the recovery tank.

The functionality of the recovery system depends on the seal integrity of the vacuum system. The operation of the vacuum motor produces a reduced pressure inside the recovery tank. Because this reduced pressure is below atmospheric pressure outside of the machine (specifically the squeegee), air will flow from the high pressure area at the squeegee to the low pressure area of the recovery tank. Any leaks in the system's seal integrity will reduce this pressure differential, and therefore, the air flow.

The vacuum motor is designed to operate in a non-wetted environment. Meaning ingestion of liquid water is to be avoided. Several features of the system design are incorporated for this purpose.

- An inlet screen protects the vacuum motor inlet from debris.
- The inlet deflector forces the incoming air flow to turn sharply before reaching the vacuum inlet, and this causes water droplets to fall out of suspension from the air flow.
- The debris cage captures large particles from the air flow before they reach the interior of the recovery tank.
- The float switch detects when the recovery tank is full, so that the vacuum can be turned off before the water level can reach the vacuum inlet.

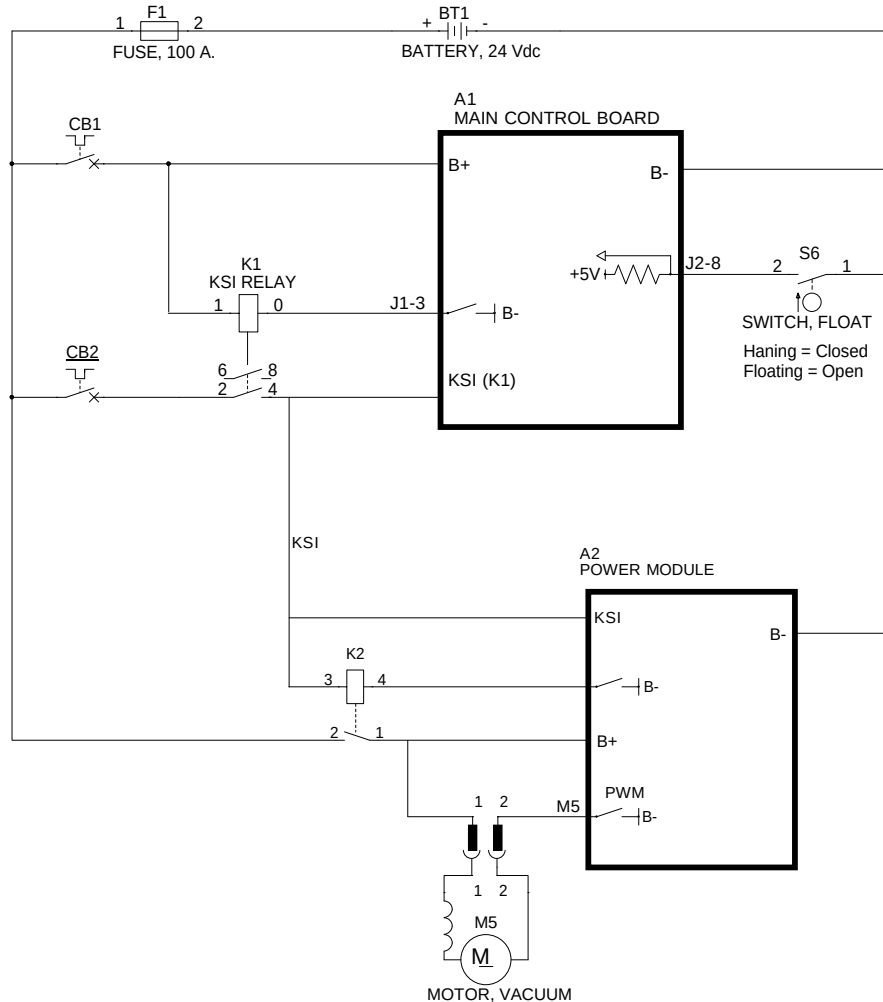
The float switch is a mechanical switch sealed inside of a buoyant housing. When the float switch housing hangs downward from its cord, the mechanical switch inside remains open. When the water level in the recovery tank gets high enough to float the housing to a horizontal position, a steel ball rolls toward the mechanical switch, activates the switch's lever, and closes the switch's contacts.



Circuit Description

The float switch connects directly to the main control board. When the water level is low and the float is hanging, the switch is closed, and the controller sees this as a low voltage. When the water level is high and the float is horizontal, the switch opens, and a pull-up resistor causes the control board to see this as 5-volts.

The vacuum motor is powered from the power module. Positive power passes through the K2 relay, which the power module energizes. To activate the vacuum motor, the power module closes the circuit to battery negative. The magnitude of the power delivered to the motor is determined by the Pulse Width Modulation (PWM) duty cycle of the battery negative signal.



Troubleshooting

Most troubleshooting scenarios are error code driven. Refer to [Troubleshooting described on page 51](#) in the Controller chapter for error code tables. The vacuum motor is controlled by the Power Module, which will report detectable errors such as motor shorts, open circuits, or overloads.

General Troubleshooting

Problem	Cause	Diagnostics
The recovery tank is not reporting full when the tank is full.	Float switch not functioning, is disconnected, or a short circuit in the wiring. Note that the float switch is sealed and not repairable.	1. Turn off the machine. 2. Gently shake or tilt the float to check if the steel ball is stuck. – Replace the float if the ball remains stuck. 3. Fill the recovery tank or other suitable container with water, and check if the float remains buoyant. – Replace the float if it has lost buoyancy. 4. Prop the float switch up, above the horizontal position. 5. Disconnect the float switch electrical connector. 6. Check the resistance between contacts 1 and 2 of the float switch connector. – If the resistance is at or near 0 ohms, replace the float switch. 7. Disconnect the J2 connector from the main control board. 8. Check continuity between contact J2-8 and contact 2 of the float switch harness connector. 9. Check continuity between contact 1 of the float switch harness connector and the ground lug in the electrical bay. – If either circuit is closed, repair or replace the wiring harness. 10. Reconnect all connectors and validate any repairs.

Problem	Cause	Diagnostics
The recovery tank is reported full when empty	Float switch not functioning, or an open circuit in the wiring. Note that the float switch is sealed and not repairable.	1. Turn off the machine and drain the recovery tank. 2. Gently shake or tilt the float to check if the steel ball is stuck. – Replace the float if the ball remains stuck. 3. Make sure the float is dangling vertically from its pendant cord. 4. Disconnect the float switch electrical connector. 5. Check the resistance between contacts 1 and 2 of the float switch connector. – If the resistance is not at or near 0 ohms, replace the float switch. 6. Disconnect the J2 connector from the main control board. 7. Check the resistance between contacts 1 and 2 of the float switch harness connector. – If the resistance is not at or near 0 ohms, repair or replace the main harness between the main control board and the float switch. 8. Reconnect all connectors and validate any repairs.
Poor water pickup.	Vacuum leaks due to: • Leaky vacuum hose. • Bad recovery tank gasket. • Drain plug not installed correctly. • Damaged tank. • Torn squeegee blades Flow restrictions due to: • Debris in the squeegee's vacuum housing. • Debris in the vacuum hose.	1. Inspect and clean the recovery tank gasket and the sealing surface of the machine hood. 2. Inspect and clean the debris cage in the recovery tank. 3. Inspect and clean the inlet screen above the vacuum motor. 4. Make sure the machine hood is closing straight and properly, with an effective seal. – With the vacuum running, the hood should be difficult to lift open. 5. Make sure the cap on the drain hose is secured and with a good seal. 6. Remove the squeegee. a. Inspect and clean the air flow channels in the vacuum housing. b. Inspect and clean the squeegee blades. Rotate or replace as necessary. 7. Inspect the vacuum hose for cuts, holes, or internal obstructions. 8. Perform the Vacuum Suction Test described on page 345.

Vacuum Suction Test

Use this procedure to verify that the vacuum system is performing within factory specifications. This procedure can also be used to isolate the cause of a vacuum problem between a clog or leak. It is a two-part procedure that verifies both static pressure and flow rate. This procedure requires a vacuum gauge (PN 56205281), a piece of 1" PVC (or similar) tube, a 1" hole saw, and some duct tape (or similar, for a seal).

1. Remove the suction hose (A) from the squeegee and then turn on the vacuum.
2. Place the vacuum gauge (B) on the hose so the taper (C) seals against the end of the hose.
3. Record the vacuum pressure reading from the gauge. This is the static pressure.
4. Turn the vacuum off while constructing and fitting the PVC restrictor tube (D).
5. Cut a piece of 1" PVC approximately 6" long, and clean off the burs. .
6. Drill a 1" hole (E) approximately in the middle of the PVC tube, and clean off the burs.



Note: 1-inch PVC pipe has an O.D. of 1.315", but the vacuum hose has an I.D. of 36mm. Use duct tape to make the pipe O.D. larger to fit.

7. As necessary, wrap duct tape around the tube so it fits snugly in the end of the end of the suction hose with no leaks.
8. Turn the vacuum on and place the vacuum gauge on the restrictor tube.
9. Record the vacuum pressure reading from the gauge. This is the restricted flow pressure.



Results Summary

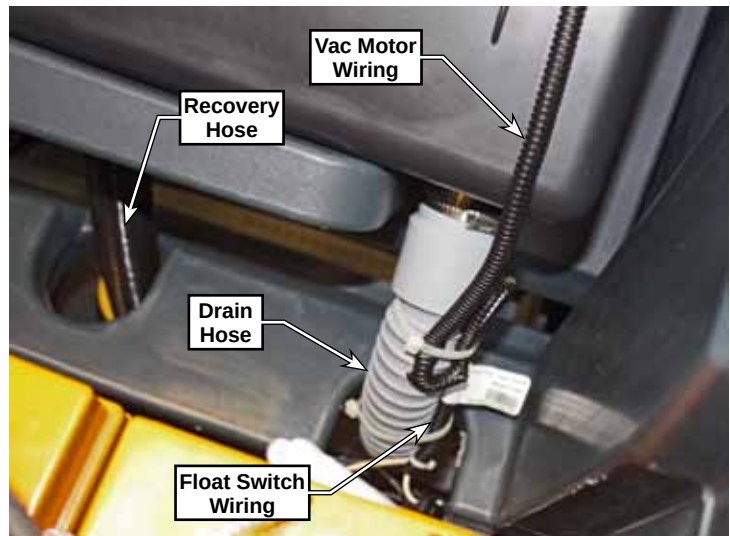
The first part of this procedure determined the static pressure of the vacuum system, and the second part determined the flow rate (by calculation). The flow rate through a restriction is determined by the pressure differential across the restriction. These two parameters may be used to determine if the vacuum system is functioning properly, and may also be used to isolate a possible cause for a problem.

- If the static pressure is at least 50 inches H₂O, then the vacuum motor is functioning properly and there are no significant leaks in the system.
- If the 1" restricted flow pressure is at least 10 inches H₂O, then there are no significant clogs in the system.
- If both parameters are below specifications, then the vacuum motor may be failing, or there may be a significant leak in the system.

Removal and Installation

Recovery Tank

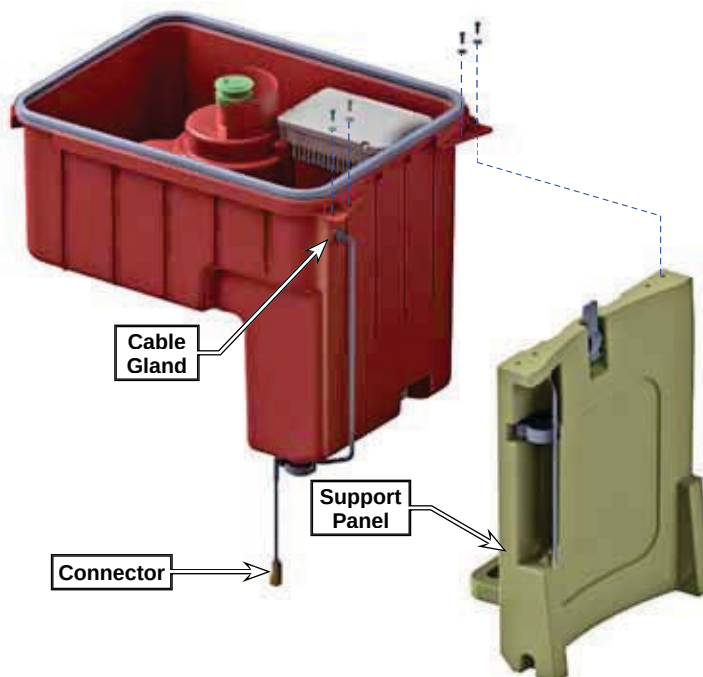
1. Drain the recovery tank. You may also want to rinse the tank and flush clean water through the hoses.
2. Disconnect the vacuum motor and float switch electrical connectors located below the left side of the machine.
3. Cut any cable ties as necessary to free the wires up to the bottom of the recovery tank.
4. Disconnect the recovery hose from the squeegee.
5. Release the drain hose from its hanger.
6. Tilt the recovery tank open, and lift it off the pivot posts on the solution tank.
7. Free up the suction and drain hoses as necessary to lift the recovery tank free of the machine.



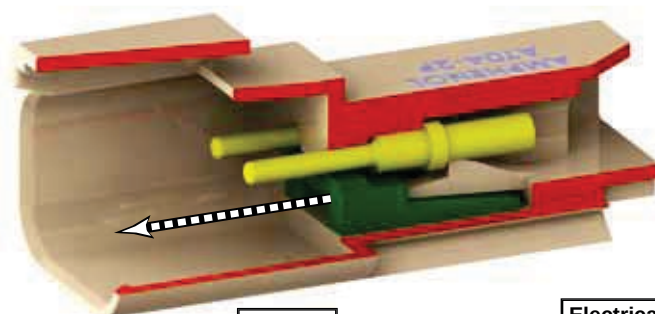
Recovery Tank Float Switch

In order to remove the float switch from the recovery tank bulkhead, you will need to disassemble the electrical connector. This will require a tool with a small hooked end.

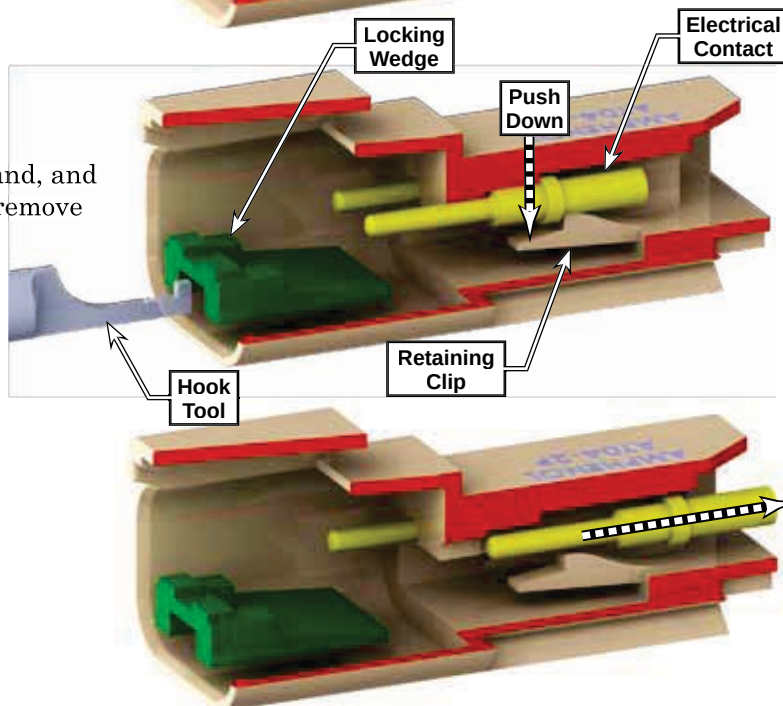
1. Remove the [Recovery Tank](#) described on page 346.
2. Place the recovery tank on a workbench.
3. Remove the 4 screws and washers that secure the recovery tank to the rear support panel.
4. Lower the support panel to remove it from the recovery tank.



5. Using a small hook tool, carefully pull out the locking wedge from the electrical connector.
6. Using a small screw driver (or the hook tool), press down on the retaining clip that holds the electrical contact into the connector shell.
7. While holding the retaining clip down, gently pull back on the wire until the contact is free from the connector shell.
8. Repeat for the second contact.



9. Remove the outer nut from the cable gland, and pull the cable into the recovery tank to remove the float switch.

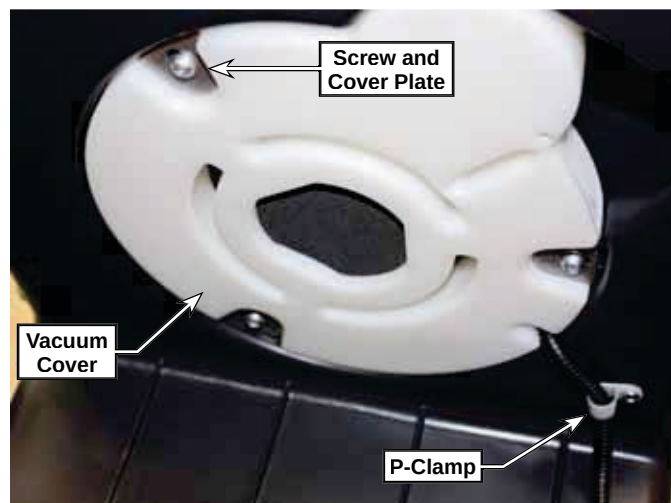


Vacuum Motor

1. Drain the recovery tank and raise it to access the vacuum motor.
2. You may choose to remove the P-clamp to provide more slack in the wiring until the electrical connector near the motor can be unplugged.
3. While supporting the vacuum cover, remove the three T25 Torx Screws and Cover Plates.



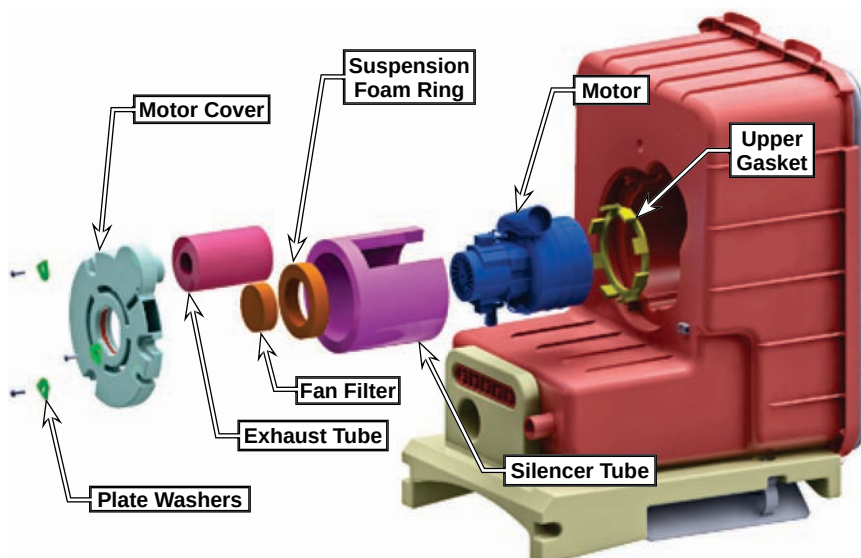
Note: The torx screws are thread-forming shanks for plastic. Do not over torque the mounting screws on reassembly. Torque the three screws to 3 NM (26 in lb)



4. Lower the vacuum cover and vacuum motor out of the recovery tank.

5. Disconnect the electrical connector for the vacuum motor, and remove the motor from the machine.

6. Separate the motor from the sound attenuation foam, as shown in the exploded view to the right.

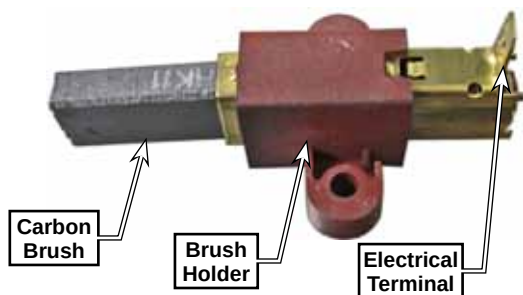
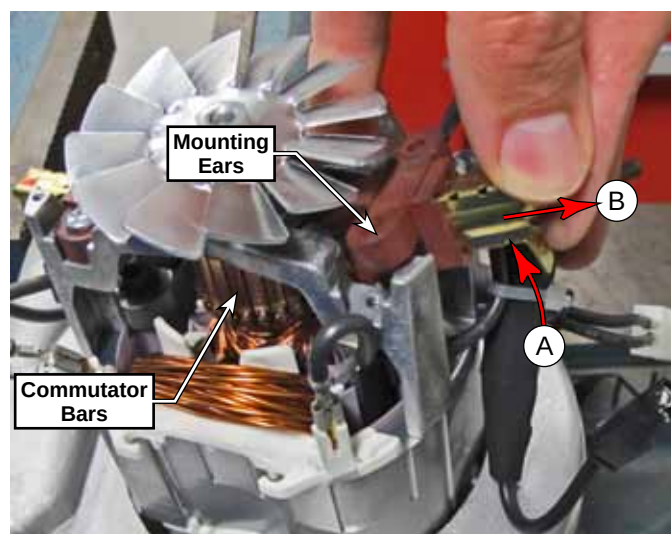
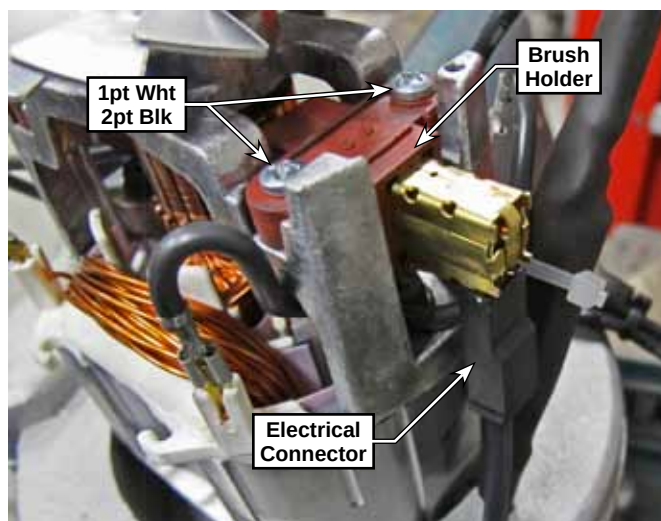


7. As necessary, clean the foam components with soapy water. Make sure to thoroughly rinse and dry the foam before reassembly.

8. Inspect and clean the interior baffles of the motor cover. As necessary, clean with soapy water. Make sure to thoroughly dry before reassembly.

Vacuum Motor Brushes

1. Remove the [Vacuum Motor](#) described on page 348.
2. Remove the two screws that secure the fan cover to the motor, and remove the cover.
3. Disconnect the electrical connector from the brush holder.
4. Remove the two screws that secure the brush holder to the motor housing.
5. Remove the brush holder:
 - a. Tilt the brush holder up until the mounting ears clear the motor housing.
 - b. Pull the brush holder away from the commutator, and remove the brush holder.
6. Inspect the commutator for damaged or missing bars. Replace the motor if any bars are damaged or missing.



Specifications

Component	Specifications	
Vacuum Water Lift	Sealed	39 Inches of Water, Minimum
	1" open hole	8 Inches of Water, Minimum

Special Tools

Vacuum Pressure Gauge
part number 56205281



1-inch open hole adapter
Fabricated from PVC

