User Manual

Segway® Robotics Mobility Platform

RMP 220 V3

SEGWAY Robotics

STANLEY INNOVATION

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Copyright, Disclaimer, Trademarks, Patent, and Contact Information

Disclaimer

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Segway Patent Information

The Segway RMP is covered by U.S. and foreign patents. For a patent listing, see *http://rmp.segway.com/RMPPatents.pdf*

Contact Information

For support, please contact Stanley Innovation or use the RMP forum at *http://rmp.segway.com/forum*

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Introduction

The RMP 220 V3 incorporates Stanley Innovation's Robotics Mobility Platform V3 (RMP V3) hardware and software improvements on top of the Segway RMP platform. The result is a product that starts with the robust and durable Segway RMP chassis and adds features to provide greater versatility and ease-of-use.

Utilizing advanced electric drive, high quality lithium batteries, drive-by-wire control, and dynamic stabilization, these mobility systems are ready to tackle the toughest challenges. The integration of the Robot Operating System (ROS) navigation and behavior system allows for advanced behaviors such as mapping and navigation.

The RMP V3 utilizes a robust Ethernet protocol which allows seamless integration of IP radios. The system also has provisions for a software update over USB so the RMP V3 can be updated whenever new code is released.

This manual describes the hardware and capabilities of the RMP V3. A separate communications manual describes the individual messages sent to and from the platform, however, thanks to our ROS drivers most users will not have to dive that far into the system. ROS allows for much higher level command and control so users can avoid packing bits into an Ethernet packet.

Stanley Innovation should be your first point of contact if you have any questions or concerns with your platform. You can reach us on our website at *http://stanleyinnovation.com/contact-us/*.

Additional Information

More information on the RMP V3 can be found in the following documents and web pages:

- *http://wiki.ros.org/Robots/RMPv3* — provides information on using ROS with your RMP V3
- *http://rmp.segway.com/forum/* — a place to ask questions and receive answers about Segway RMP products
- *RMP V3 Interface Guide* — describes the Ethernet communication protocol used to talk directly to the RMP V3

Safety

Improper use of the RMP can cause personal injury, death and/or property damage from loss of control, collision, and falls. To reduce risk of injury, read and follow all instructions and warnings in this manual.

The following safety messaging conventions are used throughout this document:

⚠ WARNING!	Warns you about actions that could result in death or serious injury.
⚠ CAUTION!	Warns you about actions that could result in minor or moderate injury.
NOTICE	Indicates information considered important, but not related to personal injury. Examples include messages regarding possible damage to the RMP or other property, or usage tips.

⚠ **WARNING!**

- Keep out of reach of children and pets. Unanticipated movement by the RMP could result in death or serious injury.
- Do not sit, stand, or ride on the RMP. Doing so could result in death or serious injury.
- Do not drive the RMP at people or animals. A collision could result in death or serious injury.
- Always alert people in the vicinity when an RMP is operating. An unexpected collision with the RMP could result in death or serious injury.
- Avoid powering off on a slope. The RMP cannot hold its position when powered off and may roll downhill, causing serious injury, death, or property damage.
- The RMP can accelerate rapidly. It is recommended that the RMP be securely raised so the wheels are off the ground (or remove the wheels) until the user becomes familiar with the controls. Unanticipated movement by the RMP could result in death or serious injury.
- Be careful when working with the DC power connections. You could shock yourself and/or damage the RMP.
- Remove batteries before working inside the RMP. You risk serious bodily injury from electric shock as well as damage to the RMP.
- Do not submerge the RMP, batteries, or powerbases in water. Do not use a power washer or high-pressure hose to clean a RMP. Avoid getting water into any of the connectors. If you suspect the batteries or powerbase have been submerged or experienced water intrusion, call Segway Technical Support immediately at 1-866-473-4929, prompt #2. Until you receive further instructions, store the RMP upright, outdoors, and away from flammable objects. Failure to do so could expose you to electric shock, injury, burns, or cause a fire.
- Unplug or disconnect the RMP from AC power before removing or installing batteries or performing any service. Never work on any part of the RMP when it is plugged into AC power. You risk serious bodily injury from electric shock as well as damage to the RMP.
- The cells within the batteries contain toxic substances. Do not attempt to open batteries. Do not insert any object into the batteries or use any device to pry at the battery casing. If you insert an object into any of the battery's ports or openings you could suffer electric shock, injury, burns, or cause a fire. Attempting to open the battery casing will damage the casing and could release toxic and harmful substances, and will render the battery unusable.
- As with all rechargeable batteries, do not charge near flammable materials. When charging, the batteries could heat up and ignite a fire.
- Do not use a battery if the battery casing is broken or if the battery emits an unusual odor, smoke, or excessive heat or leaks any substance. Avoid contact with any substance seeping from the battery. Batteries contain toxic and corrosive materials that could cause serious injury.
- Observe and follow all safety information on the warning label found on the battery. Failure to do so could result in death, serious injury, or property damage.
- Do not use cables that are frayed or damaged. You could shock yourself and/or damage the RMP.
- Use only Segway approved fasteners on the RMP. Other fasteners may not perform as expected and may come loose. Failure to do so could expose you to risk of personal injury or property damage.
- Use assistance when moving or lifting the RMP. Single person lifting could result in serious injury.

⚠ **CAUTION!**

- Be responsible about setting performance parameters. Read the relevant sections of this manual before changing any performance parameters. The RMP follows commands issued to it, and it is the responsibility of the user to properly safeguard their controls.
- Read and understand the Balancing chapter of this manual before operating the RMP in Balance Mode. The RMP's behavior while balancing is not always intuitive and may result in unexpected or undesired motion.
- Failure to charge the batteries could result in permanent damage to them. Left unplugged, the batteries could fully discharge over time, causing permanent damage.
- Use only charging devices approved by Segway and never attempt to bypass or override their charging protection circuits.
- Always protect against electrostatic discharge (ESD) when working inside the RMP. The RMP could become damaged.

NOTICE

- This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
  - Reorient or relocate the receiving antenna.
  - Increase the separation between the equipment and receiver.
  - Connect the equipment into an output on a circuit different from that to which the receiver is connected.
  - Consult the dealer or an experienced radio/TV technician for help.
- This Class B digital apparatus complies with Canadian ICES-003.
  Cet appareil numérique de la classe b est conforme à la norme NMB-003 du Canada.
- Modifications not expressly approved by Segway may void the user's authority to operate this device under FCC regulations and must not be made.

Abbreviations

ABB	Auxiliary Battery Board — a PCB used to gather and report performance information from the auxiliary battery.
BCU	Battery Control Unit — a PCB inside the battery pack that manages the charge of the individual cells.
BSA	Balance Sensor Assembly — a group of PCBs used to obtain information about the vehicle's orientation.
CAN	Controller Area Network — a message-based protocol used for communication between microcontrollers.
CCU	Centralized Control Unit — a PCB that houses the SP, UIP, and NVM; it controls the RMP and handles communication.
CRC	Cyclic Redundancy Check — a type of error-detection used to verify the accuracy of transmitted data.
DLC	Data Length Code — a part of the CAN message header that specifies the size of the data packet being sent.
DTZ	Decelerate To Zero — an operational mode in which the RMP comes to a stop and powers down.
LE	Large Enclosure — a unified chassis/enclosure for 4-wheeled RMP models.
MCU	Motor Control Unit — a PCB that controls the electric motors that turn the wheels.
NVM	Non-Volatile Memory — a type of digital memory that can retain the stored information even when not powered.
OCU	Operator Control Unit — software and hardware that provide an interface between the user and the RMP.
PCB	Printed Circuit Board — a thin board with conductive pathways and electronic components mounted on it.
PSE	Pitch State Estimate — a 3-axis inertial estimate of the orientation of the RMP.
RMP	Robotics Mobility Platform — a propulsion system that can be used as a platform for making mobile robots.
ROS	Robot Operating System — a set of open-source Linux tools for building and manipulating robots.
SCB	Smart Charger Board — a PCB that controls battery charging functions.
SE	Small Enclosure — a box that contains all of the electrical components of the RMP.
SID	Standard ID — a CAN identifier that indicates the type of message being sent.
SOC	State Of Charge — a measurement of battery charge from 0% (empty) to 100% (full).
SP	Segway Processor — a microcontroller on the CCU that contains proprietary Segway code for controlling the RMP.
SPI	Serial Peripheral Interface — a synchronous serial data link standard that operates in full duplex mode.
UDP	User Datagram Protocol — a simple, transaction-oriented network protocol on top of TCP/IP.
UDFB	User Defined Feedback Bitmap — a stored value that indicates what feedback data should be sent to the user.
UI	User Interface — the means by which an operator interacts with a device.
UIP	User Interface Processor — a microcontroller on the CCU that communicates with the OCU.
USB	Universal Serial Bus — an industry-standard bus for communication and power supply between computers and peripherals.
VAB	Vicor Adapter Board — a PCB that interfaces with Vicor DC-DC converters.

RMP 220

The RMP 220 is a battery-powered Robotics Mobility Platform (RMP) meant to be used as the propulsion system for robotic products. The RMP 220 is capable of driving in either Tractor Mode (with a third wheel) or in Balance Mode (balancing on two wheels). When in Balance Mode it operates much like the Segway PT, leaning forward or backward in the direction of movement. The platform has two MCUs and two propulsion batteries, allowing it to operate at higher payloads and over longer distances than the RMP 210. With two MCUs the propulsion system is completely redundant, allowing one MCU to fail without losing control of the platform. At the top of the RMP 220 is a mounting plate with drilled and tapped holes for mounting equipment.

The powerbase contains the MCUs and Balance Sensor Assembly (BSA). Additional electrical components are mounted inside a User Interface (UI) box located above the powerbase. Propulsion batteries are mounted to the bottom of the powerbase. The auxiliary battery is mounted to the top of the UI box.

The on/off button, external connectors, and indicator lights are mounted on an interface panel at the rear of the machine. Communication with the RMP occurs over Ethernet.

Inside the UI box are the Centralized Control Unit (CCU), Auxiliary Battery Board (ABB), Smart Charger Board (SCB), and Power Converter(s). A cable runs from the UI box to the powerbase.

Figure 1: RMP 220

Included Components

The RMP 220 comes with a Disable Button and External Power Supply. The Disable Button must be connected for the RMP to power on and enter Standby Mode. When pressed, the Disable Button will cause the RMP to immediately shut down. The External Power Supply is used to charge the RMP. When connected, indicator lights on the UI box show the charge status of each battery.

Figure 2: Disable Button

Figure 3: External Power Supply

Capabilities

The RMP is meant to be used by integrators when creating mobile robotic products. As such, the RMP was designed with flexibility and expandability in mind.

Driving

The RMP can drive forward, reverse, and can turn in place. A variety of parameters can be adjusted for easier driving in different circumstances, making it possible to have fine control at slow speeds and at high speeds. Adjustable parameters include maximum velocity, maximum acceleration, maximum deceleration, maximum turn rate, and maximum turn acceleration.

For safety, a disable button is provided with the RMP. When pressed, the disable button will cause the RMP to shut down. A Decel To Zero (DTZ) command can also be sent, either by hardware button (not supplied) or by software command. This command causes the RMP to decelerate and come to a stop.

Payload

Users can mount equipment to the rails along the sides of the RMP. Mounting holes are provided along the tops of the rails and on the ends of the rails. Users can also mount equipment to the mounting plate at the top of the RMP.

The maximum total payload is 90 kg (200 lbs), evenly distributed.

Communication

Communication with the system for command and control is via Ethernet. The primary method of communication is via a ROS driver that Stanley Innovation provides. This driver performs a Cyclic Redundancy Check (CRC) on all data and ensures that the communication link is updated periodically to ensure the on-board firmware does not automatically slew the commands to zero.

Power

With the auxiliary battery, the RMP can provide power for additional equipment. Each RMP has space for two Power Converters. For more information see "Power Converter," p. 32.

Control Interface

Stanley Innovation provides a ROS driver. For details visit *http://wiki.ros.org/Robots/RMPv3*

Physical Characteristics

For product dimensions, please refer to the diagrams below. A summary of the major dimensions is provided in Table 1.

NOTICE
Product options may change the characteristics of the RMP.

Table 1: RMP 220 Physical Characteristics

Characteristic	Value
Overall	
Length	664 mm (26.1 in)
Width	637 mm (25.1 in)
Height	761 mm (30.0 in)
Chassis	
Length	419 mm (16.5 in)
Width	423 mm (16.7 in)
Height	212 mm (8.3 in)
Clearance	93 mm (3.7 in)
Tires	
Tire Size	19 in Segway i2 Tire
Wheel Base	N/A
Track Width	544 mm (21.4 in)
Recommended Tire Pressure	6–15 psi
Other	
Weight	73 kg (161 lbs)

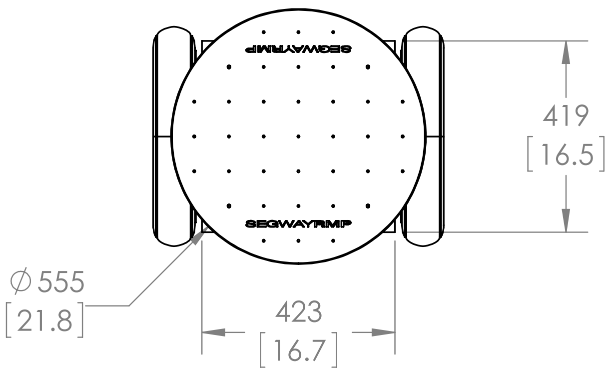


Figure 4: RMP 220 Top View

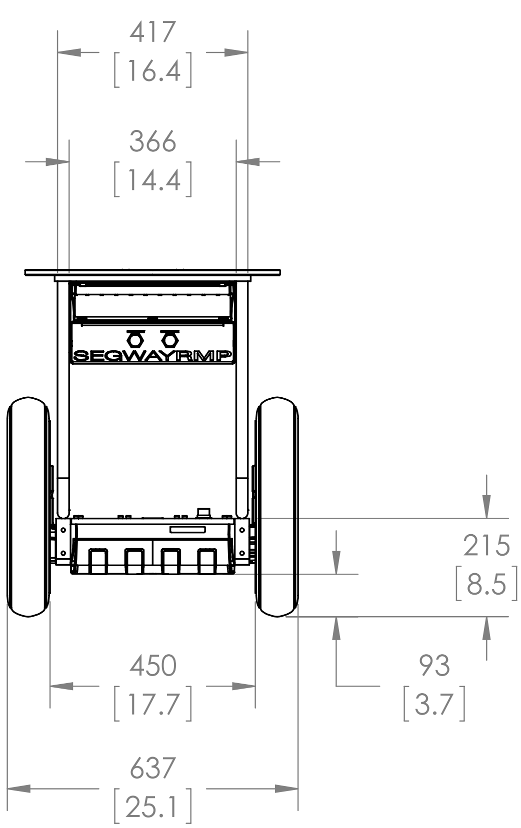


Figure 5: RMP 220 Rear View

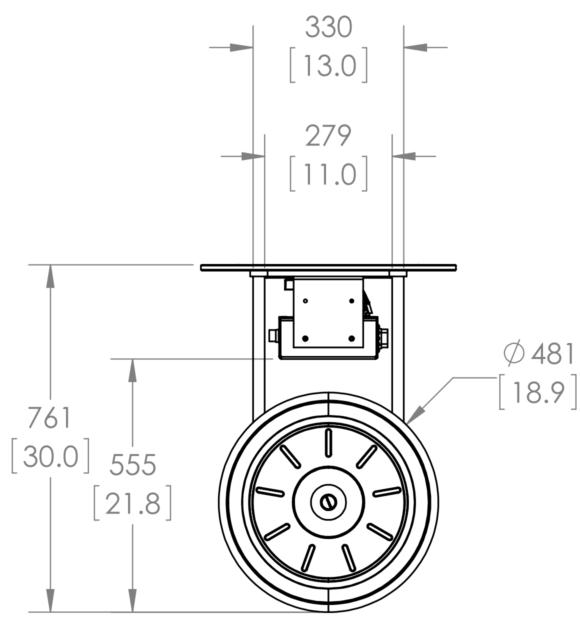


Figure 6: RMP 220 Side View

Mounting Locations

Equipment can be mounted to the RMP using the provided mounting locations. Tapped holes are located on the tops and ends of the rails. The RMP 220 also includes a mounting plate at 761 mm (30.0 in) high. Tapped holes are M8x12. Dimensions are mm [in].

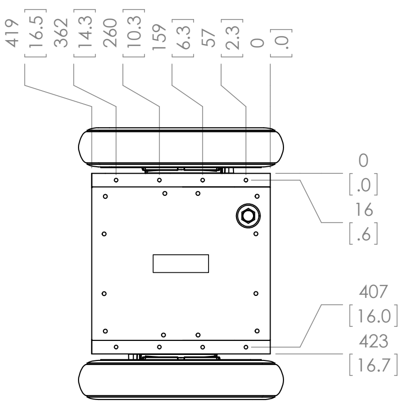


Figure 7: Lower Mounting Holes

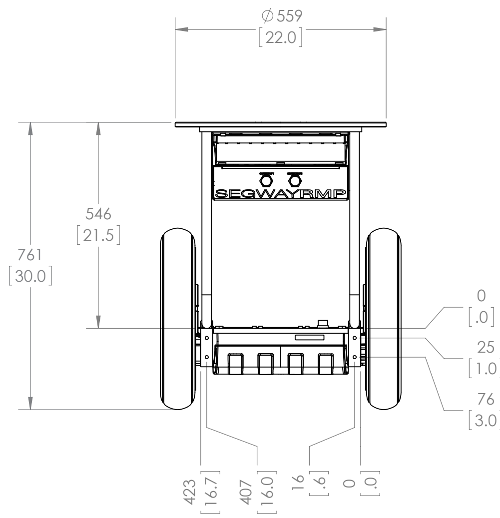


Figure 9: End Mounting Holes

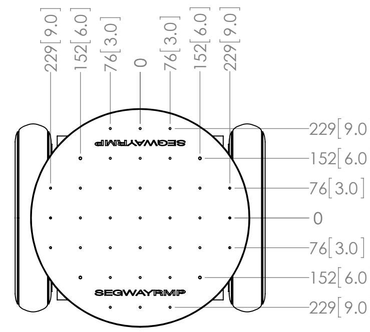


Figure 10: Mounting Plate

NOTICE

Only mount equipment via the provided mounting locations. Drilling holes in the enclosure or other modifications to the RMP may adversely affect the FCC rating, IP rating, and/or structural integrity of the RMP.

Turn Envelope

The RMP can turn in place, so its turn envelope is very small.

The caster plate (optional) is designed to fit within the turn envelope.

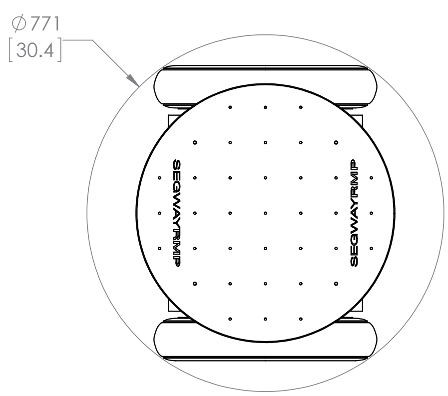


Figure 8: Turn Envelope, RMP 220

User Interface Panel

The power button, LEDs, and external connectors for the RMP are all located on the User Interface Panel on the rear of the RMP. Users should familiarize themselves with the various connectors and LEDs. For information on the connectors and what plugs into them see "Connecting," p. 41.

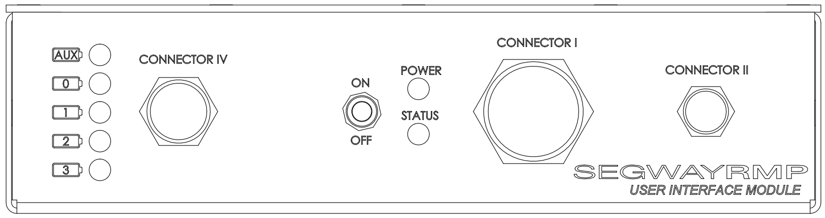


Figure 11: Interface Panel

ON/OFF Button

Pressing this button for 2 seconds will start the machine and turn on the auxiliary power supplies. If the button is pressed during operation for 2 seconds the machine will send a power down signal to any connected computers, wait 30 seconds for them to shut down, and then turn off the auxiliary power.

Power and Status LEDs

These two LEDs indicate what mode the RMP is in. They can be used to troubleshoot startup issues. See "Powering On/Off," p. 39, for a list of what the LEDs indicate.

Connector I

This connector is used for communication and for auxiliary power. Auxiliary power available depends on the Power Converters installed. Up to two different DC voltages can be made available.

Connector II

The Disable Button connects here. The Disable signal must be sent for normal operation. Other signals include: the Decel Request, used to initiate a Decel to Zero (DTZ); the Boot1 signal, used to enter Diagnostic mode; and the Boot2 signal, used to enter Bootloader mode.

Connector IV

This connector is used in conjunction with the External Power Supply for charging the RMP batteries. For more information on charging see "Charging," p. 37.

Charge Status LEDs

When charging the batteries, the Charge Status LEDs will light up, indicating the status of each battery. Each LED corresponds to a specific battery. For more information see "Charging," p. 37.

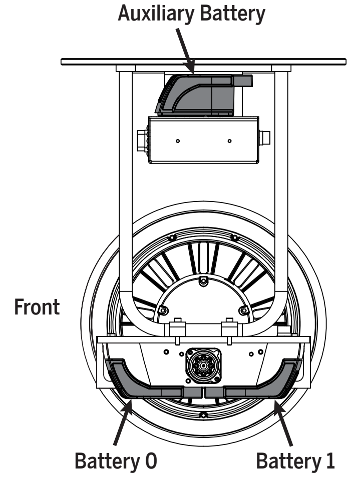


Figure 12: Battery Locations

Powerbase Connections

On the side of the enclosure there are two powerbase connectors. The left-hand connector goes to the powerbase; the right-hand one is unused. If two powerbases are used, the right-hand connector goes to the rear powerbase. The powerbase must be plugged into the proper connector for the charge status LEDs to be correct.

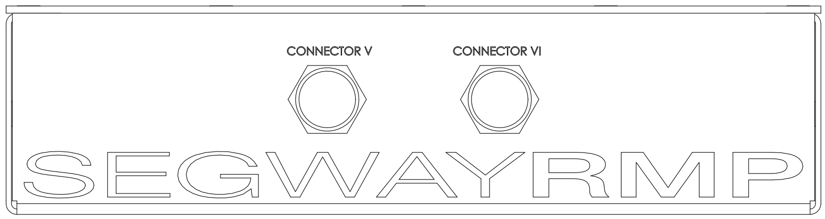


Figure 13: Powerbase Connections

Connector V

Connect the powerbase to this jack.

Connector VI

Cover this jack with the protective cap.

Performance Specifications

The RMP is driven by two independent and fully redundant brushless DC drive motors. It can operate both outdoors and indoors. Traversable terrain includes asphalt, sand, grass, rocks, and snow.

Table 2: Performance Specifications

Characteristic	Value
Mobility	
Max. Speed	8.0 m/s (18 mph)
Max. Speed Balancing	4.5 m/s (10 mph)
Turn Radius	0 minimum
Turn Envelope	771 mm (30.4 in)
Max. Slope[1]	10° non-balancing 5° balancing
Peak Torque (Each Wheel)	100 N-m (74 lb-ft)
Maximum Range[2]	50 km (30 mi)
Power	
Batteries	2 Propulsion Batteries 1 Auxiliary Battery
Run Time[3]	Up to 24 hours
Charge Time	2-3 hours
Battery Chemistry	$LiFePO_4$
Propulsion Battery Capacity	380 Wh each
Auxiliary Battery Capacity	380 Wh
Payload	
Max. Payload[4]	100 lbs[5] (Balance Mode) 200 lbs (Tractor Mode)

[1] Based on an unloaded platform.

[2] Based on an unloaded platform with 15 psi tires travelling in a straight line on level pavement. Actual performance may vary.

[3] Run time based on a stationary RMP running on internal battery power. Extended run time is possible with charger connected.

[4] Performance specifications are not guaranteed under maximum payload situations. See "Payload Gain Schedules," p. 22.

[5] Maximum payload in Balance Mode is determined by the gain schedule (page 22). It is possible to use higher payloads with custom gain schedules.

Environmental Specifications

The Segway RMP was designed to withstand environmental conditions both indoors and outdoors.

Table 3: Environmental Specifications

Characteristic	Value
Operating Temp. Range	0°–50° C (32°–120° F)
Storage Temp. Range	-20°–50° C (-5°–120° F)

Endurance

Platform endurance is determined by measuring battery draw while performing various maneuvers.

In many cases the propulsion batteries will limit the runtime of the RMP. However, there are some scenarios in which the auxiliary battery will be the limiting factor. Such cases include stationary operation and situations in which additional equipment is using the auxiliary battery as a power source.

To calculate the energy used by a given maneuver, first determine the length of time the maneuver will be performed. Then multiply that time (in hours) by the Watts used while performing the maneuver. This will give you the Watt-hours used per battery. Subtract those Watt-hours from the Watt-hours remaining in the battery. Maximum battery capacity is 380 Watt-hours.

NOTICE
In the equations below, Power Draw (W) represents how much power is used by a single propulsion battery. Because every propulsion battery will deplete at roughly the same rate, it is safe to assume this single battery is representative of all propulsion batteries.

Stationary Power Usage

When the RMP is maintaining a stationary position on level ground, the auxiliary battery is the limiting factor when calculating runtime. The internal RMP components use approximately 16 Watts, allowing the auxiliary battery to last nearly 24 hours.
In contrast, the propulsion motors require only 4.5 Watts to maintain position on level ground, leaving 84% SOC left in the propulsion batteries after 24 hours. During actual use, the power used by the propulsion batteries may be greater, especially if maintaining position on a slope.

Straight Line Power Usage

The following empirical relationship can be used to provide a rough estimate of power usage when travelling in a straight line. These relationships are based on tests performed on dry, level pavement and represent best-case scenarios. Actual performance may vary.

Straight line power draw:

$$W = 20v + 4.5$$

W = Power Draw (Watts)
v = Velocity (m/s)

This equation describes the power usage while travelling at constant speed. When accelerating and decelerating, the RMP will momentarily draw significantly more power. Because of the nature of how the RMP balances, the payload size has very little effect upon power usage when travelling at a constant speed.

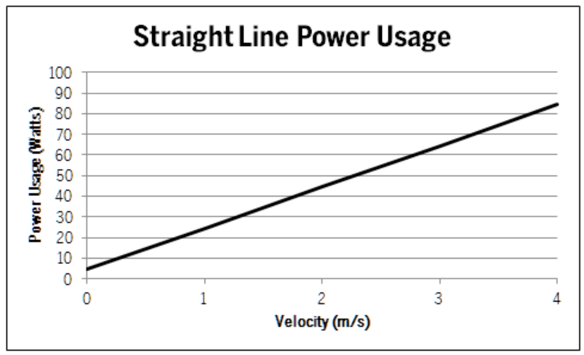


Figure 14: Straight Line Power Usage

Turn-in-Place Power Usage

The following empirical relationships can be used to provide a rough estimate of power usage when turning in place. These relationships are based on tests performed on dry, level pavement and represent best-case scenarios. Actual performance may vary.

Turn-in-place power draw:

$$W = g \times v + 4.5$$

W = Power Draw (Watts)
g = Gain schedule constant
v = Velocity (m/s)

The gain schedule constants are shown in Table 4.

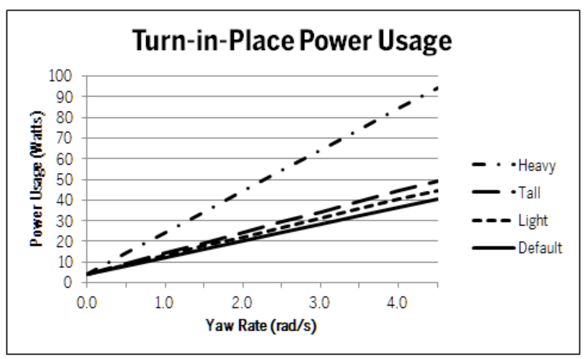


Figure 15: Turn-in-Place Power Usage

Table 4: Gain Schedule Constants

Gain Schedule	Constant
Default	8
Light	9
Tall	10
Heavy	20

Transportation and Shipping

NOTICE

Lithium-ion batteries are regulated as "Hazardous Materials" by the U.S. Department of Transportation. For more information, contact the U.S. Department of Transportation at *http://www.phmsa.dot.gov/hazmat/regs* or call 1-800-467-4922.

To prevent damage to your RMP, always ship it in the original crate it came in. The crate disassembles for storage. If you do not have the original crate, contact Segway for a replacement (see "Contact Information," p. 6).

Ground Shipment — Batteries Installed

When shipping the RMP by ground with the batteries installed, ship it in the original crate with a Class 9 Hazardous Materials label affixed to the outside of the crate. Make sure that your shipper is HAZMAT certified for Class 9 hazardous materials. See Table 5 for more detailed information.

Table 5: Ground Shipment — Batteries Installed

Characteristic		Value
RMP Packaging	Material	Palletized Corrugated Cardboard Box
	Size	114 x 84 x 89 cm (45 x 33 x 35 inches)
	Weight	93 kg (205 lbs)
	Label	Class 9 Hazardous Materials
	Commodity Description	UN3171 Battery Powered Equipment, 9 (Class 9 Hazardous Materials)
NMFC No.		190285 (for LTL shipments)
Class		100 (for LTL shipments)

Ground Shipment — Batteries Separate

When shipping the RMP by ground with the batteries packaged separately, only the batteries require special accommodation. There are no restrictions on packaging and transportation for non-battery RMP components.

Ship the batteries in their original UN marked packaging with a Class 9 Hazardous Materials label affixed to the outside of each battery box. Make sure that your shipper is HAZMAT certified for Class 9 hazardous materials. See Table 6 for more detailed information.

Table 6: Ground Shipment — Batteries Separate

Characteristic		Value
RMP Packaging	Material	Palletized Corrugated Cardboard Box
	Size	114 x 84 x 89 cm (45 x 33 x 35 inches)
	Weight	77 kg (170 lbs)
Battery Packaging	Material	Corrugated Cardboard Box
	Size	38 x 23 x 23 cm (15 x 9 x 9 inches)
	Weight	One Battery: 7 kg (16 lbs) Two Batteries: 12 kg (26 lbs)
	Label	Class 9 Hazardous Materials
	Commodity Description	UN3480 Lithium-ion Batteries, 9 (Class 9 Hazardous Materials)

Air Shipment — Batteries Separate

When shipping the RMP by air, package the batteries separately. Only the batteries require HAZMAT accommodation. There are no restrictions on packaging and transportation for non-battery RMP components.

Ship the batteries in their original UN marked packaging with a Class 9 Hazardous Materials label affixed to the outside of each battery box. Also affix a "Cargo Aircraft Only" label to the outside of each battery box. Make sure that your shipper is HAZMAT certified for Class 9 hazardous materials. In addition, prepare 4 copies of the DGD (Declaration for Dangerous Goods) document. See Table 7 for more detailed information.

Table 7: Air Shipment — Batteries Separate

Characteristic		Value
RMP Packaging	Material	Palletized Corrugated Cardboard Box
	Size	114 x 84 x 89 cm (45 x 33 x 35 inches)
	Weight	77 kg (170 lbs)
Battery Packaging	Material	Corrugated Cardboard Box
	Size	38 x 23 x 23 cm (15 x 9 x 9 inches)
	Weight	One Battery: 7 kg (16 lbs) Two Batteries: 12 kg (26 lbs)
	Labels	Class 9 Hazardous Materials Cargo Aircraft Only
	Commodity Description	UN3480 Lithium-ion Batteries, 9 (Class 9 Hazardous Materials)
	Documents	Declaration for Dangerous Goods, 4 copies

Balancing

In Balance Mode the RMP balances on two wheels and accepts motion commands. As in Tractor Mode, it can be commanded to drive forward, backward, and turn left/right. When moving, the RMP tilts slightly in the direction of motion (see Figure 16).

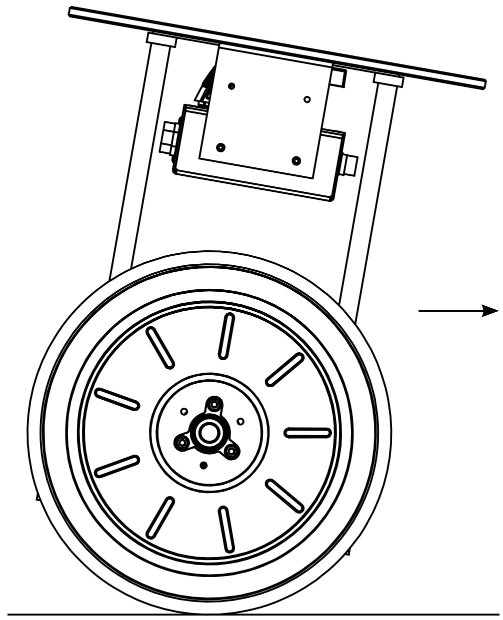


Figure 16: Tilting in the Direction of Travel

In order to enter Balance Mode a mode transition is commanded (refer to the *RMP V3 Interface Guide*). Then the RMP is tipped upright. When it is vertical, the RMP will begin balancing. At this point the RMP may rock back and forth as it gains its balance. Do not hold onto the RMP or restrict its movement in any way. Allow it to balance on its own.

NOTICE
When standing still, the RMP may rock forward and backward slightly. This is normal. The RMP is simply maintaining its balance.

Any outside force applied to the RMP while it is balancing will cause it to react. For example, if the RMP is standing still and you press down on the front of the mounting plate the RMP will tilt. The RMP will push back, attempting to drive forward and tipping the front of the mounting plate up. For more information on how the RMP will act in a variety of situations, read the rest of this chapter.

Payload Gain Schedules

In order to balance safely and accurately the controller's gain schedules must be precisely tuned for a given payload and weight distribution. Four pre-defined gain schedules can be selected, and Segway can create custom gain schedules for specific applications.

⚠ **CAUTION!**
The Tall configuration requires extra care. Small tilt angles can result in large relative displacements of the wheel and upper payload.

Each gain schedule has been optimized for a particular payload at a particular height. For best performance, the user should endeavor to combine their payload with ballast to reproduce mass properties that are close to the configurations defined below.

In general, all gain schedules operate with a wide range of payloads. Choosing the gain schedule that best fits a user's payload has one main advantage: the handling and dynamics of the RMP will be better damped and more predictable. While each of the gain schedules can balance a wide variation in payload, the degree of oscillation and control activity will change as the payload is altered. For example, both the Light and Heavy gain schedules can handle a 75 lb payload on the mounting plate, however the response of each controller will be slightly different in the presence of disturbances. Note that the Tall payload configuration will not balance with the Light or Heavy gain schedules.

The gain schedule is assigned when the RMP enters Balance Mode. Changes to the gain schedule cannot be performed while in Balance Mode. The RMP will have to enter Tractor Mode for the gain schedule to change.

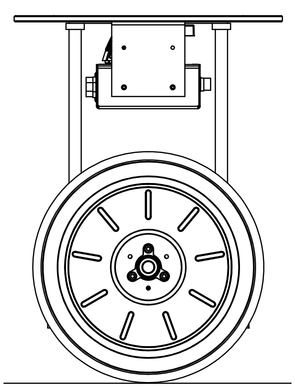


Figure 17: Unloaded

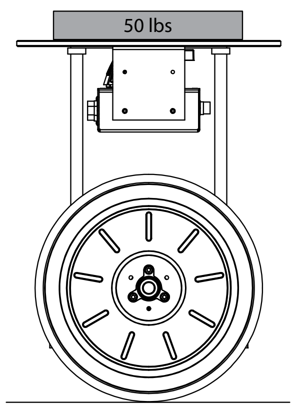


Figure 18: Light

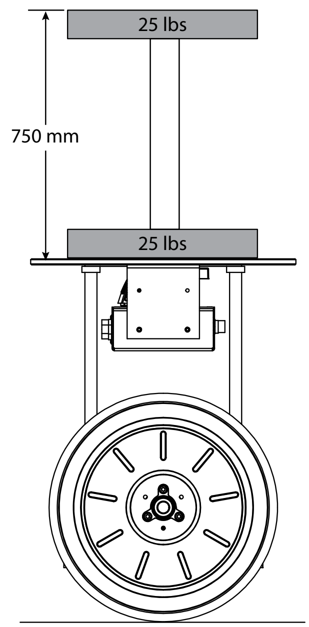


Figure 19: Tall

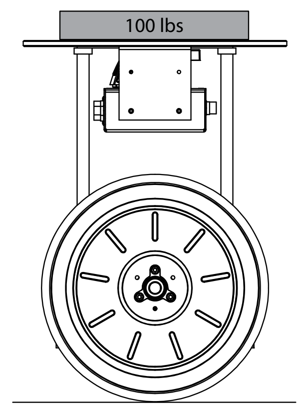


Figure 20: Heavy

Unloaded (Default)

Use this gain schedule for an RMP with no additional mass loaded onto it. This is the default gain schedule.

> **NOTICE**
> This physical playform configuration represents the minimum mass ballast required for safe operation in Balance Mode.

Custom

Custom gain schedules can be created for specific applications and payloads. The gain schedule parameters are stored in NVRAM so they will not be forgotten across reboots. Contact Segway for more information ("Contact Information," p. 6).

Light

Use this gain schedule for an RMP with a 50 lb (22.7 kg) payload mounted directly on the mounting plate.

Tall

Use this gain schedule for an RMP with 25 lbs (11.3 kg) mounted on the mounting plate and an additional 25 lbs (11.3 kg) mounted 750 mm (29.5 in) above the mounting plate.

Heavy

Use this gain schedule for an RMP with 100 lbs (45.4 kg) mounted directly on the mounting plate.

Balance Mode Requirements

In order to safely balance, the RMP must meet the following requirements.

- Ability to tip to 35° (to safely allow the RMP full maneuverability).
- Correct weight distribution as per the gain schedule selected (see "Payload Gain Schedules," p. 22).

⚠ CAUTION!
The Balance Frame Assembly (Tube Frame, U-Bracket for high mounting of User Interface Box, and Mounting Plate) provides the minimum mass ballast required for operating in Balance Mode and must be installed as shown before entering Balance Mode. Optional brackets for mounting the User Interface Box low are available, but are not compatible with Balance Mode operation.

Also, before entering Balance Mode the Balance Enable Bit must be set to 1 via dynamic_reconfigure. Refer to *http://wiki.ros.org/dynamic_reconfigure*. The purpose of this bit is to lock out Balance Mode in situations where it would be unsafe to enter Balance Mode.

Entering Balance Mode

The RMP will enter Balance Mode if:

- Balance Mode is enabled (refer to the *RMP V3 Interface Guide*).
- A Balance Mode transition is commanded.
- The BSA is initialized.
- The RMP crosses the vertical axis.

The BSA initializes when the RMP is within 30° of vertical and takes a few seconds to occur. During this time the RMP should remain stationary. To enter Balance Mode, follow these steps:

1. Verify that the RMP meets the Balance Mode requirements (above).
2. Turn on the RMP.
3. Command a transition to Balance Mode (see the *RMP V3 Interface Guide*, and see "Hardware Balance Request," p. 30).
   The RMP will emit a beep-beep sound if the BSA is not initialized.
4. Tip the RMP upright until it is vertical (see Figure 21).
   Once the BSA initializes, the beep-beep sound will change to a repeating beep.
   The RMP will beep with increasing frequency as it approaches vertical.
5. Allow the RMP to balance on its own.
   You can now send motion commands.

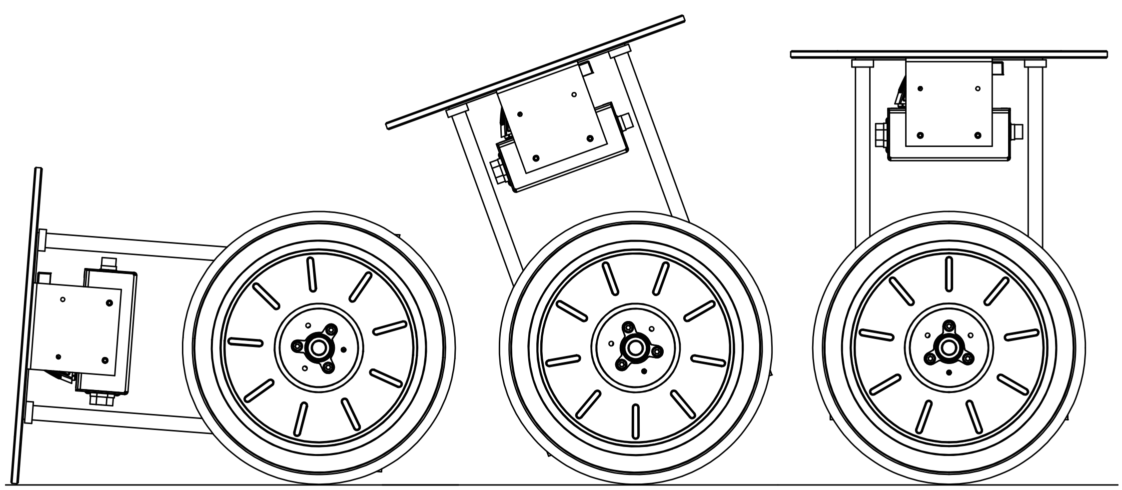


Figure 21: Tip the RMP Upright When Entering Balance Mode

Exiting Balance Mode

When exiting Balance Mode the RMP will stop balancing and will tip over. Be prepared to catch the RMP if you do not want it to slam into the ground.

1. Bring the RMP to a stop.
2. Exit Balance Mode by commanding a mode transition (refer to the *RMP V3 Interface Guide*).
3. Catch the RMP as it begins to tip over.

⚠ **WARNING!**
Do not let the RMP fall onto your foot or any other part of your body. The mounting plate is heavy and could cause injury.

The RMP can exit Balance Mode in a variety of ways. Any mode transition out of Balance Mode will cause the RMP to stop Balancing (transitioning to Standby Mode, Tractor Mode, Disable Mode, etc.). Also, pressing the ON/OFF Button will cause the RMP to stop balancing and begin shutting down.

Performance Limits

Roll Over

In order to balance the RMP needs to have its payload mounted relatively high. This is because the RMP operates as an inverted pendulum while balancing. Unfortunately, the property that helps the RMP to balance (a high center of mass) also makes the RMP more likely to roll over.

Figure 22 shows how velocity and yaw rate combine to make the RMP roll over. The area above the curve(s) is where the RMP is likely to roll over. This graph assumes that the RMP is operating on level ground. Any slope, however slight, will increase the likelihood of roll-over.

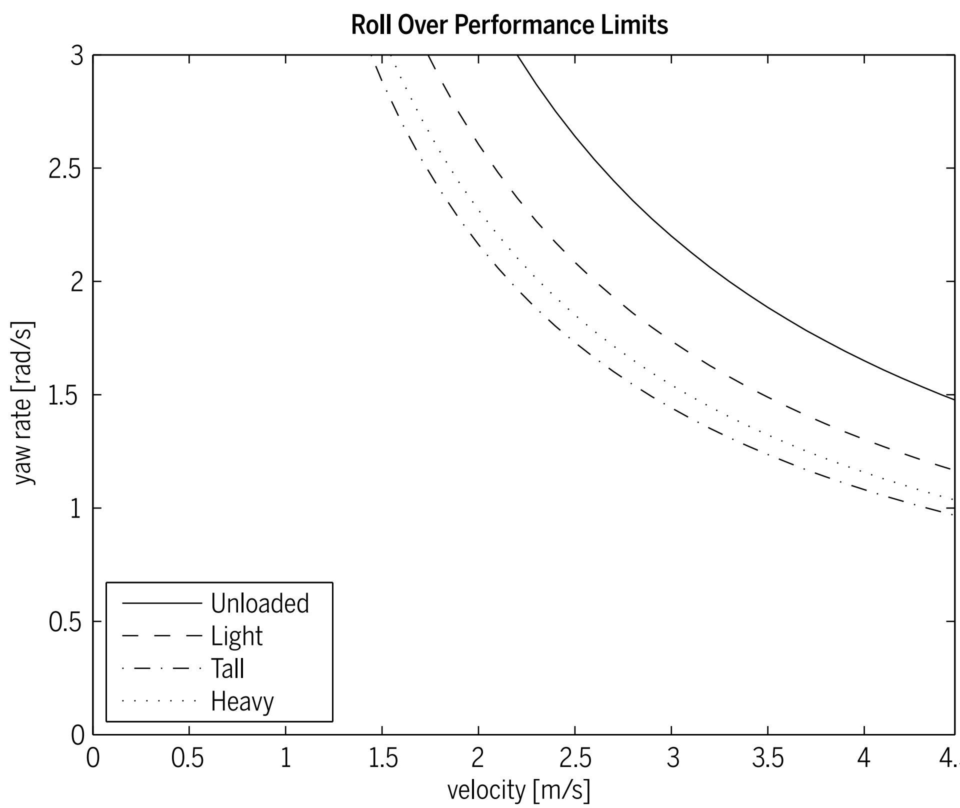


Figure 22: Roll Over Performance Limits

Turn Radius

The RMP's speed and yaw rate can be used to calculate the turn radius. Higher speeds increase the turn radius while higher yaw rates decrease it. Be sure not to exceed the Roll Over limit described above.

$$R = \frac{V}{Y}$$

Where,

R = Turn Radius (m)
V = Velocity (m/s)
Y = Yaw Rate (rad/s)

This equation provides the turn radius to the center of the RMP. To calculate the radius to the outside of the RMP just add half of the RMP's width (0.32 m) to the final radius.

Using this equation and the Roll Over limit, the minimum safe turn radius can be determined for a variety of speeds.

Stopping Distance

Changing the deceleration limit can have a big effect on how far the RMP travels as it slows to a stop. If the RMP cannot stop soon enough it may collide with obstacles. If it stops too quickly it may tip far enough and fast enough to jostle equipment or startle bystanders. Because of this it is important to reach a balance between stopping distance and tip angle.

These same principles also apply to the DTZ deceleration limit and the acceleration limit. The DTZ decleration limit controls the rate at which the RMP will come to a stop when a DTZ command is issued or when a fault triggers a DTZ response. The acceleration limit affects how far the RMP travels while coming up to speed. Remember to set the DTZ deceleration limit high enough to stop the RMP quickly in case of an emergency.

To calculate the stopping distance from the velocity and deceleration rate, use the following formula:

$$D = \frac{V^2}{2A}$$

Where,

D = Distance Travelled (m)
V = Initial Velocity (m/s)
A = Acceleration/Deceleration Rate (m/s^2)

Interaction With The Environment

When the RMP makes contact with other objects in the environment, the results can be counter-intuitive at first.

⚠ **WARNING!**
Read and understand this section before operating an RMP in Balance Mode. Proper understanding of how the RMP will act is necessary to avoid personal injury and property damage.

Displacement

If the RMP is displaced from its desired position, it will lean against the displacement force, creating a new equilibrium position. The harder it is pushed, the more it will lean.

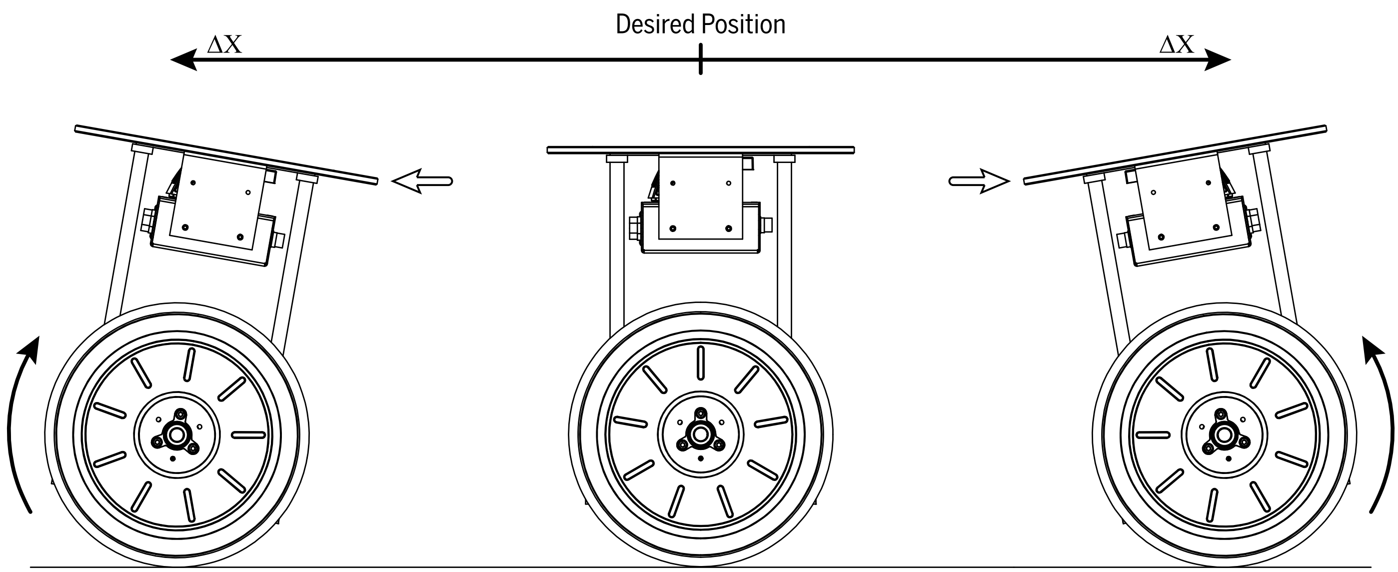


Figure 23: Displacement Direction

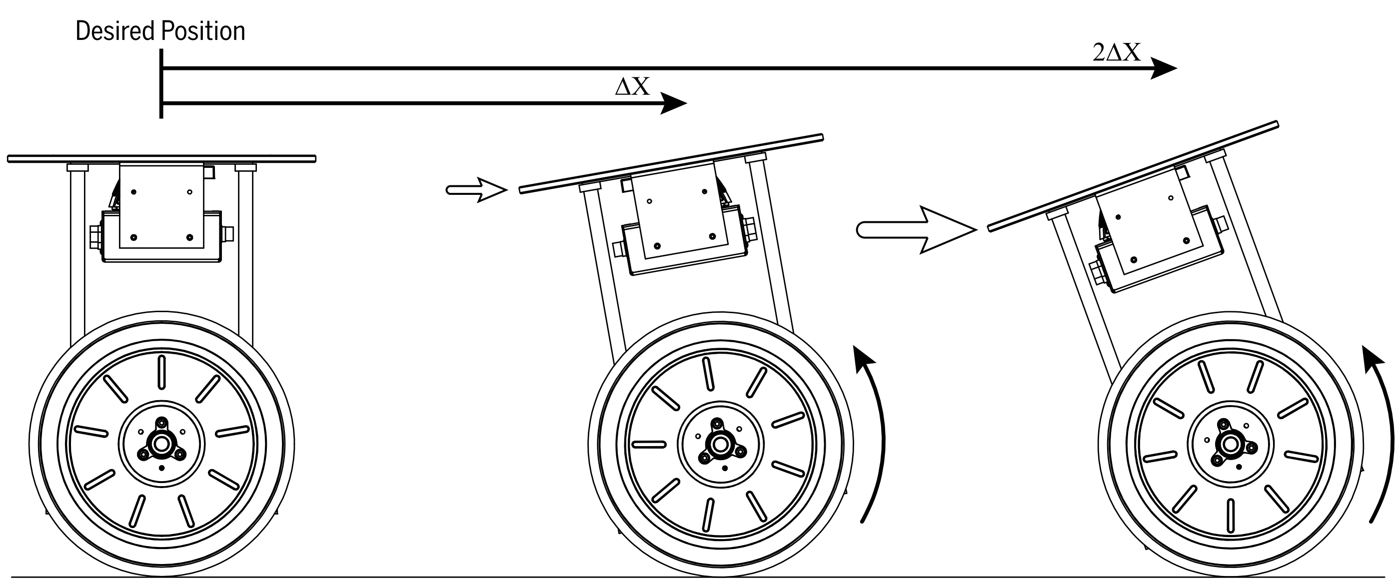


Figure 24: Displacement Magnitude

Unable to Right Itself

If an external force causes the RMP to tip forward or backward, the RMP will attempt to right itself. This simple concept can have some surprising consequences.

If a downward force is applied to the mounting plate, the RMP will drive in the direction that it is tipped. This could occur if someone presses down on the mounting plate, or if the payload center of gravity is off-center. See Figure 25.

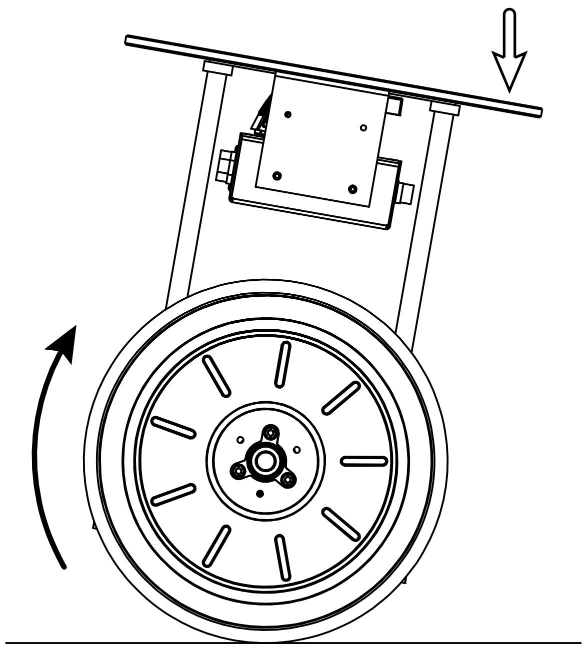


Figure 25: Downward Force

Something similar happens when the RMP gets caught under something, as is shown in Figure 26 where the mounting plate is caught under a table. In this case the RMP will push up against the table in an attempt to right itself. The force applied by the RMP can be quite strong, lifting the table or tipping it over.

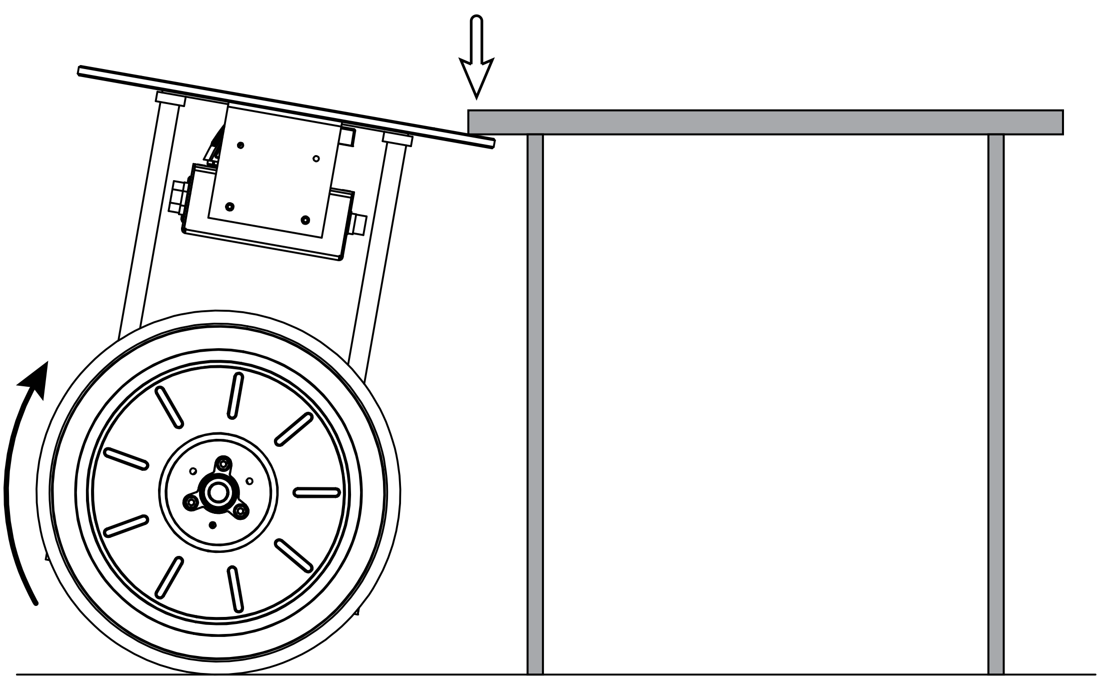


Figure 26: Caught Under a Table

The situation shown in Figure 27 is very different from a dynamic standpoint, but the controller cannot differentiate between this configuration and the ones in Figure 25 and Figure 26. In this case the RMP will accelerate faster and faster to the right trying to bring the machine to a level equilibrium. It will quickly trip the position error limit of 12 feet and Disable.

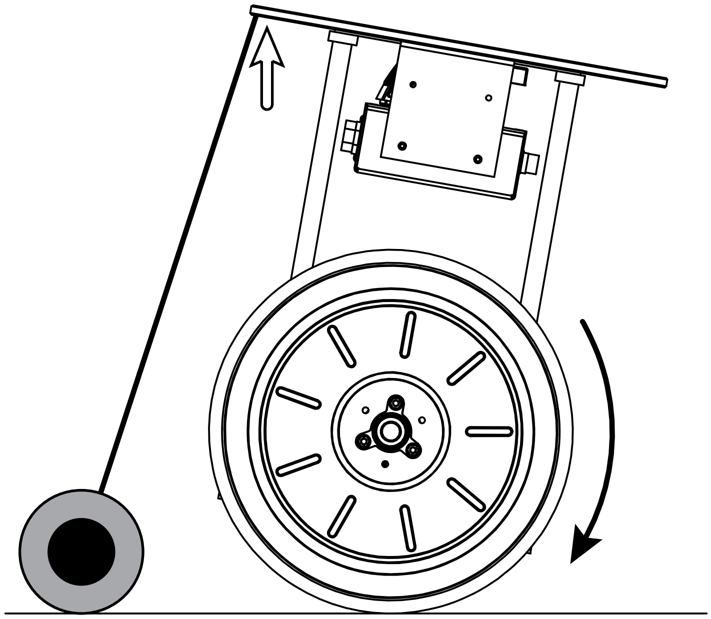


Figure 27: Caster Wheel

A caster wheel can cause the RMP to accelerate rapidly even if it does not normally contact the ground. If the RMP hits an obstacle or encounters a slope, the caster wheel will tip the RMP and start it accelerating in the opposite direction.

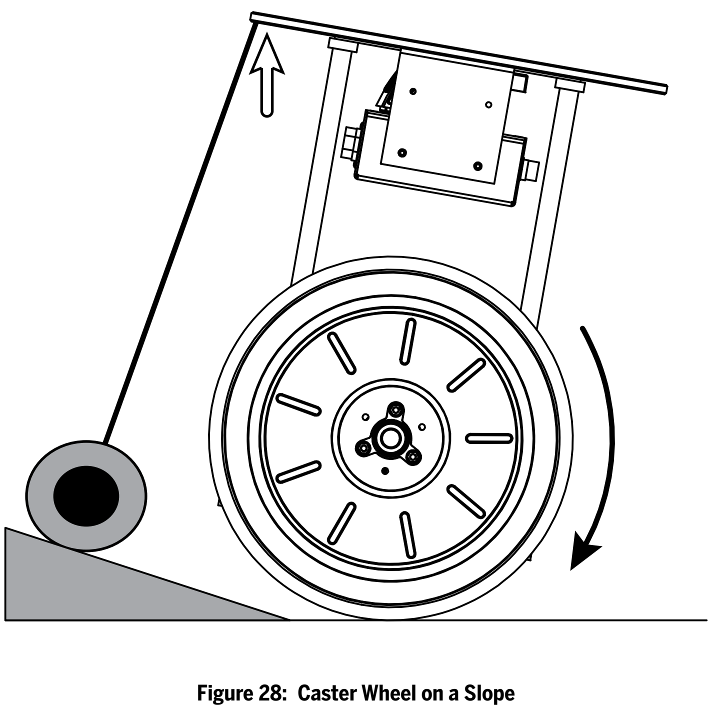


Figure 28: Caster Wheel on a Slope

Obstacles

When the RMP needs to roll over an obstacle, the CG of the RMP must tilt forward over the contact point. When the tire makes contact with the obstacle, it stops rolling and the frame tilts forward. Once the CG is over the contact point with the obstacle, the RMP will roll over the obstacle (provided the obstacle is small and sufficient traction exists). Because torque is required to hold the tilted position, there is a tendency to overshoot the obstacle. Approaching obstacles with a small initial velocity typically helps in traversing obstacles.

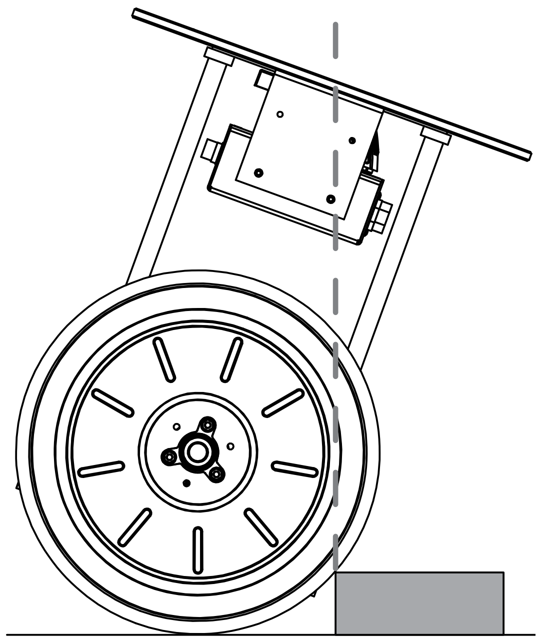


Figure 29: Crossing an Obstacle

⚠ **WARNING!**

- If the RMP is traveling too fast over an obstacle, the wheels could leave the ground. When this happens the RMP will have difficulty maintaining its balance and will move very quickly trying to right itself. This could result in death or serious injury to bystanders, or property damage.
- If there are multiple obstacles in a row, the RMP must be able to catch its balance after each one. When obstacles are too close together the RMP will not be able to maintain its balance and will move very quickly trying to right itself. This could result in death or serious injury to bystanders, or property damage.

Balance Mode Faults

There are some faults that occur only in Balance Mode. For information on how the RMP will respond to other faults, refer to the *RMP V3 Interface Guide* and see "Faults," p. 54.

Pitch Angle Exceeded

If the RMP tips forward or backward greater than 30° from normal, the RMP will Disable and power off. This is because the BSA's Pitch State Estimate is only accurate within this range. Furthermore, if the RMP tips past 30° it is likely that it will be difficult or impossible for it to right itself.

Roll Angle Exceeded

If the RMP tips sideways greater than 30° from normal, the RMP will Disable and power off. This is because the RMP will not be able to right itself and is in the process of falling over.

Speed Limiter Hazard

In order to maintain its balance the RMP must sometimes move very quickly. Usually this is acceptable, however if the RMP tries to move too fast it is an indicator that the RMP is having difficulty righting itself. When the actual speed exceeds the the speed limiter value, the RMP will Disable and power off.

Position Control Failed

During normal operation, the RMP will attempt to hold position when no movement is commanded. If the RMP is unable to hold position for any reason and the wheels rotate too far from the original resting location (an equivalent of 12 feet of displacement), the RMP will Disable and power off. This could happen if the wheels are slipping, a force pushes the RMP away from the equilibrium position, or some other condition is preventing the RMP from reaching its equilibrium position (e.g. the RMP is lifted off the ground).

Velocity Control Failed

During normal operation, the RMP will attempt to match the commanded velocity (or hold position if no velocity is commanded). If the RMP's actual velocity moves outside of the acceptable range, the RMP will Disable and power off. This could occur if the RMP is trying to regain its balance after losing traction, or if some condition is preventing the RMP from reaching its equilibrium position (e.g. the RMP is lifted off the ground).

Hardware Balance Request

A Balance Mode transition can also be commanded via a hardware button. While in Standby Mode or Tractor Mode, momentarily sending a Boot1 signal will initiate the Balance Mode request.

A Boot1 signal is sent by connecting pins D and E on Connector II.

Sending a Boot1 signal while in Balance Mode will not cause a transition out of Balance Mode. Instead a mode request must be made to transition to Standby Mode, Tractor Mode, Disable Mode, or DTZ (Decel To Zero).

Velocity Filter

When in Balance Mode the RMP can tip quite suddenly, especially when large changes in velocity are commanded. To mitigate this a velocity filter can be applied that smooths velocity transitions by limiting the rate at which the acceleration rate can change. For more information refer to the *RMP V3 Interface Guide*.

Electrical Overview

This section describes the RMP components and how they interact.

System Components

A brief overview of each component is provided to help you become familiar with these components and their functions.

Centralized Control Unit

The Centralized Control Unit (CCU) contains the Segway Processor (SP) and the User Interface Processor (UIP). These processors use synchronized timing to control the RMP in real time. They communicate via a Serial Peripheral Interface (SPI) link.

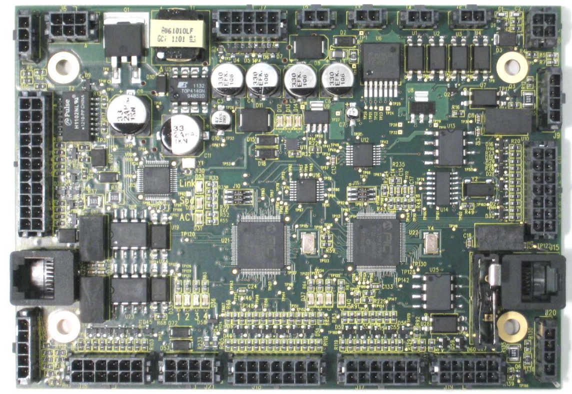


Figure 30: Centralized Control Unit

Segway Processor

The SP controls essential system functions including timing management, control algorithms, safety kernel functions, redundancy management, estimation algorithms, and Segway hardware interfaces. In addition, a real time clock and Non-Volatile Memory (NVM) allow for diagnostic fault logging.

User Interface Processor

The UIP controls the interaction between the user and the RMP. It allows the user to command RMP motion, configure machine parameters, and access faultlog information.

The UIP consists of four layers: System layer, I/O layer, Toolkit layer, and Application layer.

1. The System layer manages hardware-specific functionality like interrupts and timing.
2. The I/O layer manages all processor I/O including GPIO, ADC, DAC, CCP, USB, UDP, CAN, RS232, TTL Serial, and the SPI link. The I/O layer is responsible for gathering all raw UIP data and presenting it to the Toolkit layer.
3. The Toolkit layer abstracts the information gathered by the I/O layer and interprets it into meaningful system level data. The Toolkit layer then relays that information to various interfaces for consumption by the user.
4. The Application layer consists of an application stump for future expansion and development of the system.

Powerbase

The powerbase is one of the main components of the Segway PT and has been leveraged for use as the propulsion unit of the RMP. Each RMP 220 has one powerbase that controls both wheels. Inside the powerbase are two Motor Control Units (MCUs) and a Balance Sensor Assembly (BSA). The powerbase is not serviceable by the user; this information is provided for completeness only.

Motor Control Unit

The MCU is a Segway motor drive. It utilizes the robustness of the Segway PT propulsion system as a motor drive. Each MCU has two motor drives that drive half of a dual hemisphere Segway motor. Each MCU performs its own internal fault detection and communicates with the SP via CAN interface. The user does not have access to the MCU interface.

Balance Sensor Assembly

The BSA provides redundant raw three-axis inertial data to the SP. The SP uses this information to compute the Pitch State Estimate (PSE). The PSE algorithm estimates the machine orientation and movement based on the combined raw inertial information and wheel odometry.

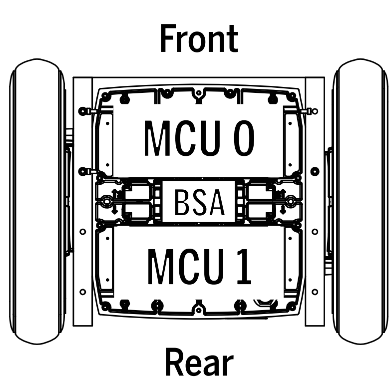


Figure 31: Segway Powerbase

Smart Charger Board

The Smart Charger Board (SCB) distributes charging current from the External Power Supply to the ABB and both powerbases. It controls multiple high current smart chargers and manages charging. It has 5 monitored channels at 100 VDC each and can perform fault detection down to the level of the power supply, board, and battery.

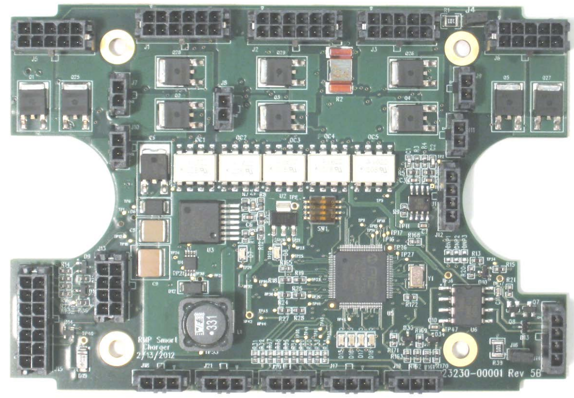


Figure 32: Smart Charger Board

Auxiliary Battery Board

The Auxiliary Battery Board (ABB) monitors voltage, current, state of charge, and battery flags of the auxiliary battery pack. It has software protected outputs to prevent over-discharge of the battery. The board can act as a standalone unit or can connect to the CCU. It interfaces with the UIP via CAN and provides real-time battery data and status information for the auxiliary battery pack. The ABB can communicate via CAN, USB, and RS232.

If the fuse blows, the entire board must be replaced.

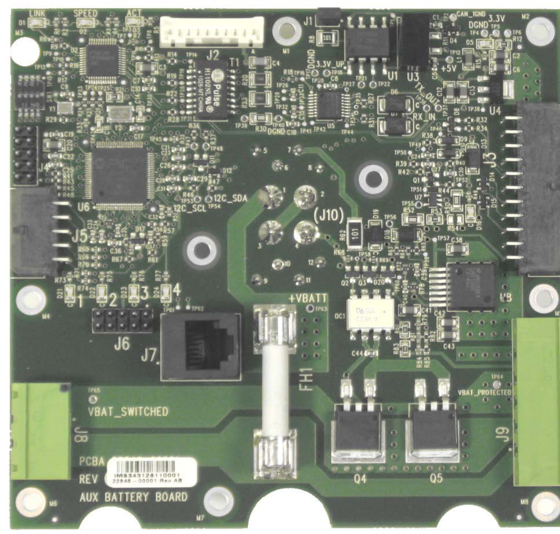


Figure 33: Auxiliary Battery Board

Power Converter

The RMP 220 accommodates up to two Power Converters. Each Power Converter accepts 72 VDC input power and provides DC output power at a different voltage. One Power Converter provides 12 VDC power for internal use and customer use. The other Power Converter is selectable at time of purchase. Output voltage options include 5 VDC, 12 VDC, 24 VDC, 36 VDC, and 48 VDC.

Figure 34: Power Converter

Operational Model

This chapter describes powering on, powering off, and the various modes of operation.

Operational States

At any given time, the RMP will be in one of the following operational states:

- Initialization
- Diagnostic Mode
- Bootloader Mode
- Standby Mode
- Tractor Mode
- Balance Mode
- Disable Mode
- DTZ Mode
- Off

Figure 35 shows how these states interact. Each of these states is discussed in more depth on the following pages.

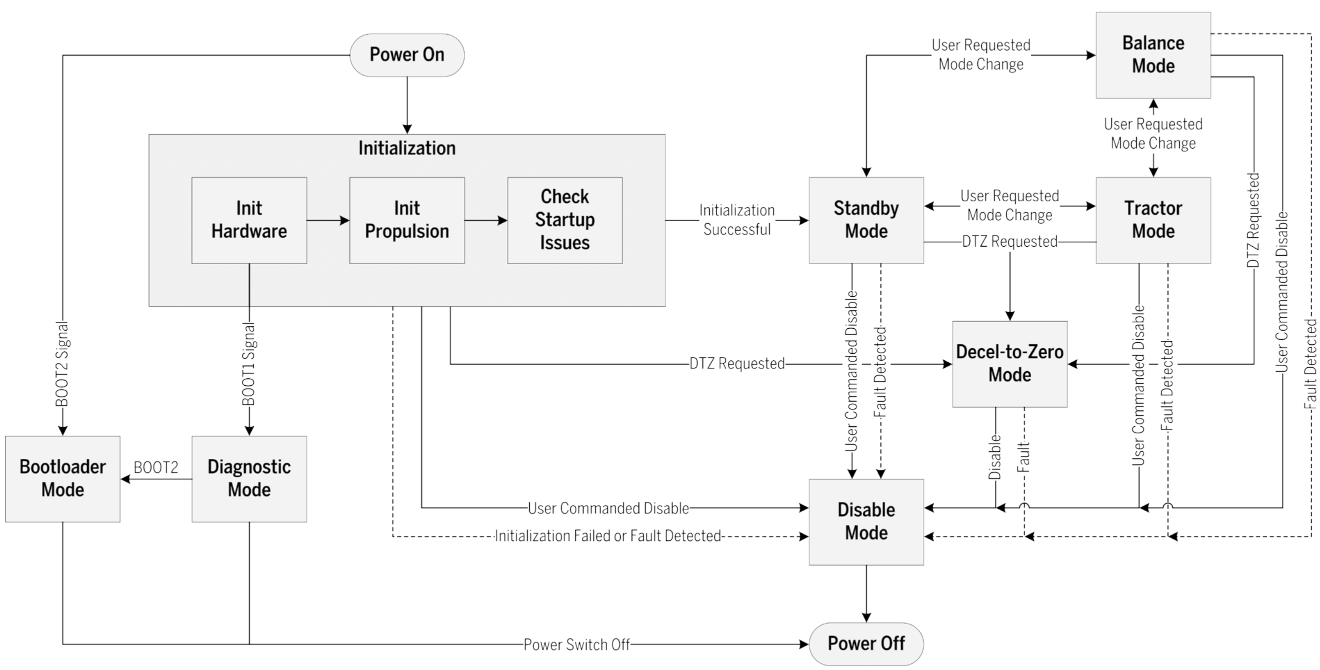


Figure 35: System State Diagram

Faults

Faults occur in response to events that impact the RMP. This could include anything from receiving a user-commanded DTZ signal to detecting a failed battery. Sometimes faults are the result of a problem that needs to be resolved. Other times they are merely informative.

In response to a fault the RMP may simply log the fault or it may take an action. There are four types of fault responses:

- No fault response — fault is logged. No change in RMP behavior.
- DTZ response — fault initiates a Decel To Zero. RMP comes to a stop, logs the fault, and maintains position. Transitions to Balance Mode or Tractor Mode are disabled.
- Disable response — fault causes RMP to power off. RMP logs the fault and powers off immediately.
- Disable MCU response — fault causes a single MCU to go down. RMP will continue to balance (if applicable) and hold position.

Initialization

Initialization is composed of three sub-states: Init Hardware, Init Propulsion, and Check Startup Issues. First, the control hardware is initialized; this includes the CCU and ABB. Then, the propulsion system is initialized (the MCUs and BSA). If there are no issues with the system, the RMP transitions to Standby Mode. Otherwise it shuts down.

If the BOOT1 or BOOT2 signal is pulled low the RMP will enter Diagnostic Mode or Bootloader Mode, respectively.

Init Hardware

During Init Hardware, the following steps are performed:

1. UIP and SP initialize hardware, interrupts, and software.
2. UIP and SP synchronize their timing.
3. UIP-SP communication is established.
4. SP reads configuration parameters from NVM, initializes dependent data, and passes the parameters to the UIP for UIP dependent data initialization.
5. UIP and SP verify configuration validity.
6. SP extracts the faultlog from NVM and relays the faultlog array to the UIP for user access.

Init Propulsion

During Init Propulsion the SP initializes each MCU using a state machine. Each state verifies a certain MCU operational status. If any MCU is not operating as expected, the RMP will transition to Disable Mode and power off. Information regarding the failure is stored in the faultlog.

Check Startup Issues

In this sub-state the SP checks for various parameters that will gate entry to Standby Mode. When the RMP detects an issue, Standby Mode entry is gated and the RMP will emit a tone and blink the LEDs for five seconds before failing initialization. If the issue is corrected in this time, the transition to Standby Mode will be allowed.

The following issues will gate transition to Standby Mode:

- An MCU declares a fault.
- The RMP is charging (this can be overridden: refer to the *RMP V3 Interface Guide*).
- An MCU battery open circuit voltage is below the operational threshold.
- An MCU battery state of charge is below the operational threshold.
- 7.2 VDC battery (if present) has low or high voltage.
- Any detected machine motion (RMP moving un-commanded).
- Tractor mode request is present from the user.
- BSA communication has not been established.

Diagnostic Mode

In Diagnostic Mode the RMP stays in the Init System state without transitioning to Standby Mode. In this mode the RMP has initialized the CCU and ABB, but has not initialized propulsion. The user can communicate with the RMP but cannot command it to move. This mode allows the user to update configuration parameters and extract the faultlog without fully initializing the RMP; this is useful when a fault causes the RMP to shutdown before entering Standby Mode.

In this state the RMP will remain on as long as power is available.

To enter Diagnostic Mode:

1. Turn the RMP off.
2. Connect pins D and E on the 6-pin connector (Connector II).
3. Turn the RMP on.

This will pull the BOOT1 signal low. The RMP will begin initialization but will stop at Init System and remain there.

Bootloader Mode

In Bootloader Mode, the RMP remains in the bootloader stage without continuing on to the RMP applications. The user can then load new applications into either of the processors using the Bootloader Application (refer to *RMP Applications*).

In this state the RMP will remain on as long as power is available.

To enter Bootloader Mode:

1. Turn the RMP off.
2. Connect pins D and F on the 6-pin connector (Connector II).
3. Turn the RMP on.

This will pull the BOOT2 signal low. The RMP will stop at the bootloader stage without loading any applications or beginning initialization.

Standby Mode

In Standby Mode the RMP is fully functional with the exception that motion commands are not executed. The MCUs are enabled, the controllers are initialized, and the RMP is holding its position. Any motion commands issued will not be executed by the platform.

Standby mode is entered automatically after successful initialization. From here the user can initiate a transition to tractor mode or disable the RMP.

Tractor Mode

In Tractor Mode the RMP will accept motion commands from the user. In this mode the RMP can be commanded to move. The MCUs are enabled and the controllers are running. Motion commands issued by the user will be accepted.

Tractor Mode can only be entered from Standby Mode as the result of a user mode request (refer to the *RMP V3 Interface Guide*). From here the user can initiate a transition back to Standby Mode or can disable the RMP.

Balance Mode

In Balance Mode the RMP will balance on two wheels and will accept motion commands from the user. The RMP's actions in Balance Mode are not always intuitive. For more information see "Balancing," p. 21.

Balance Mode can be entered from both Standby Mode and Tractor Mode as a result of a user mode request (refer to the *RMP V3 Interface Guide*) or by sending a hardware Boot1 signal (see Diagnostic Mode, above). From here the user can initiate a transition to Standby Mode, Tractor Mode, or Disable Mode.

Disable Mode

⚠ WARNING!
When the RMP powers off it may continue to move (for example, it could roll downhill). This could cause serious personal injury and property damage.

⚠ CAUTION!
If the RMP is in Balance Mode, entering Disable Mode will cause the RMP to fall over.

In Disable Mode the RMP performs housekeeping functions and then powers off. In this mode the propulsion drives are disabled and all user commands are ignored.

In this mode the following actions are performed:

1. Drives are disabled via software and hardware.
2. The RMP broadcasts a shutdown message on the UDP broadcast address for that subnet (e.g. 10.66.171.255). The shutdown message is a single 32-bit number "0x8756BAEB".
3. The RMP waits for some time to allow any connected computers to shut down.
4. The ABB shuts down the protected +72 V output.
5. The processors go into reset.
6. The RMP powers off.

Disable Mode can be entered at any time via user command (refer to the *RMP V3 Interface Guide*). Some faults will also cause a transition to Disable Mode.

Decel To Zero (DTZ) Mode

In DTZ Mode, the RMP decelerates at the DTZ Decel Rate (refer to the *RMP V3 Interface Guide*) until it reaches zero velocity (no movement). The RMP beeps and holds position indefinitely until the RMP is powered off. In this mode, all motion commands are ignored.

DTZ Mode can be entered at any time via user command (refer to the *RMP V3 Interface Guide*) or by connecting pins A and C on Connector II. Some faults will also cause a transition to DTZ Mode.

To exit DTZ Mode the RMP must power off. This can be achieved via the power button, a disable request, or the disable button.

Charging

⚠ **WARNING!**
Do not plug in the charger if the charge port, power cord, or AC power outlet is wet. You risk serious bodily injury or death from electric shock as well as damage to the RMP.

⚠ **CAUTION!**
Failure to charge the batteries could result in damage to the batteries. Left unplugged, the batteries could fully discharge over time, causing permanent damage. Use only charging devices approved by Segway.

⚠ **CAUTION!**
Do not connect or disconnect the External Power Supply while it is powered ON. Doing so could damage the RMP.

The RMP 220 requires the External Power Supply to charge the batteries. This power supply converts AC power to DC power for use by the RMP. The Smart Charger Board inside the RMP distributes this power as needed to the batteries for charging.

Charging requires the temperature to be within 10°–50° C (50°–120° F) and the humidity be <90%, non-condensing.

Using the External Power Supply

An External Power Supply is supplied with the RMP.

The charge port (Connector IV) is located on the interface panel next to the Charger Status LEDs.

1. Make sure the ambient temperature is between 10°–50° C (50°–120° F) and humidity is less than 90% non-condensing.
2. Make sure the RMP is powered off.
3. Connect the External Power Supply to the charge port on the RMP (Connector IV).
4. Plug the power cord into the IEC connector on the External Power Supply and into a grounded AC outlet (100 – 240 V, 50 – 60 Hz).
5. Toggle the power switch on the External Power Supply to the ON (I) position.
6. Charge new batteries for 12 hours. To fully charge in-use batteries, charge for about two hours.
7. When charging is complete, toggle the power switch to the OFF position, unplug the External Power Supply from the grounded AC outlet, and disconnect the External Power Supply from the RMP.

Table 8: External Power Supply Input/Output

Characteristic	Value
Input Voltage	100 – 240 VAC, 50 – 60 Hz
Input Current	12 A Maximum
Output Voltage	57 – 95 VDC
Output Current	2.1 A per channel

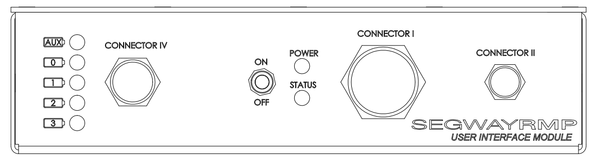


Figure 36: User Interface Panel

Figure 37: External Power Supply

Charge Status LEDs

There is one LED for each 72 V Segway battery attached to the RMP. When charging, the LEDs turn green. If a battery is at maximum charge, its LED blinks. See Table 9 for a complete list of what the LEDs indicate.

NOTICE
The RMP 220 only has three batteries: Batt 1, Batt 2, and AUX. All other Charge Status LEDs will remain red.

NOTICE
If the RMP is already charging and the RMP is powered on, the RMP will error and turn itself off. This is to prevent users from turning on the RMP and driving it away while it is still plugged in. This functionality can be changed by modifying the settings via dynamic_reconfigure. For more information, refer to *http://wiki.ros.org/dynamic_reconfigure*.

Table 9: Battery LEDs

LED Status	Meaning
Off	Battery is not charging.
Green	Battery is charging.
Green Blinking	Battery in balance mode. The time between blinks gets longer as the cells come into balance.
Red	Fault or battery not present.
Red Blinking	Charging fault. See "Charging Faults," p. 58.

Powering On/Off

Powering On

The RMP can be turned on and off using the push button mounted on the interface panel.

When successfully powered on, the RMP enters Standby mode, which is indicated by a blinking yellow LED and a solid green LED.

To power on the RMP:

1. Make sure the disable button is connected and has not been pressed.
2. Press and hold the On/Off button for 2 seconds.
3. Wait for the RMP to enter Standby mode.

NOTICE
If the red LED blinks rapidly and then turns off, double-check the disable button (see "Troubleshooting," p. 53).

Table 10 shows the various operational modes and LED indicator patterns.

Table 10: Indicator LEDs

Mode	Power LED	Status LED
System Initialization	Yellow Blinking	Off
Standby Mode	Yellow Blinking	Green Solid
Tractor Mode	Yellow Blinking	Green Blinking
Balance Mode	Yellow Blinking	Green Blinking, Rapid
Bootloader Mode	Yellow/Red Toggling	Off
Diagnostic Mode	Red Blinking, Sync'd	Green Blinking, Sync'd
Reset Processors	Red Blinking Rapid	Off
Disable Power	Red Solid	Off

Powering Off

When the RMP powers down, it broadcasts a shutdown message on the UDP broadcast address for that subnet (e.g. 10.66.171.255). The shutdown message is a single 32-bit number "0x8756BAEB".

⚠ **WARNING!**
When the RMP powers off it may continue to move (for example, it could roll downhill). This could cause personal injury and/or property damage.

Table 11: Power Down Methods

Method	Resulting Behavior
User commanded Power Down	The machine will send a power down signal to any connected computers, wait 30 seconds for them to shut down, and then turn off the auxiliary power.
User commanded Disable	The RMP logs the disable request as a fault and powers down.
On/Off button pressed for 2 seconds	The machine will send a power down signal to any connected computers, wait 30 seconds for them to shut down, and then turn off the auxiliary power.
Disable button is pressed	The RMP logs the disable button press as a fault and powers down.
Hardware DTZ input	The RMP comes to a stop, logs the DTZ Input as a fault, and powers down.

NOTICE
- A fault response may also result in the machine powering off.
- Auxiliary power is provided for use with a computer. After the on/off button is pressed the system will wait 30 seconds before removing auxiliary power. This time is set so a connected computer can safely shut down.

Connecting

This chapter describes how to connect to the RMP. Included are the pinouts for all the panel connectors as well as instructions on how to set up an Ethernet connection with the RMP.

Connector I

Connector I is the largest external connector on the RMP. This approximately 2-inch diameter connector is a MIL-DTL-38999/24FJ4SN socket with 56 pins. Mating connector is a MIL-DTL-38999/26FJ4PN plug. It houses all the communication interfaces to the platform and provides power available for customer loads.

Power available is dependent upon which Power Converters have been selected. Power is only available when the auxiliary battery option is included.

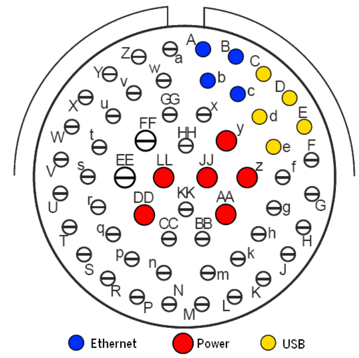


Figure 38: 56-Pin Connector

Table 12: Connector I Pinout

Pin	Signal
A	ETHERNET TX+
b	ETHERNET TX–
B	ETHERNET RX+
c	ETHERNET RX–
C	USB_VBUS
D	USB_D+
d	USB_D–
E	USB_ID
e	USB_GND

Pin	Signal
y	POWER_1+
z	POWER_1–
AA	POWER_2+
JJ	POWER_2+
DD	POWER_2–
LL	POWER_2–

Power

The auxiliary battery feeds up to two Power Converters in the RMP 220. At time of purchase, the customer has the option to select the output voltage of the Power Converters. Possible options are: 5 VDC, 12 VDC, 24 VDC, 36 VDC, and 48 VDC. One of the options selected must be 12 VDC, in order to power the CCU.

Specifics about the regulation, available current, and available power can be found by reviewing the datasheet for the 72 V micro family DC/DC regulators from Vicor (*http://cdn.vicorpower.com/documents/datasheets/ds_72vin-micro-family.pdf*).

Available DC voltages:

- 5 V
- 12 V
- 24 V
- 36 V
- 48 V

There are multiple slots for Power Converters. One slot must be 12 VDC; all others may be chosen from the above options at time of purchase.

Table 13: Power Pinout (16 AWG Contacts)

Wire Color	Voltage	Connector I Pin
Red	Power1+	y
Green	Power1– (Return)	z
Purple	Power2+	AA
	Power2+	JJ
Yellow	Power2– (Return)	DD
	Power2– (Return)	LL

⚠ **CAUTION!**
When a 5 V power converter is present it is always installed on Power2. When drawing 10 Amps or more over the 5 V line, be sure to use both pairs of wires. Failure to use both pairs of wires could result in damage to the RMP.

Connector II

This panel connector provides pins for the disable button, the DTZ (Decelerate To Zero) signal, and for entering Bootloader mode and Diagnostic mode. During normal operation, the #DISABLE_5V signal must be pulled up to +5 V by connecting pins A and C, which is what the provided Disable Button achieves. Otherwise the RMP will fail the startup check and fault. For more information on these signals see "Operational Model," p. 33, and "Hardware Controls," p. 45.

This is a MIL-DTL-38999/24FB98SN socket. Mating connector is a MIL-DTL-38999/24FB98PN plug.

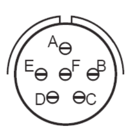


Figure 39: 6-Pin Connector

Table 14: Connector II Pinout

Signal	Pin
+5 V	A
DTZ_REQUEST	B
#DISABLE_5V	C
DGND	D
BOOT1	E
BOOT2	F
Chassis Ground	Housing

Disable Button

The Disable Button is a normally-closed pushbutton that attaches to Connector II. When the RMP boots up, it checks if the #DISABLE_5V signal has been pulled up to +5 V. The Disable Button achieves this by connecting pins A and C. If the #DISABLE_5V signal is not pulled up to 5 V(e.g. the Disable Button is absent or has been pressed), the RMP immediately powers down.

Figure 40: Disable Button

Additional Signals

This connector can also be used with a custom harness to send DTZ requests (by connecting pins A and B) as well as Boot1 (pins D and E) and Boot2 (pins D and F). Boot1 is used for entering diagnostic mode. Boot2 is used for entering bootloader mode. For more information see "Operational Model," p. 33, and "Hardware Controls," p. 45.

Boot1 also doubles as a Balance Mode toggle on balancing platforms.

Connector IV

This connector is used in conjunction with the External Power Supply. Charging is accomplished by connecting the External Power Supply to the RMP and then plugging the External Power Supply into a standard AC outlet. The pinout for this connector is provided for completeness.

For more information on charging see "Using the External Power Supply," p. 37.

This is a MIL-DTL-38999/24FD19PA plug. Mating connector is a MIL-DTL-38999/26FD19SA socket.

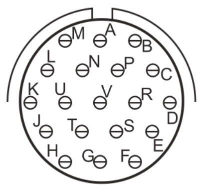


Figure 41: 19-Pin Connector

Table 15: Connector IV Pinout

Signal	Pin
DC+1	B
GND1	P
DC+2	M
GND2	N
DC+3	J
GND3	U
DC+4	G
GND4	T
DC+5	E
GND5	R
Not Connected	A, C, D, F, H, K, L, S, V

Ethernet Connection

The RMP has a 10 Mbps Ethernet connection.

When connecting to a router, configure the RMP like any other device with a static IP address.

When connecting directly to a computer:

- Computer IP address and RMP base address must match, but computer and RMP must have unique addresses.
- Computer subnet and RMP subnet must match.
- Computer gateway and RMP gateway must match.

See Table 17 for recommended computer settings.

The RMP uses UDP port 8080 to communicate over the Ethernet connection. The port number is user-configurable (refer to the *RMP V3 Interface Guide*). The RMP sends and receives data on that port, so a connected computer must send and receive data on the same port as the RMP.

The RMP will only connect to one host computer at a time. A 30-second communication timeout is required when changing hosts.

The RMP will respond to ICMP ping requests.

When the RMP powers down, it broadcasts a shutdown message on the UDP broadcast address for that subnet (e.g. 10.66.171.255). The shutdown message is a single 32-bit number "0x8756BAEB".

Table 16: Default RMP Ethernet Settings

Parameter	Default Value
IP Address	10.66.171.5
Port	8080
Subnet Mask	255.255.255.0
Gateway	10.66.171.1

Table 17: Recommended Computer Settings

Parameter	Default Value
IP Address	10.66.171.100
Subnet Mask	255.255.255.0
Gateway	10.66.171.1

Internal Connections

This section describes the hardware connections inside the Segway RMP enclosure. Some of these connections are used within the RMP for internal communication between components. Other connections are for external communication and can be used to control the RMP. Additional connections are for sending power between components.

Hardware Controls

The RMP is designed to accept hardware Disable and DTZ requests in case of emergency. A Disable request immediately cuts power to the motor drives and turns off the RMP. A DTZ request decelerates the RMP and brings it to a stop, but remains powered on. These modes can also be set via software commands (refer to the *RMP V3 Interface Guide*). CCU J8 provides connections for both signals.

Table 18: CCU J8

J8 Pin	Name
1	+5 V
2	DECEL_REQUEST
3	#DISABLE_5V
4	DGND

Hardware Disable

On the CCU there are four optically isolated outputs (J2, J3, J4, and J5) which allow for control of the hardware disable function on the MCUs inside the Segway powerbases.

Table 19: MCU Hardware Disable

CCU J2, J3, J4, J5	Name
1	Collector (more positive)
2	Emitter (more negative)

The MCUs have a weak pull up resistor such that if the disable input is allowed to float, the MCU will immediately stop providing power to the motors. The CCU prevents this from occurring during normal operation by powering up the diode inside the opto-coupler and thereby connecting the collector to the emitter.

Control of the opto-couplers is accomplished by two different methods:

Method 1 — Internal Segway Logic

At any point if the Segway processor logic needs to immediately disable the system it can do so by releasing one of its DIO lines. This will stop current flowing and prevent the opto-couplers from pulling down on the disable input.

Method 2 — External Disable Signal

The opto-coupler is powered by Pin 3 of J8. +5 V must be provided to Pin 3 of J8 continuously to prevent the CCU from disabling the motor drives. Conveniently, +5 V is provided as an output from the CCU on Pin 1 of J8. Therefore, it is possible to connect a normally closed switch between Pin 3 and Pin 1 to control the disable response. This allows for the simple connection of a Disable Button (such as the one provided with the RMP).

Hardware DTZ

A Decel To Zero (DTZ) can be initiated in hardware via Pin 2 of J8 on the CCU. This signal is normally pulled low by a 10K Ohm resistor. If this pin is pulled up to +5 V then the system will immediately begin to decelerate. The rate of deceleration is set in software; refer to the *RMP V3 Interface Guide*.

Conveniently, +5 V is provided on Pin 1 of J8, allowing the user to easily connect a normally open momentary type switch between Pin 2 and Pin 1 of J8 and control the deceleration request. Segway has found this useful when connecting some types of remote control disable systems.

After the RMP has stopped moving, it will hold position and remain powered on.

Mode Selection

The CCU defaults to normal operation, however, for the purpose of fault troubleshooting or for reloading code the user can change the mode. Mode selection is via CCU J1.

Table 20: CCU J1

J1 Pin	Name	Function
1	BOOT1	Diagnostic Mode
2	BOOT2	Bootloader Mode
3	GND	Ground

Normal Operation

With Pin 1 and Pin 2 both floating, the CCU operates normally. Connecting either Pin 1 or Pin 2 after the system is running will have no effect.

Diagnostic Mode

Connecting Pin 1 to Pin 3 sends the BOOT1 signal. If connected at startup, the CCU will enter Diagnostic mode. For details, see "Diagnostic Mode," p. 35.

Bootloader Mode

Connecting Pin 2 to Pin 3 sends the BOOT2 signal. If connected at startup, the CCU will enter Bootloader mode. For details, see "Bootloader Mode," p. 35. If both pins 1 and 2 are connected to pin 3 (ground), the CCU will enter Bootloader mode.

Status Indicators

There are two status indicators on the CCU that are intended to be connected to LEDs (the Power LED and the Status LED on the UI Panel). On the UI Panel, the Power indicator is a bicolor yellow/red LED and the Status indicator is a green LED. For information on the indicator LEDs and what their patterns mean see "Powering On," p. 39. Status indicators are connected at CCU J16.

Table 21: Status Indicators

J16 Pin	Name
3	Power Indicator (Yellow bicolor LED)
4	Status Indicator (Green LED)
5	Power Indicator (Red bicolor LED)
12	Ground

Coin Cell Battery

The coin cell battery on the CCU maintains power to the Real-Time Clock (RTC). If the battery is removed while the RMP is powered off, the RTC will reset. This battery is not user replacable. Removing this battery will result in zeroing the clock and will void your warrantee.

Maintenance

To ensure that your RMP continues to function optimally, please follow these routine maintenance guidelines.

⚠ WARNING!

- Failure to heed these warnings could lead to death, serious injury, or property damage.
- Before performing any maintenance, verify that the Segway RMP is unplugged and powered off. It is not safe to perform maintenance while the RMP is powered on or charging: the RMP could move unexpectedly.
- Use only Segway approved fasteners on the RMP. Other fasteners may not perform as expected and may come loose.
- Always use thread lock on fasteners to keep them from coming loose.
- Insert fasteners slowly and carefully. Do not cross-thread or over-tighten fasteners. Tighten only to the prescribed torque.
- Do not attempt to repair any stripped or damaged screw hole. Instead, replace the part. If a replacement part is not available, do not reassemble.

Fastener Torque

⚠ CAUTION!

Adhere to torque specifications when tightening fasteners. Over-tightening or under-tightening fasteners can result in malfunction or damage to the RMP.

Periodically check the fastener torques. Fastener torque specifications are provided in Table 22.

Table 22: Fastener Torque Specifications

Fastener Location	Fastener Type	Drive Type	Torque
Wheel Nut	M8 Flange Nut	13 mm Hex	35 N-m
Hub Adapter	M10 x 22 SHCS	8 mm Hex	30 N-m
Battery	M4 x 30 SHCS	3 mm Hex	1.6 N-m
Enclosure Cover	M5 x 10 FHCS	3 mm Hex	3 N-m
Enclosure to Bracket	M6 x 12 SHCS	5 mm Hex	6 N-m
Bracket to Rail	M8 x 25 SHCS	6 mm Hex	10 N-m
Gearbox	M8 x 34 SHCS	T45 Torx	40 N-m
Mounting Plate	M8 x 25 SHCS	6 mm Hex	30 N-m
Tube Frame	M8 x 45 SHCS	6 mm Hex	40 N-m
Powerbase Cover	M6 x 25 SHCS	5 mm Hex	10 N-m

Tire Pressure

Ideal tire pressure for the supplied tires depends on both the surface being driven across and the payload being carried. Because every situation is different, Segway recommends keeping the tire pressure within the range of 6–15 psi. Do not allow the tire pressure to exceed what's stated on the sidewall of the tire. For best results, tire pressure should be adjusted to match the payload and the environment. In general, lower pressures increase traction and roll damping and higher pressures increase range and roll stiffness.

To ensure that the RMP tracks straight, both tires must be inflated to the same pressure.

When inflating tires to a different pressure, be sure to update the tire diameter (refer to the *RMP V3 Interface Guide*). The tire diameter is used internally when calculating velocity, acceleration, position, and differential wheel speed.

Table 23: Tire Pressure

Payload	Tire Pressure
0 lbs (0 kg)	6 psi
50 lbs (20 kg)	10 psi
100 lbs (45 kg)	12 psi
200 lbs (90 kg)	15 psi

Parts List

Use the diagram and table below to identify part names and numbers.

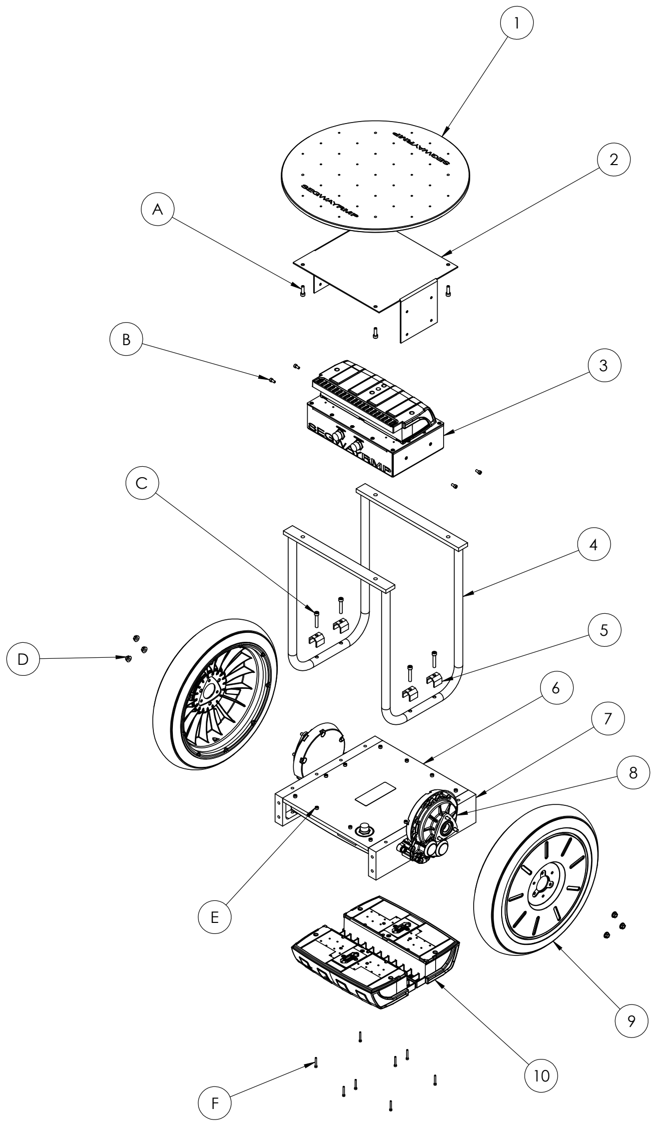


Figure 42: RMP 220 Parts Breakdown

Table 24: Components, 220

Label	Name	Part No.	Description
1	Mounting Plate	23366-00001	22 in.
2	Bracket	23379-00001	U-Bracket
3	Enclosure	23271-00001	UI Module
4	Tube Frame	23262-00001	21 in.
5	Clamp	23263-00001	Standard
6	Powerbase	23088-00001	2MB
7	Rail	23172-00001	Standard
8	Gearbox	20919-00002	Standard
9	Wheel Assembly	20162-00004	Tire and Hub
10	Battery	20967-00001	Li-ion

Table 25: Fasteners, 220

Label	Fastener Location	Part No.	Description
A	Mounting Plate	23368-00002	M8 x 25 SHCS
B	Enclosure to Bracket	23091-00004	M6 x 12 SHCS
C	Tube Frame	23368-00001	M8 x 45 SHCS
D	Wheel Nut	20158-00001	M8 Flange Nut
E	Powerbase Cover	23091-00002	M6 x 25 SHCS
F	Battery	20541-00002	M4 x 30 SHCS

Removing Wheel Assemblies

Tool Required: 13 mm socket wrench

1. Make sure the RMP is powered off and unplugged.
2. Raise the RMP up so the tires are not touching the ground.
3. Use a 13 mm socket wrench to remove the three wheel nuts (Figure 43).
4. The tire/hub assembly can now be removed.

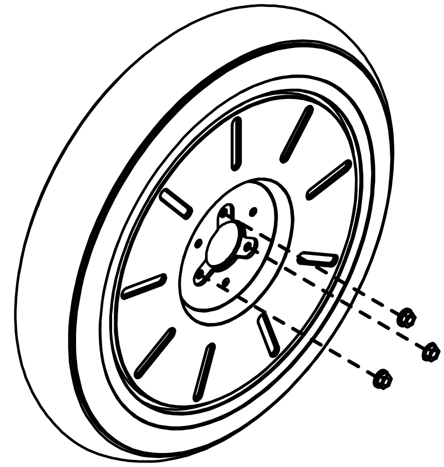


Figure 43: Wheel Nut Locations

Replacing Wheel Assemblies

Tools Required: 13 mm socket wrench
Torque wrench

1. Make sure the RMP is powered off and unplugged.
2. Raise the RMP up off the ground.
3. Slide the tire/hub assembly onto the gearbox flange so the three fasteners on the gearbox flange fit through the holes in the tire hub.
4. Install the three wheel nuts using a torque wrench with a 13 mm socket head and tighten to **35.0 N-m (25.8 ft-lbf)**.

Cleaning

WARNING!
Do not use a power washer or high pressure hose to clean your RMP. Use of these devices could force water into components that must stay dry. See "Safety," p. 8, for more information. Failure to do so could expose you to electric shock, injury, burns, or cause a fire.

The outside of the RMP can be cleaned by scrubbing with soap and water to remove any dirt and grime. Avoid getting water in the connectors. Do not submerge in water.

If the inside of the RMP needs to be cleaned, contact Segway (see "Contact Information," p. 6). Do not use water or any liquid cleaning agents inside the enclosure.

Software Updates

Periodically, Stanley Innovation releases new software updates for the RMP V3. Checking for new software updates should be included as part of your regular platform maintenance schedule. New software may improve performance and/or change how the RMP V3 functions. Always read the release notes prior to upgrading. Some upgrades may require an update to the PC side ROS drivers as well.

To stay notified on new software updates you can “watch” the software on Github. Simply sign in to Github.com then navigate to *https://github.com/StanleyInnovation* and select the software you'd like to be notified for. When it is updated you will automatically get a notification via email. Stanley Innovation recommends signing up for *https://github.com/StanleyInnovation/segway_v3_embedded_firmware* which is the code that runs on the platform.

Instructions for loading new firmware can be found at *http://wiki.ros.org/Robots/RMPv3*

Batteries

A pair of propulsion batteries mount to the bottom of the powerbase. An auxiliary battery mounts to the enclosure.

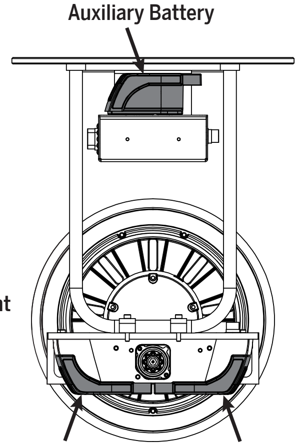


Figure 44: Battery Locations, 220

Battery Care

In order to keep your Segway batteries performing at their best, fully charge the batteries for at least 12 hours before the first use. Charge the batteries after each use or once every eight hours of operation — whichever comes first. Charge your batteries only when they are within the specified charging temperature range (see Table 26). When not in use, you may leave the RMP charging; the RMP contains smart charging logic that will maintain the battery over time.

When storing the RMP, charge the batteries once a month. When storing spare batteries, or storing batteries not attached to the RMP, charge them once every six months.

⚠ **CAUTION!**
Failure to charge the batteries could result in damage to the batteries. Left unplugged, the batteries could fully discharge over time, causing permanent damage.

Table 26: Lithium-ion Battery Specifications

Characteristic	Value
Charging Time	
Before First Use	12 hours
Recharge From Empty	~2 hours
Temperature Ranges	
Operating	32° F – 122° F (0° C – 50° C)
Charging	50° F – 122° F (10° C – 50° C)
Storage and Transport	-4° F – 122° F (-20° C – 50° C)
General	
Capacity (Ah) and Voltage	5.2 Ah, 73.6 volts
Dimensions	14 in x 7.5 in x 3.2 in (35.7 cm x 19 cm x 8.2 cm)
Weight	11.4 lbs (5.1 kg)

Replacing Batteries

Whenever you replace a propulsion battery, consider replacing all propulsion batteries. Replacing only one battery will not necessarily increase the performance or range of your Segway RMP because it is designed to operate only at the level allowed by the lower-energy battery. Therefore, you should replace all propulsion batteries together (except in the unusual situation where a battery is replaced because of damage or defect and the others are relatively new).

Installation and Removal Instructions

⚠ **WARNING!**
Unplug or disconnect your Segway RMP from AC power before removing or installing batteries or performing any service. It is hazardous to work on any part of your RMP when it is plugged into AC power. You risk serious bodily injury from electric shock as well as damage to your RMP.

Install and remove the batteries in a dry location only.

Removing Batteries

Tool required: 3 mm hex wrench.

1. Tip the RMP onto its side so one wheel lies flat against a clean, smooth surface.
2. Use a 3 mm hex wrench to remove the fasteners (four per battery).
3. Pull the batteries straight off the chassis.

Installing Batteries

⚠ **CAUTION!**
Replace battery fasteners every time a battery is installed. Use only Segway-approved fasteners. Failure to replace fasteners jeopardizes the watertight seal of the RMP. To avoid risk of damage, do not use power tools.

NOTICE
Do not cross thread or over-tighten fasteners. Tighten only to the prescribed torque. To avoid risk of damage, do not use a power tool to thread in or tighten fasteners. Use only Segway-approved fasteners.

Tools required: 3 mm hex wrench.
Torque wrench

1. Tip the RMP onto its side so one wheel lies flat against a clean, smooth surface.
2. Seat the batteries on the chassis with the curved edge facing the outside of the chassis.
3. Secure the batteries to the chassis with fasteners (four per battery, install center fasteners first) and tighten with a 3 mm hex wrench. Torque fasteners to **1.6 N-m (14 in-lbf).**

Transportation and Shipping

Lithium-ion batteries are regulated as "Hazardous Materials" by the U.S. Department of Transportation. For more information, contact the U.S. Department of Transportation at *http://www.phmsa.dot.gov/hazmat/regs* or call 1-800-467-4922. See "Transportation and Shipping," p. 19.

Proper Disposal

The Li-ion batteries used in the Segway RMP can be recycled. Recycle or dispose of batteries in accordance with local environmental regulations. Do not place in fire or incinerate. For more information, contact Segway at 1-866-4SEGWAY (1-866-473-4929), or visit our website at *http://rmp.segway.com*.

Troubleshooting

This section covers common problems and their solutions.

Reporting Problems to Segway

The RMP forum (*http://rmp.segway.com/forum*) is the best way to contact Segway about troubleshooting issues and problems. See "Contact Information," p. 6. Please search the forum before posting; your issue may have been discussed previously.

To ensure a prompt and helpful response from Segway, please include the following when posting to the forum:

- Upload a copy of the faultlog. See "Extracting the Faultlog" below.
- Explain what you were doing when the fault occurred.
- What is the model number of your RMP?
- How much mass (weight) was on the RMP?
- What surface/slope was the RMP on?
- What were the environmental conditions (temperature/humidity)?
- Have you modified the RMP?

Extracting the Faultlog

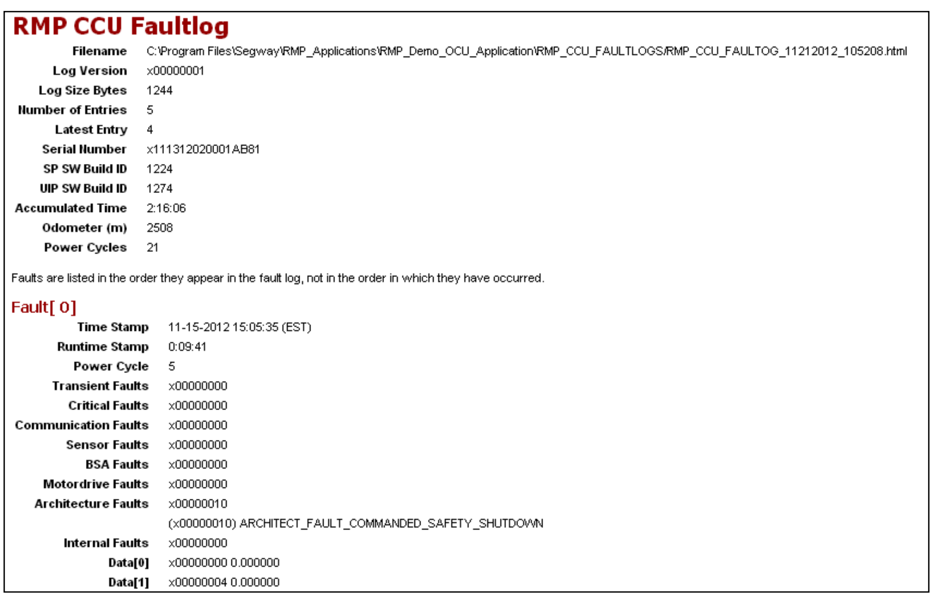
See the Faultlog Instructions on the ROS wiki at *http://wiki.ros.org/Robots/RMPv3/indigo/troubleshooting*

Reading the Faultlog

The faultlog is arranged with a header at the top and the 20 most recent faults below. The first fault logged is recorded as Fault[0], the second fault as Fault[1] and so on until the 20th fault is recorded as Fault[19]. At this point there are no empty slots remaining in the faultlog, so the 21st fault overwrites Fault[0]. Similarly, the 22nd fault overwrites Fault[1] in the log. This process continues indefinitely so that only the latest 20 faults are present in the log.

For your convenience the latest entry is listed in the header. In the example below the latest entry is 4, so Fault[4] is the most recent fault.

If a fault provides more information, that information is available in Data[0] and Data[1]. Often these contain bitmaps which can be decoded to provide additional information.



RMP CCU Faultlog

Filename	C:\Program Files\Segway\RMP_Applications\RMP_Demo_OCU_Application\RMP_CCU_FAULTLOGS/RMP_CCU_FAULTOG_11212012_105208.html
Log Version	x00000001
Log Size Bytes	1244
Number of Entries	5
Latest Entry	4
Serial Number	x111312020001AB81
SP SW Build ID	1224
UIP SW Build ID	1274
Accumulated Time	2:16:06
Odometer (m)	2508
Power Cycles	21

Faults are listed in the order they appear in the fault log, not in the order in which they have occurred.

Fault[0]

Time Stamp	11-15-2012 15:05:35 (EST)
Runtime Stamp	0:09:41
Power Cycle	5
Transient Faults	x00000000
Critical Faults	x00000000
Communication Faults	x00000000
Sensor Faults	x00000000
BSA Faults	x00000000
Motordrive Faults	x00000000
Architecture Faults	x00000010
	(x00000010) ARCHITECT_FAULT_COMMANDED_SAFETY_SHUTDOWN
Internal Faults	x00000000
Data[0]	x00000000 0.000000
Data[1]	x00000004 0.000000

Figure 45: Faultlog Example 1

Faults

Descriptions of the most common faults are provided below. These descriptions may provide sufficient information for users to solve problems on their own. As always, if you need help please see "Reporting Problems to Segway," p. 53.

The RMP stores all faults in four 32-bit fault status words. Fault status is transmitted as part of the RMP response (refer to the *RMP V3 Interface Guide*).

CRITICAL_FAULT_INIT_PROPULSION

There is a problem initializing the propulsion system. Make sure everything is properly connected, the batteries are charged, and the RMP is resting on a level surface.

CRITICAL_FAULT_FORW_SPEED_LIMITER_HAZARD

System speed exceeds the user-defined forward limit. If speed limit is set to zero and RMP is moved, you may see this fault.

CRITICAL_FAULT_AFT_SPEED_LIMITER_HAZARD

System speed exceeds the user-defined reverse limit. If speed limit is set to zero and RMP is moved, you may see this fault.

CRITICAL_FAULT_CHECK_STARTUP

There was a fault during startup. The output of Data[0] indicates the specific fault that occurred.

Table 27: Startup Faults

Data[0]	Meaning
0x00000001	One of the MCUs has faulted.
0x00000002	The RMP is plugged in and the "Check AC Present" flag is set.
0x00000004	Low battery voltage — attempt to charge the system.
0x00000008	Low battery voltage — attempt to charge the system.
0x00000010	The system must be stationary during startup. Movement was detected.

CRITICAL_FAULT_APP_VELOCITY_CTL_FAILED

This indicates that the RMP is moving at a different speed than what was commanded for a period of time. This can occur if you are commanding zero velocity while towing the RMP.

CRITICAL_FAULT_ABB_SHUTDOWN

This indicates that the ABB experienced a fault. The response will include four bitmaps: ABB Status, Battery Hazards, Battery Faults, and Build ID. All four of these bitmaps are packed into the two Data bitmaps in the faultlog. They are arranged as such:

ABB Status	Data[0] High
Battery Hazards	Data[0] Low
Battery Faults	Data[1] High
Build ID	Data[1] Low

The following tables provide the bitmaps for ABB Status (Data[0] High) and Battery Hazards (Data[0] Low). If Battery Faults (Data[1] Low) is anything other than 0x0000, contact Segway to purchase a replacement battery.

The mask for ABB Status Bitmap is 0x1FFF000 on Data[0].

Table 28: ABB Status Bitmap (Data[0] High)

Bit	Name	Description	Action
0x0000	ABB_OK	ABB is operational.	None.
0x0001	BCU_COMM_INIT_TIMEOUT	The ABB was not able to start communications with the battery BCU.	Check ABB connection to battery.
0x0002	LOW_BATTERY_SOC	The battery State Of Charge is lower than 5%.	Charge the battery.
0x0004	LOW_BLOCK_VOLTAGE	Battery has detected low block voltage internally on one of its banks.	Charge the battery. If this error occurs frequently, replace the battery.
0x0008	BATTERY_IS_HOT	The internal battery temperature is too high for operation.	Turn off the RMP and let the battery cool down.
0x0010	BATTERY_IS_COLD	The internal battery temperature is too low for operation.	Turn off the RMP and warm the battery up.
0x0020	INTERNAL_BCU_FAULT	Internal Battery Control Unit fault.	Replace the battery.
0x0040	LOW_PACK_VOLTAGE	Battery pack voltage has dropped below its operating range.	Charge the battery.
0x0080	ABB_OVER_CURRENT	ABB has detected that the current draw has exceeded the fuse rating for a period of time.	Reduce external load. Check for shorts.
0x0100	BCU_LINK_FAILED	Communication between the ABB and the BCU has failed.	Check the connection between the ABB and battery.
0x0200	ABB_HIT_INTERNAL_FAULT	The ABB has reached points in the software it should not.	Report to Segway.
0x0400	ABB_HOST_COMMANDS_ SHUTDOWN	The Host has commanded the ABB to shutdown.	None. If it was unintentional check the host code.
0x0800	ABB_GOING_TO_SHUTDOWN	A condition has triggered the ABB to shutdown.	Check the condition in this bitmap.
0x1000	AC_IS_PRESENT	The ABB has detected that a charger is connected and charging the battery.	This is informational only.

The mask for Battery Hazards is 0x0000EE00 on Data[0].

Table 29: Battery Hazard Bitmap (Data[0] Low)

Bit	Name	Description	Action
0x0000	BCU_NO_HAZARD	ABB is operational.	None.
0x0200	BATTERY_COLD_CHARGE_ LIMIT_HAZARD	The battery is too cold to charge.	Move the battery to a warmer place to charge.
0x0400	BCU_BATTERY_COLD_HAZARD	The battery is too cold to operate.	Turn off the RMP and warm the battery up.
0x0800	BCU_BATTERY_COOL_HAZARD	The battery is approaching the threshold for cold operation.	Move the battery to a warmer place.
0x2000	BCU_BATTERY_LOW_BLOCK_ VOLTAGE_HAZARD	A battery bank voltage has dropped below its operating range.	Charge the battery. If this error occurs frequently, replace the battery.
0x4000	BCU_BATTERY_HOT_HAZARD	The internal battery temperature is too high for operation.	Turn the RMP off and let the battery cool down.
0x8000	BCU_BATTERY_WARM_ HAZARD	The battery is approaching the threshold for hot operation.	Move the battery to a cooler place.

SENSOR_FAULT_7P2V_VBAT_RANGE_FAULT

The voltage differential between the two cells in the 7.2 V battery exceeds the allowed threshold. Replace the battery.

SENSOR_FAULT_7P2V_VBAT_INBALANCE_FAULT

Something is wrong with the 7.2 V battery. Charge the RMP for 24 hours. If the error persists, replace the battery.

SENSOR_FAULT_7P2V_BATT_TEMPERATURE_FAULT

Battery temperature has gone outside the recommended range. See the RMP operating temperature range ("Environmental Specifications," p. 17). Physically inspect the battery for damage.

BSA_FAULT_SIDE_A_RATE_SENSOR_SATURATED

The RMP has exceeded the acceleration rate threshold (0.7 g). If driving over rough terrain, do so more slowly.

BSA_FAULT_SIDE_B_RATE_SENSOR_SATURATED

The RMP has exceeded the acceleration rate threshold (0.7 g). If driving over rough terrain, do so more slowly.

BSA_FAULT_SIDE_A_TILT_SENSOR_SATURATED

The RMP has exceeded the tilt rate threshold (6.2 rad/s). If driving over rough terrain, do so more slowly.

BSA_FAULT_SIDE_B_TILT_SENSOR_SATURATED

The RMP has exceeded the tilt rate threshold (6.2 rad/s). If driving over rough terrain, do so more slowly.

ARCHITECT_FAULT_COMMANDED_DISABLE

The RMP received a user-commanded disable signal. Refer to the *RMP V3 Interface Guide*.

ARCHITECT_FAULT_COMMANDED_SAFETY_SHUTDOWN

The RMP received a user-commanded DTZ signal. Refer to the *RMP V3 Interface Guide*.

ARCHITECT_FAULT_DECEL_SWITCH_ACTIVE

The hardware DTZ button has been pressed.

ARCHITECT_FAULT_KILL_SWITCH_ACTIVE

The disable button has been pressed, or is not present.

ARCHITECT_FAULT_BAD_MODEL_IDENTIFIER

The wrong code is loaded in the machine. Check the serial number in the fault log header against the serial number on the RMP. The last 7 bits of the serial number on the RMP should match the last 7 bits of the serial number in the fault log.

MCU_TRANS_BATTERY_TEMP_WARNING

This fault occurs as the battery temperature approaches the limit. See the RMP operating temperature range ("Environmental Specifications," p. 17).

MCU_CRITICAL_BATTERY_TEMP

This fault occurs when the battery temperature reaches or exceeds the limit. See the RMP operating temperature range ("Environmental Specifications," p. 17). Physically inspect the battery for damage.

MCU_TRANS_BATTERY_COLD_REGEN

As temperature drops battery resistance increases, which in turn increases the current required for regeneration. The battery has a limit for regeneration current under low temperatures. Warm up the battery or move the RMP inside.

MCU_TRANS_BATTERY_LOW_BATTERY

The battery is low. Charge the battery.

MCU_TRANS_BATT_OVERVOLTAGE

The RMP will generate power when driving downhill. This fault occurs when the voltage approaches the threshold for damage.

MCU_CRITICAL_BATT_OVERVOLTAGE

⚠ **WARNING!**

Avoid contact with any substance seeping from the battery. Do not use battery if the battery casing is broken or if the battery emits an unusual odor, smoke, or excessive heat or leaks any substance.

Similar to MCU_TRANS_BATT_OVERVOLTAGE, the RMP will generate power when driving downhill. This fault occurs when the voltage reaches or exceeds the threshold for damage. Physically inspect the battery for damage.

MCU_COMM_CU_BCU_LINK_DOWN

A connection to the battery cannot be reliably established. Check to make sure the battery is properly connected and the fasteners are fully tightened. For proper torque see "Maintenance," p. 47.

MCU_JUNCTION_TEMP_FAULT

You may be overloading the RMP. Try reducing the payload mass. See "Performance Specifications," p. 17.

MCU_MOTOR_WINDING_TEMP_FAULT

The motor temperature has reached or exceeded the threshold for damage. Try reducing the payload mass. See the RMP operating temperature range ("Environmental Specifications," p. 17).

MCU_BATTERY_FAULT

The battery has an internal error. Replace the battery.

MCU_ACTUATOR_POWER_CONSISTENCY_FAULT

The RMP is operating at its limits. Reduce the performance parameters. Reduce the mass on the RMP.

Charging Faults

If the Charge Status LEDs blink red, there is a fault with the battery. The following table provides the meanings of the blink patterns and some suggested actions.

Table 30: Battery Charging Faults

LED Status	Meaning	Action
Red blink 1 time every 5 seconds.	HV input is out of range.	Check charger connection. If problem persists contact Segway.
Red blink 2 times every 5 seconds.	HV output is out of range.	Check connections to the powerbase.
Red blink 3 times every 5 seconds.	DC reference is out of range.	Contact Segway.
Red blink 4 times every 5 seconds.	Temperature is out of range.	Move the platform to a warmer or cooler area. If problem persists contact Segway.
Red blink 5 times every 5 seconds.	Output current is out of range.	Contact Segway.

Other Issues

RMP doesn't drive in a straight line.

Check the tire pressures on your RMP. Slight differences in pressure can cause changes in tire diameter, which can cause the RMP to track right or left.

RMP still doesn't drive straight.

If you are using a joystick or hand-held controller, check if it is sending slight yaw rate signals even when not commanded to. Some joysticks do not hold center very well and will continuously send small signals.

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