

# Startup Guide

## HRP Mower

### 1 Introduction

HRP stands for Husqvarna Research Platform and is a way for Husqvarna to provide an open robust robot platform for various research projects both within universities and industry.

This document describes how to setup and control a HRP Mower.

It also describes how you can install extra equipment inside the mower, and shows two examples for this using a Raspberry Pi and a BeagleBone Black.

If you are unfamiliar with robot mowers you can find how a normal installation is made in a garden here [Garden Installation](#).

A printed user manual is sent together with the machine. It can also be found here:

[Automower 430X User Manual](#)

### 2 Boundary Wire

The robot requires a boundary wire to define the cutting area.

The safety of the mower is guaranteed with the boundary wire. If the robot comes outside the boundary it will automatically stop. When running in the HRP mode the robot will stop after being about 10 seconds outside the boundary wire.

#### 2.1 Running the mower without boundary wire

When running the robot in a safe area indoors, it is possible to deactivate the boundary wire detection. This can be done in two different ways:

**Deactivating boundary wire from user interface:**

1. Activate the robot on the control panel by entering the pin code "1111".
2. Then enter menu.
3. Press the buttons 7 and 9 simultaneously for a few seconds. A new symbol



for the tools menu will be visible.

4. Enter the tools menu and select *special settings*.
5. Select *override loop detection*.

### Deactivating boundary wire via software interface

The simple remote control ROS node `hrp_teleop.py`, see chapter 4.4, implements a software deactivating of the loop.

## 3 Software Environment

With the software installed on a host computer with Linux and ROS you are able to both run a simulated environment and also remotely control the mower.

### 3.1 Install software on host computer

The software is developed to run under Linux with Ubuntu 16.04 and ROS Kinetic. The software also works under Ubuntu 14.04 and ROS Indigo.

Installations steps are:

- Unpack the latest delivery file, i.e. `hrp.2017-02-28-17-03.tar.gz` into the source folder of a catkin workspace (`tar -xvf [delivery file]`)

- Install dependencies

```
sudo apt-get install ros-indigo-gazebo-ros-control
sudo apt-get install ros-indigo-joint-state-controller
sudo apt-get install ros-indigo-hector-gazebo-plugins
sudo apt-get install ros-indigo-hector-gazebo
sudo apt-get install python-pygame
```

- Build all new ROS parts

```
catkin_make
```

- setup the model path:

```
export GAZEBO_MODEL_PATH=[the source folder]/hrp/am_gazebo/models:$GAZEBO_MODEL_PATH
```

### 3.2 Run simulated environment on host

- Start the simulation

```
roslaunch am_gazebo am_gazebo_hrp.launch gui:=true
```

- Launch keyboard control with

```
roslaunch am_driver hrp_teleop.py
```

- You can now hopefully drive around in the simulated garden in gazebo!

### 3.3 Installing software on target

The software is developed to run under Linux with Ubuntu 16.04 and ROS Kinetic. The software also works OK under Ubuntu 14.04 and ROS Indigo. Other Linux versions is likely OK also, but has not been verified by Husqvarna. Example of target boards which have been used by Husqvarna are: Beaglebone Black, Odroid XU4, Raspberry Pi2 and Raspberry Pi3.

The target software is a subset of the host software.

Installation steps:

- unpack and build the latest target software (file *hrp\_target.201XXXX.tar.gz*) on the target computer.
- make sure that the serialPort defined in the launch file (am\_driver\_safe/launch/automower\_hrp.launch) match that on your target computer.
- Unless you already have it, setup a WiFi-connection to the host so you can access the target computer. One possibility is to setup the target computer as an WiFi access point. It is also possible to use an Ethernet cable from target to host computer.

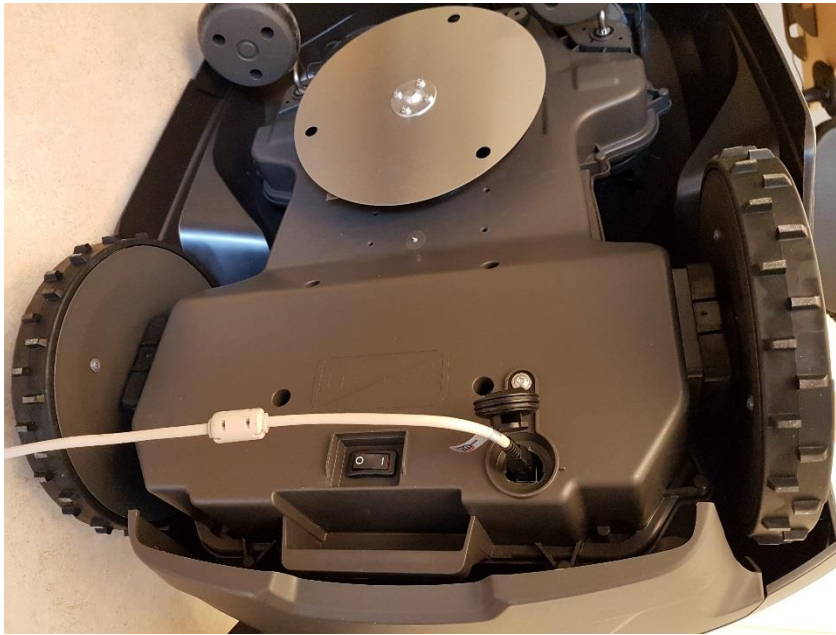
## 4 Remote Control Of Mower

The mower can be externally controlled from an external (host) LINUX computer. This can be done in two different ways:

### 4.1 USB-cable connection without target computer

It is possible to control the HRP mower directly from the host computer, without any modification of the mower. It shall be noted that Husqvarna has loaded the HRP mower with a special software version which opens up the external interface. A standard mower with original software is not possible to control in this way.

The USB cable is connected at the underside in the rear end, see *Figure 1*.



*Figure 1 USB cable connection*

**On the automower:**

- Turn on main power switch, or open lid to wake it up from standby.
- Enter pin code (1111)

**On the host computer:**

- In a terminal window start `am_driver` (make sure the correct USB-port is set as serial port in the launch file)

```
roslaunch am_driver_safe automower_hrp.launch
```

- In another terminal window start the keyboard control

```
roslaunch am_driver hrp_teleop.py
```

**On the automower:**

- Press Start button
- Close the lid

Now you can control the automower from the keyboard terminal. An overview of the system is shown in *Figure 2*.

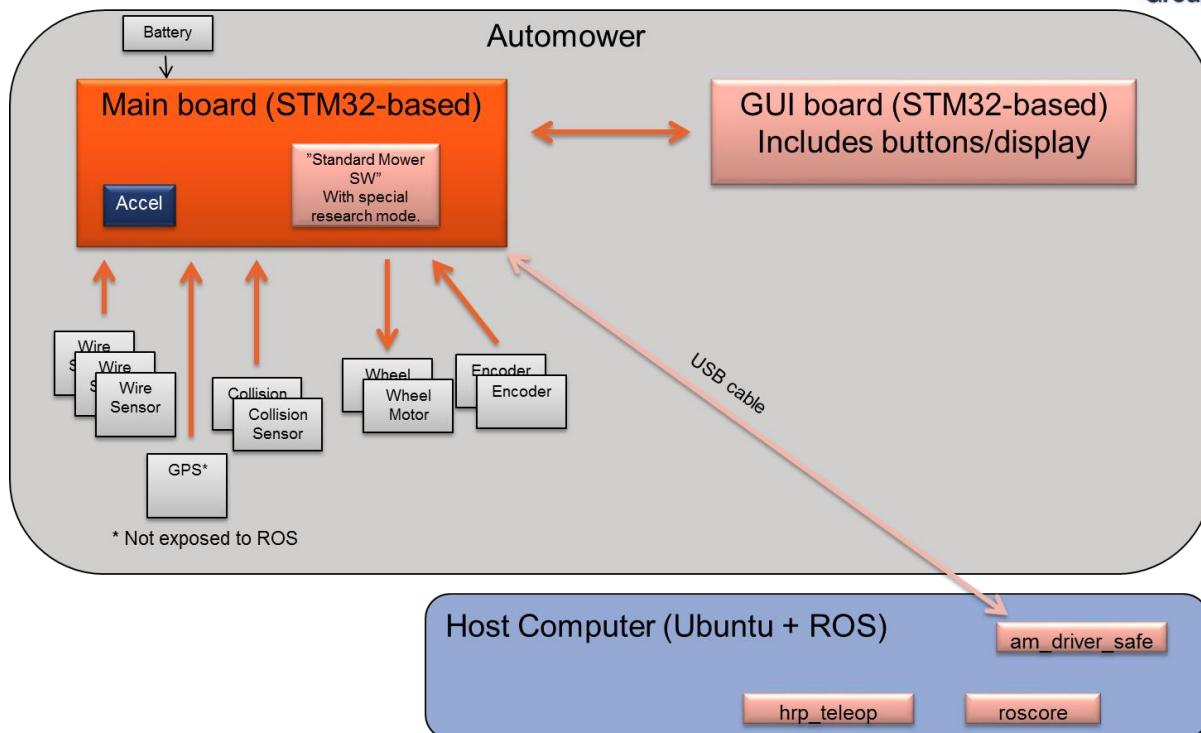


Figure 2 Remote controlling mower via USB

## 4.2 WiFi/Ethernet control of Linux system on target board mounted inside automower.

It is more practical to control the automower wireless with help of a target computer on the automower. To get a rugged implementation the target computer should be installed inside the mower. In chapter XX, you can find two examples of how this can be done. The system structure for this is shown in *Figure 3 Controlling mower with WiFi and target computer*. It is possible to add more sensors and ROS nodes in the system, as indicated with "Magic". You can also run the mower standalone without any host computer.

### On the automower:

- Turn on main power switch, or open lid to wake it up from standby.
- Enter pin code (1111)

### On the target computer:

In a terminal window start `am_driver` (make sure the correct port is set as serial port in the launch file)

```
roslaunch am_driver_safe automower_hrp.launch
```

### On the host computer:

- Tell host that ros master is on target by exporting correct ROS\_IP, ROS\_HOSTNAME and ROS\_MASTER\_URI

- Start the keyboard control

```
roslaunch am_driver hrp_teleop.py
```

### On the automower:

- Press Start
- Close the lid

Now you can wireless control the automower from the keyboard control. An overview of the system is shown in *Figure 3*.

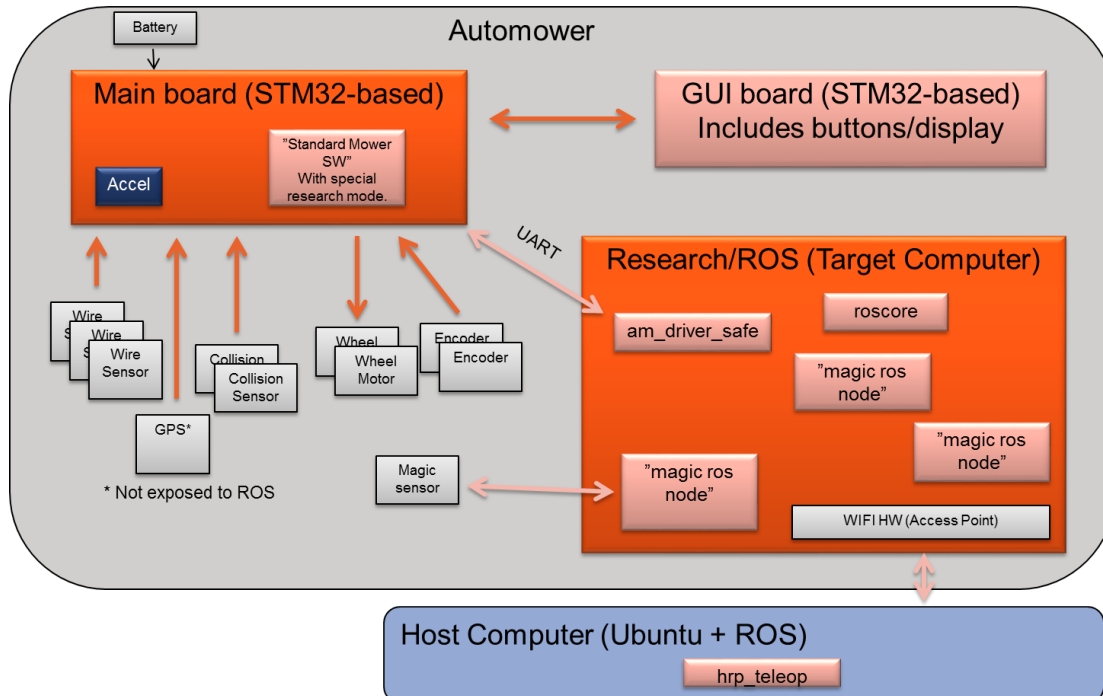


Figure 3 Controlling mower with WiFi and target computer

### 4.3 Node: am\_driver\_safe

**Description:** Interface to the Automower via serial port. It also implements a PID-regulator for controlling the wheel motors when the mower is manually controlled.

As long as this driver is communicating with the mower main board, the mower will not enter standby. If the battery charge level becomes too low, the mower will however shutdown anyway.

**Published topics:**

- /odom - position of robot given encoder data
- /loop - status of boundary loop sensors
- /sensor\_status - status of collision sensors
- /wheel\_encoder - ticks read from the automower
- /battery\_status - voltage and current for the Li-Ion battery in the automower.

**Subscribed topics:**

- /cmd\_vel - speed to assign to mower (linear and angular)
- /cmd\_mode - mode of control for mower

### 4.4 ROS node hrp\_teleop

**Description:** A simple ROS node to control the automower from keyboard. It is run in a terminal window, and all keys are explained in the printout. It communicates with the automower by publishing topics which am\_driver\_safe listens to and then sends to the automower.

**Published topics:**

- /cmd\_vel - speed to assign to mower (linear and angular)
- /cmd\_mode - mode of control for mower

**Subscribed topics:**

- /sensor\_status - status of collision sensors
- /battery\_status - voltage and current for the Li-Ion battery in the automower.

## 5 Power Options

### 5.1 Power alternatives

When adding a target computer and different sensors to the mower you want to access power from the automower. This can be done either by connecting to internal auxiliary connectors or accessing Battery Power directly. In *Table 1* you have an overview of the different options. The two alternatives are described in detail in the following sections.

See chapter 7.1, for how to disassemble the automower, to access the interior.

Voltage	Connector	Max Current	Common limits	Main Switch Controlled	Protection
5V	AUX1, AUX2, AUX3, AUX4, MMI:AUX5	750 mA	Total Max 750 mA	Yes	Fast Logic
3.3V	AUX1,AUX2, AUX3,AUX4,MMI:AUX5	400 mA, 400-750 mA (3,2V)		Yes	Fast Logic
~18 V	AUX1,AUX2, AUX3,AUX4	1000 mA	Total max 1000 mA	Yes	Fast Logic
~18 V	MMI:AUX5/MMI Solder	1000 mA	N/A	Yes	Slow SMD Fuse 2A
~18 V	Main Board Solder	5000 mA, mowing 10000 mA, no mowing	N/A	No	Battery Protection Circuit

Table 1 Internal Power options

### 5.2 Auxiliary connectors

There are 5 different auxiliary connectors in the automower from which power can be fetched. Common for all of these are that power is only available when the automower is powered on. If the automower is left passive for more than **XX** minutes, it will automatically go down to standby mode, and the power to the auxiliary connectors are shutdown.



The pinout of the micro-Match connector for AUX1 to 5 is:

Pin	Signal
1	UART_TX
2	UART_RX
3	GND
4	AUX_GPIO
5	3.3 V, max 400 mA
6	5 V, max 750 mA
7	18 V, max 1000 mA
8	GND

Table 2 AUX connector pinout

### Auxiliary Connectors on mainboard

There are 4 auxiliary connectors (AUX1 – AUX4) on the mainboard, see *Figure 4*.

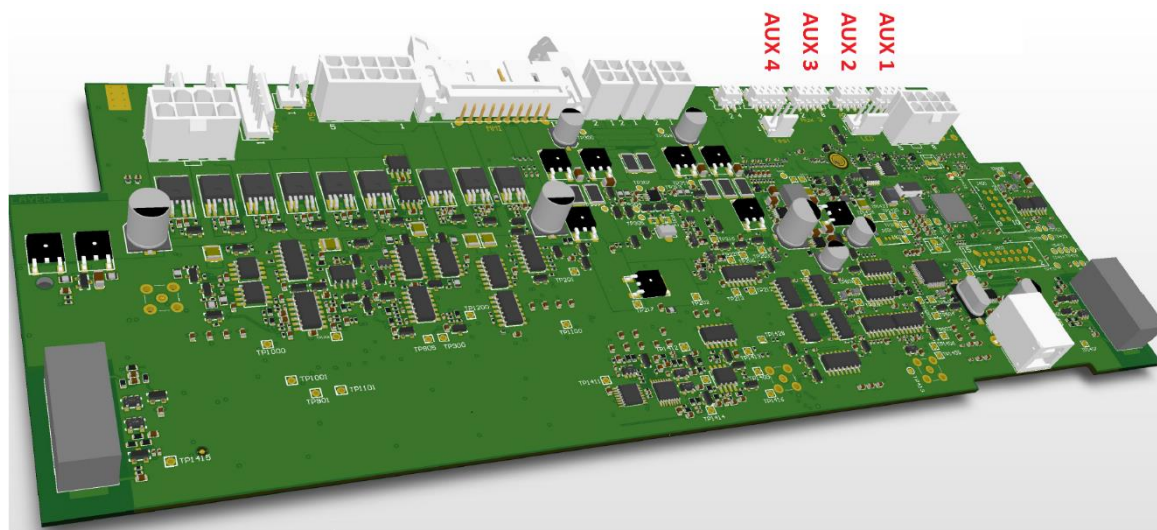


Figure 4 Aux connectors on mower main board

From these it is possible to take.

5V, max 750 mA, max 750 mA in total for all AUX connectors.

18V, max 1000 mA, max 1000 mA in total for AUX1-AUX4 connectors.

These power outlets has a built in current protection which will shut down both 5V and 18V if one of them is overloaded. Note that the response is quite fast, so even a short

transient will cause the supply to be shutdown.. The automower needs to be restarted with the main switch if the current protection is activated.

### Auxiliary Connectors on mmi board

There is one auxiliary connector, AUX5, on the MMI board. The MMI board is located below the display. Available supplies:

5V, max 750 mA, max 750 mA in total for all AUX connectors.

~18V, max 1000 mA, (varies from 16-21 V due to charge level of battery)

The 5V share the same protection logic as the AUX1-AUX4, see above.

The 18V is protected by a slow SMD 2A fuse on the main board. If this fuse is broken, the SMD need to be replaced on the main board.

In the 430x mower is the GPRS/GPS board connected to AUX5.

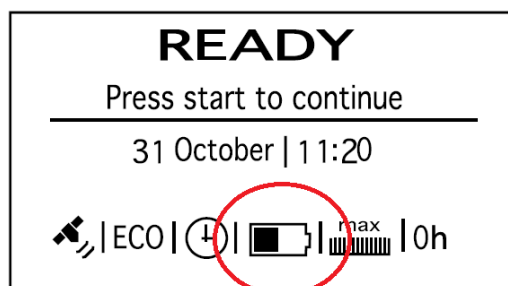
## 5.3 Powering directly from the battery

If you need access to high power or you want to have power at all times, even when the mower has entered standby mode, you can connect directly to battery power. To do so you need to solder to wires directly to the mainboard. See *Figure 5*, for the location of these. It is recommended to add an extra power switch for this. In section 7.3 you can find an example of this type of installation. The voltage will vary from 16 to 21 V, depending on battery charge level. It is recommended to install some kind of DC/DC converter to get stable voltage at your required level.

The Robot has internal Li-Ion batteries. These are charged when the mower is parked in the charging station. The Raspberry Pi is powered directly from the internal Li-ion batteries. Power is activated with the extra “Pi Power” switch, see below.

This means that the power to the Pi is independent of the Mower Power.

The charge level of the batteries can be checked in the mower control panel. It is also available as a voltage level in the topic Battery\_status. It is also visible in the hrp\_teleop node.



If you run the mower for too long time without charging there is risk to drain the batteries to a too low level. With fully charged batteries the mower can run about two hours without charging.

Note that the standard mower electronics are surveying the battery voltage and will in case of low battery voltage do one of two things:

- Go back to charging station, if the mode is set to *random*.
- or
- Stop and shut down main power for mower electronics. Note that the power directly from the battery will still be on. **To prevent draining the batteries you must shut down your internal equipment . If the battery voltage drop too low the charging station will not charge the mower.**

If you have installed an extra switch is also possible to power only you extra equipment. If doing so outside the charging station the same restriction applies. Meaning: **Don't power you equipment to long outside the charging station . If the battery voltage drop too low the charging station will not charge the mower.** The available time depends on the power consumption. A 430X has a Li-ion battery of nominal 18V and 5,2Ah.

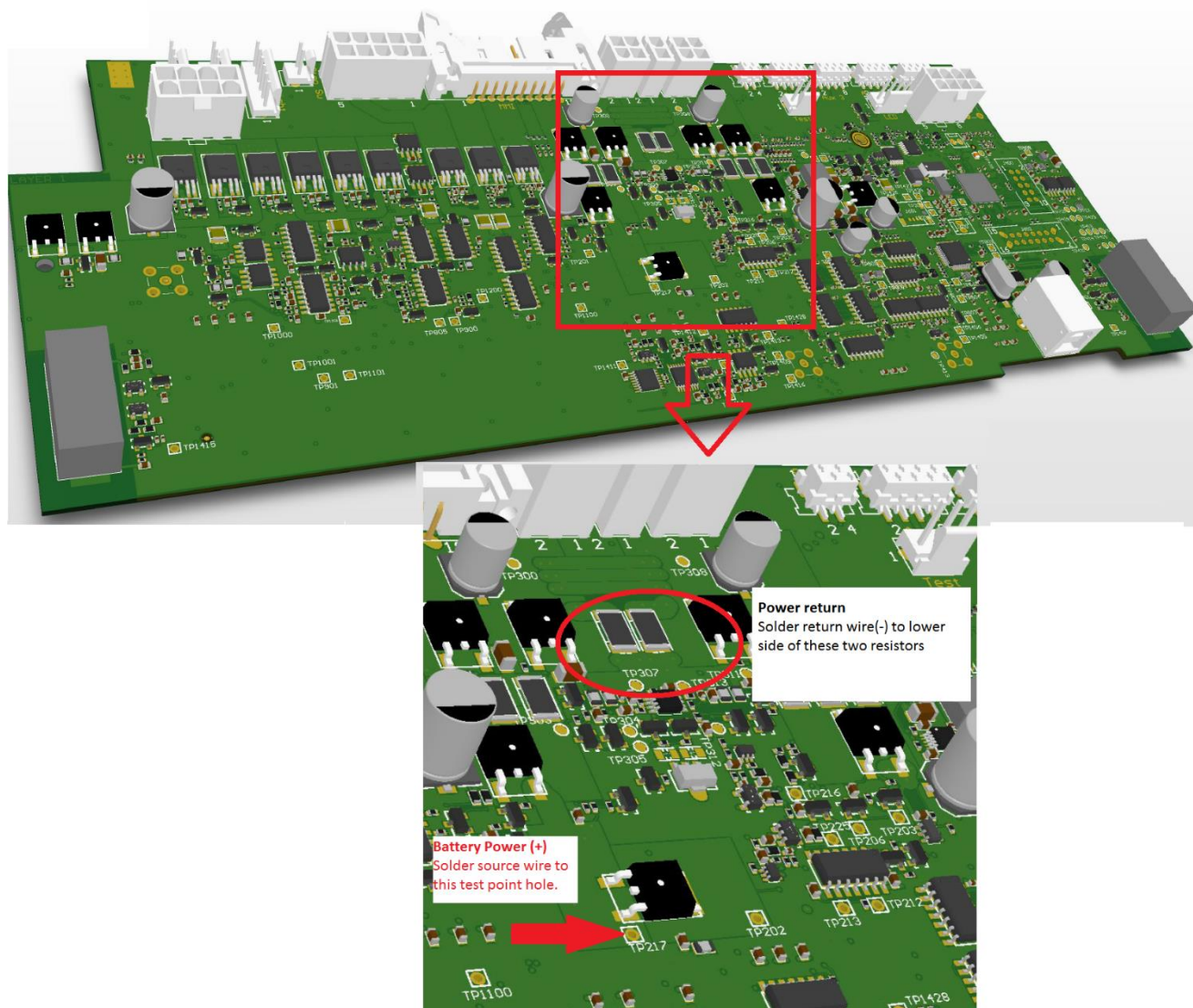


Figure 5 Soldering points for direct access to battery power.

## 6 Cutting blades

The cutting blades on the HRP mower are very sharp if you use the mower for other tests then cutting grass, we recommend you to remove them, to prevent anyone getting injured.

## 7 Installation examples

### 7.1 Overview

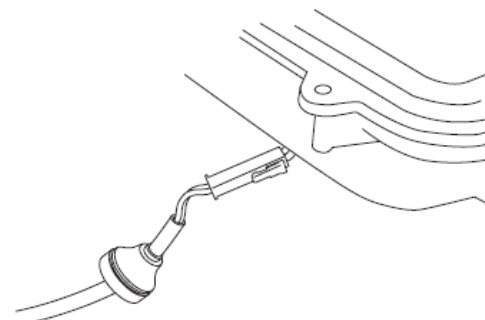
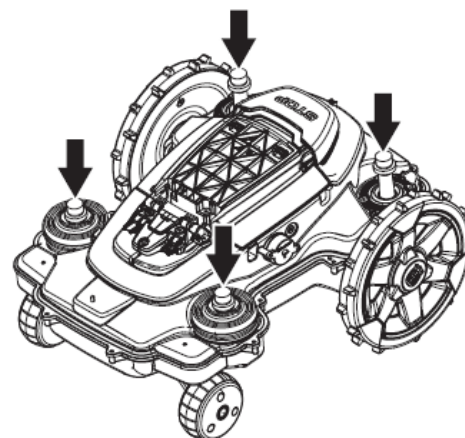
In this chapter two different examples of target computer installation will be shown. Common for both examples are that you need to access the interior of the mower. Below is a cutout from the manual describing how to disassemble the mower:

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#### Disassembling the body

The body is fitted to the chassis using four quick-mounted, snap-on brackets. The charging cable fastened to the body's contact plate must be uncoupled so that the body can be completely removed from the chassis.

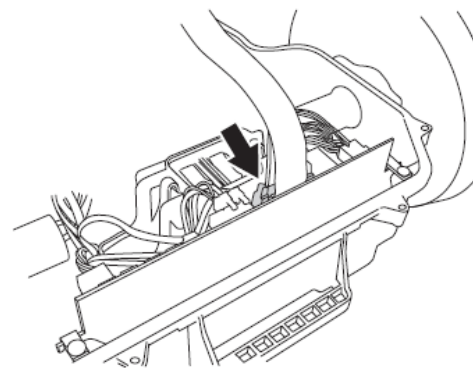
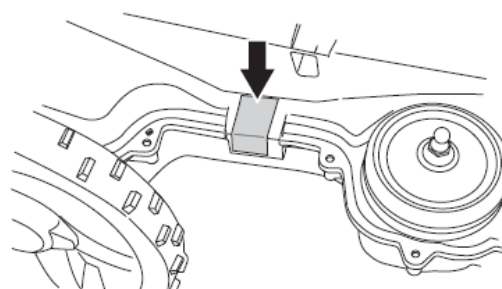
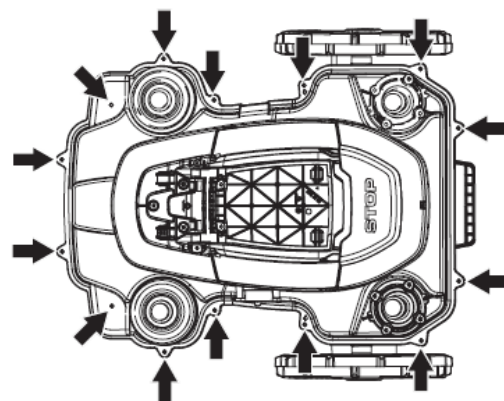
1. Set the main switch to position 0.
2. Clean the area around the grommet for the charging cable found at the very front under the mower.
3. Pull out the rubber grommet on the charging cable and carefully loosen the connector.
4. Loosen the body from the chassis by lifting the body one corner at a time while holding the chassis in place.





## Dismantling the chassis

1. Loosen all 14 screws (Torx 20).
2. Remove the guarantee seal at the point of separation between the chassis halves on the right-hand side.
3. Carefully lift the back edge of the upper section of the chassis.
4. Disconnect the MMI cable from the main circuit board and remove the upper section of the chassis.



## 7.2 Example 1 - BeagleBone Black installation

For this installation we use the following:

- BeagleBone Black
- 16 GB SD card memory
- 8 wire ribbon cable
- 8-pin Micro-MaTch connector, [7-215083-8](#)
- DC plug (optional)
- Connectors to expansion connector P9 on Beaglebone.
- ASUS WiFi-adapter [USB-N13](#)

The ribbon cable is prepared with a Micro-MaTch connector in one end.

The pinout of the AUX4 is:

AUX4 Pin	Signal
1	UART_TX
2	UART_RX
3	GND
4	AUX_GPIO
5	3.3 V, max 400 mA
6	5 V, max 750 mA
7	18 V, max 1000 mA
8	GND

The used pins On the Beagle Bone connector P9 are:

BeagleBone Black Connector P9	Signal
1,2	GND
5,6	VDD_5V
11	RX
13	TX

The ribbon cable is connected to Beagle Bone Black as follows:

(Power can be connected to DC jack or via P9)

Wire 1 => P9:11	Mower Tx => BBB Rx
Wire 2 => P9:13	BBB Tx => Mower Rx
Wire 3 => P9:1	GND
Wire 4 not connected	
Wire 5 not connected	
Wire 6 => P9:5 or to DC-plug +	5V
Wire 7 not connected	
Wire 8=> P9:8 or to DC-plug -	GND

The installation is shown in *Figure 6*. In this installation is the power to the beagle bone connected via a Power plug.

A complete software installation for this configuration is available as a disk image. This image has a complete setup of linux Ubuntu 14.04, ROS Indigo and a version of the HRP software.

The disk image is named `bb_image_hrp_2017-03-06.img.tar.gz`.

To use this you must have a SD card of 16GB, or larger and the specified WiFi-adapter from Asus. The image is copied with the linux dd command to the SD card.

After installing this to the SD-card the BeagleBone Black will act as an Wifi-spot with the SSID HVA\_BBB\_AP. The key is "1234567890".

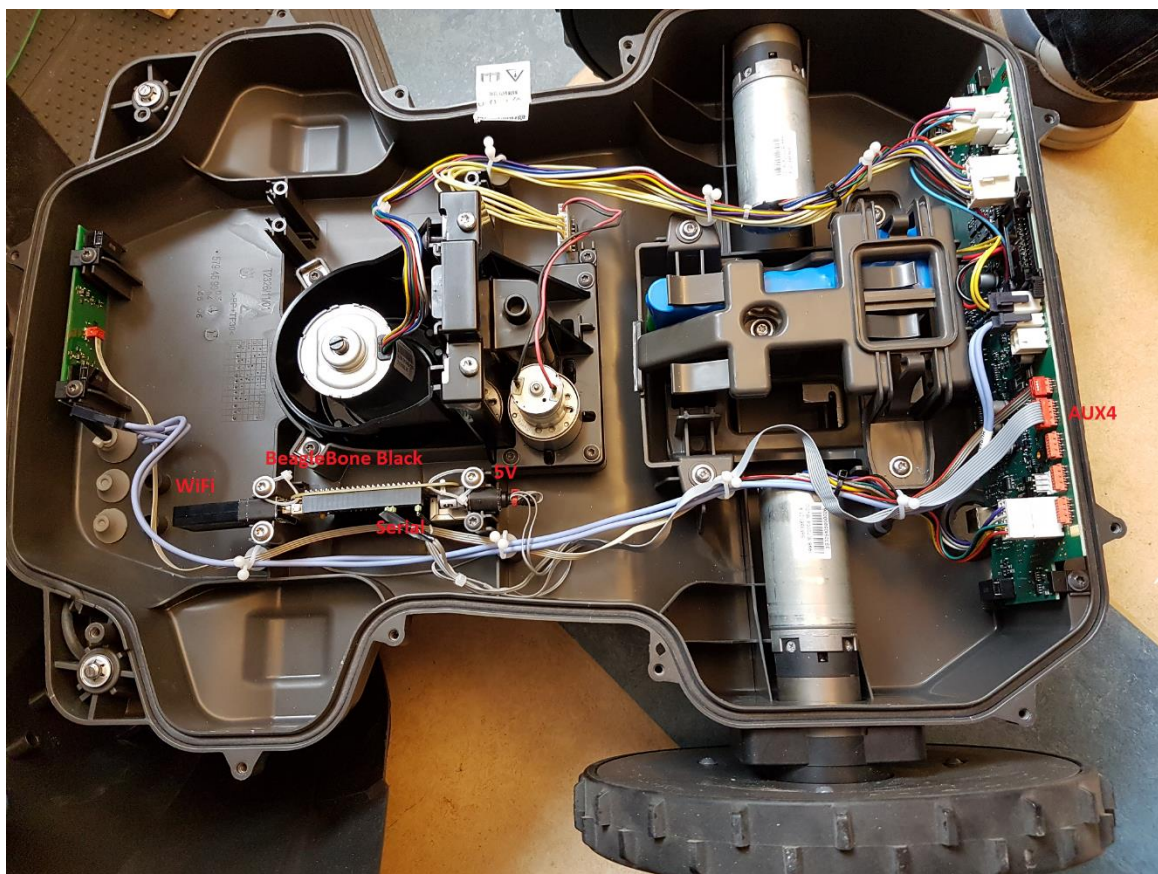


Figure 6 Beagle Bone Black installation

## 7.3 Example 2 - Raspberry Pi installation

For this installation we used the following:

- Raspberry Pi2
- WiFi USB-dongle - WiPi
- DC/DC-converter 5V, 9A, [www.pololu.com/product/2866](http://www.pololu.com/product/2866)
- USB to UART converter, FTDI, with cable.
- 8-pin Micro-MaTch connector, [7-215083-8](http://www.pololu.com/product/7-215083-8)
- USB cable for powering the Raspberry Pi
- Connection cables.
- Power switch, same type as the Mower Power.



An extra power switch is mounted by making a whole in the plastic cover.

The DC/DC converter is connected to Battery Power via the extra power switch, by soldering directly on the main board, see chapter 5.3. 5V output from the DC/DC is connected to the mini-USB connector on the Raspberry Pi.

The serial communication to the mainboard is accomplished by connecting an FTDI (USB to UART converter) on one of the USB-ports on the Raspberry Pi. The other end of this cable (Rx, Tx and GND signals, is wired to a Micro-MaTch connector. The pinout is found in *Table 2*. This is then connected to the AUX3 connector on the mainboard. (Any of the four different AUX connectors can be used).

The WiFi dongle is connected to a USB port on the Raspberry Pi.

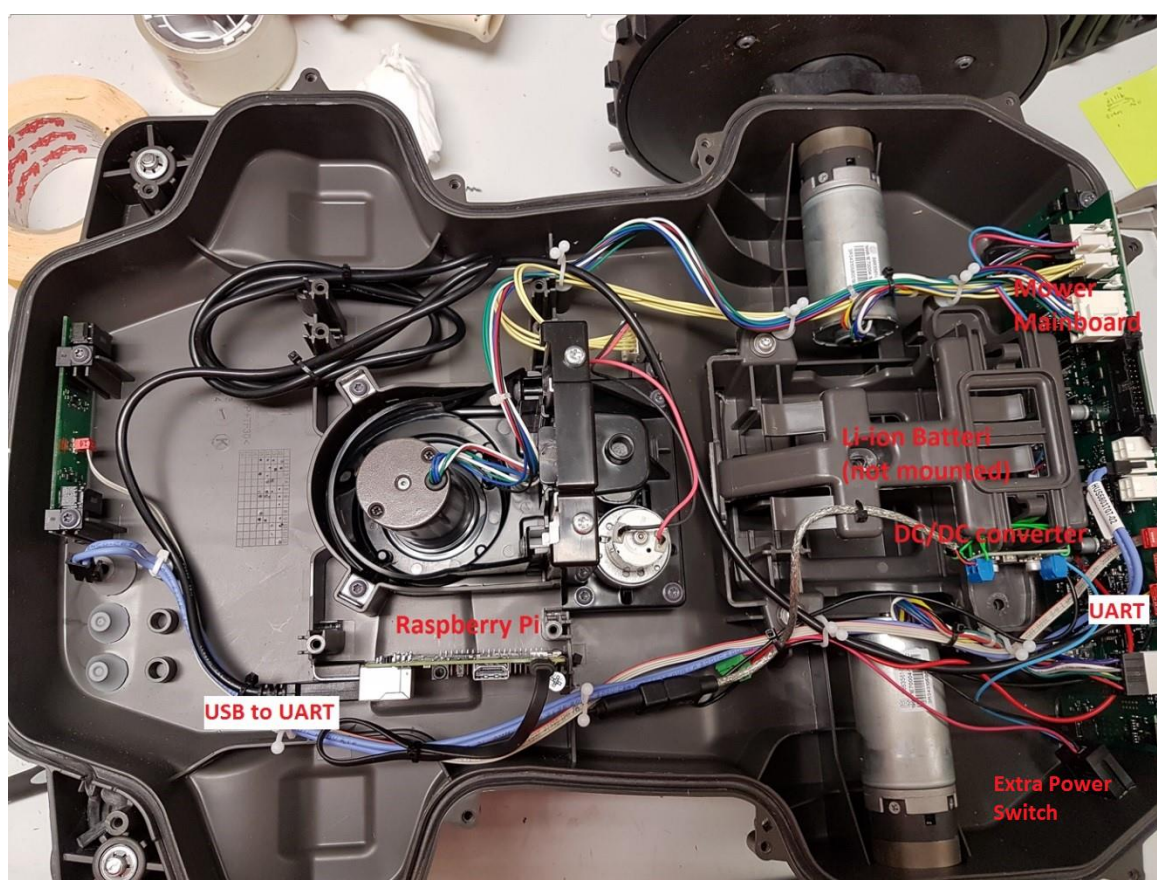
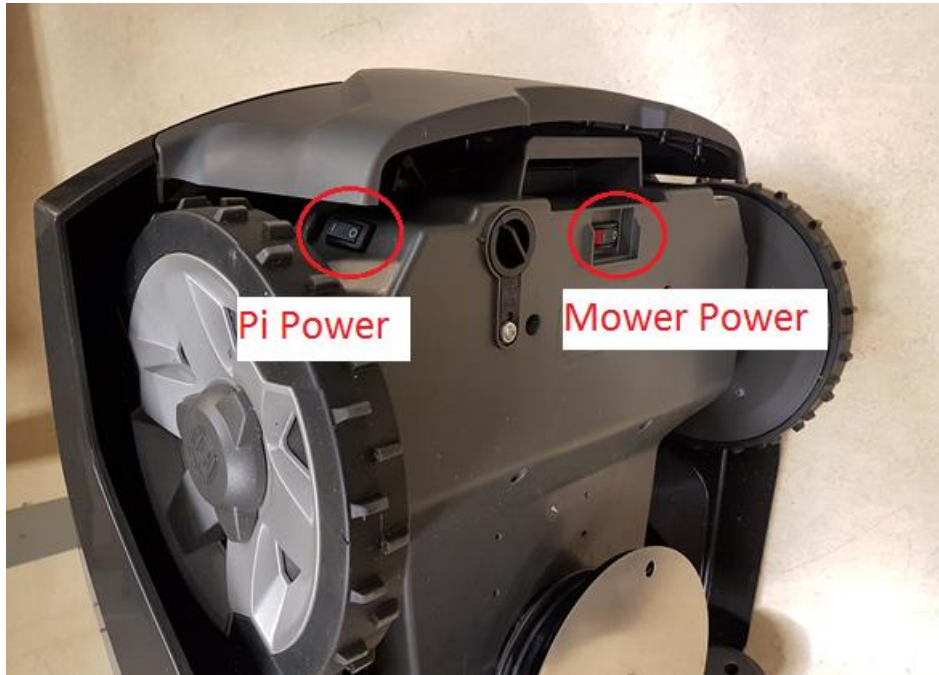


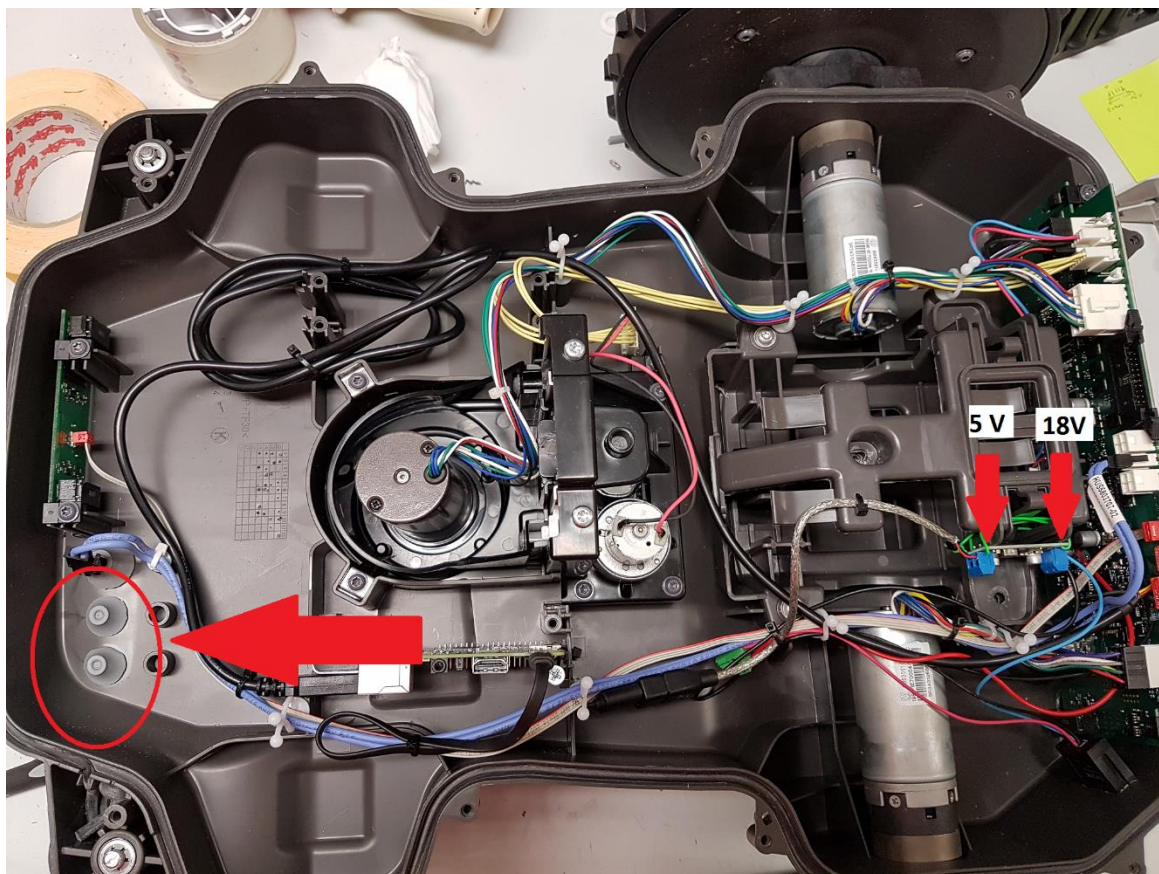
Figure 7 Raspberry Pi installation



*Figure 8 Power Switches, The original Mower Power, and the extra Pi Power.*

## 7.4 Adding outside sensors outside Raspberry Pi installation

To connect the cables to the Raspberry Pi you need to make holes in the top cover. If you want to keep the mower weather proof, you should enter the interior cover via the rubber grommet, see picture below. Of course you can make more holes in the interior cover and add similar grommet.



*Free cable holes with rubber grommets, and available voltages.*

To power external devices you can access a regulated 5V from the internal DC/DC converter, or from Raspberry Pi USB.

The DC/DC converter is capable of delivering 9A, and the Raspberry Pi only use a small part of this.

You can also access the unregulated 18V voltage, which is simplest accessed from the input connector to the DC/DC. This 18V is switched on/off with the “Pi Power” button as described in chapter **Error! Reference source not found..**

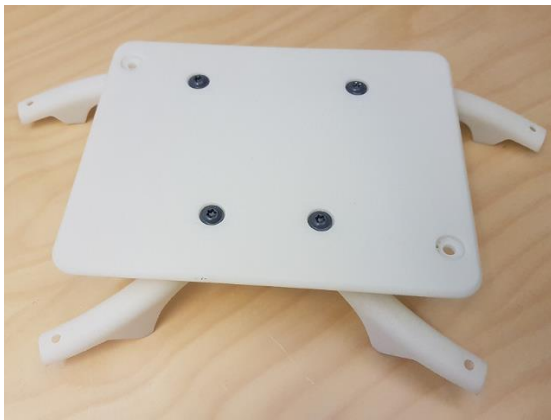
Maximum power consumption on 18V and 5V all together is 100 W.



## 8 Adding extra equipment

Additional equipment like cameras, scanners etc, can be mounted on top of the mower. Husqvarna has designed an accessory rig which fits on the top cover. Husqvarna provides STL-files for this so you can produce them in your own 3D-printer.

The rig can be fixed to the mower by four screws. It is OK to make holes in the plastic cover for these.



*Accessory rig*



*Accessory rig mounted*