

**CUSTOM
CIRCUIT CO.**

Prusa MK2/2.5/S

Silent Driver Upgrade Board

REV: V1.1

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1 Introduction

Thank you for purchasing this upgrade board and hopefully the LED light as well. In this short guide I will go through the main steps of how to install the board, so lets begin!

2 Disclaimer

The following information is provided "as is" and without warranty of any kind, express or implied. I, will not be liable for any damages of any kind arising from the installation or use of this upgrade product for your Prusa printer, including, but not limited to, direct, indirect, incidental, punitive, and consequential damages. The user assumes all responsibility and risk for the installation and use of this upgrade product.

3 Prerequisites

Please note that the assembly of the upgrade board requires proficiency in soldering. If you are not familiar with this skill, I strongly recommend seeking assistance from someone who is knowledgeable in this area.

In addition, the following tools are necessary for the installation process: hex drivers in various sizes, a Phillips screwdriver, a soldering iron, multimeter, tweezers, and pliers. These tools will aid you in assembling the upgrade board and completing the installation process.

You also need to make sure that you have printed the holder for the upgrade board (can be downloaded at Printables) and that you have the following items that are included with the upgrade board:

- Upgrade board
- 14 pin data cable
- 2 Pin power cable
- 2x M3 14mm (3x for XYZE board)
- 4x self tapping screw

Please note that the upgrade board does not come with stepper drivers, and you will need to purchase your own to complete the installation. The board is only intended to work with TMC2208 or TMC2209 standalone! However, I would strongly suggest TMC2209's!

3.1 Protection Addon

If you have version V1.1 or lower of the upgrade board, you may consider adding this board to your existing installation. However, the risks it prevents and minimizes are relatively rare and should only be necessary in exceptional circumstances, such as encountering issues with your drivers or boost converter.

The protection addon includes the following features:

- Reverse polarity protection on the 5V line
- Fusing of 5V
- Protection of the datalines

The protection of the datalines ensures that if the external driver malfunctions and sends high voltage (12-24V) on the datalines, the Rambo board will remain protected. Similarly, it safeguards against 12-24V reaching the 5V rail. The fuse protects and interrupts the 5V supply to the external drivers if, for example, one of them malfunctions.

Upgrade boards V1.2 and higher already incorporate these added protections, rendering this additional board unnecessary.

Installation of this board is plug and play; no tools or additional parts are required other than the board itself.

NOTE, the protection provided by this board is not guaranteed to be 100% protected but it greatly reduces the risks of something damaging the expensive Rambo board.

3.2 Light bar (optional)

If you ordered the optional light bar, then you in addition to the previously mentioned supplies should have printed the holder and its accessories that can be downloaded on Printables. Make sure you received the following items with the LED light:

- LED light with cable, glued in aluminium frame
- 1x self tapping screws
- 1x M3 16mm

3.3 24V Upgrade (Optional)

If you are interested in also upgrading the voltage for the motors to 24V you will in addition need the following:

- 150W DC-DC boost converter
- Short 2 pin power cable
- 4x self tapping screw

The boost converter can be purchased from many places like Amazon, Aliexpress, etc, it looks like the one in Figure 1. NOTE, there is a very similar board that is a Buck converter, make sure to get the Boost converter one, its usually differentiated with its red solder mask and single blue potentiometer instead of two.

Also make sure to print the holder for the upgrade board with the mount for the boost converter (Printables).

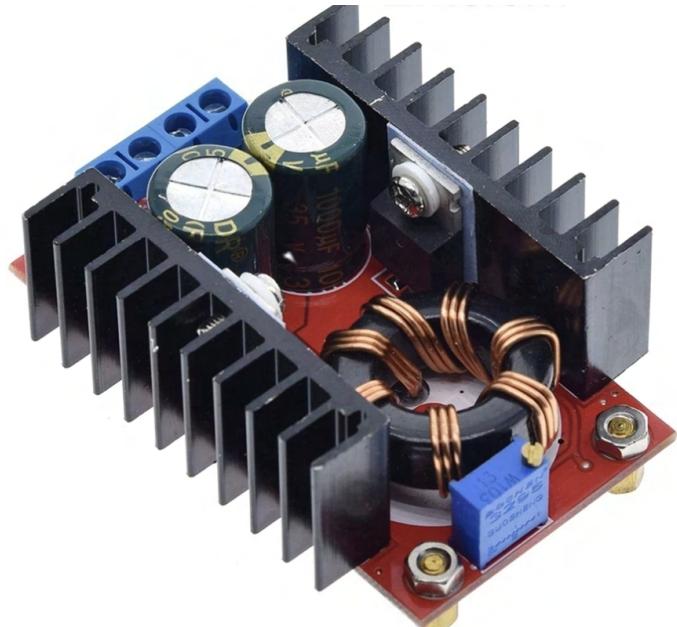


Figure 1: 150W DC-DC boost converter.

4 Power supply

Prior to beginning the assembly process, it is important to ensure that the Z-axis on your Prusa printer is raised to a sufficient height, allowing you easy access to the two front screws of the PSU, as shown in Figure 2. Additionally, you must unplug the printer from the mains outlet before beginning the disassembly process.

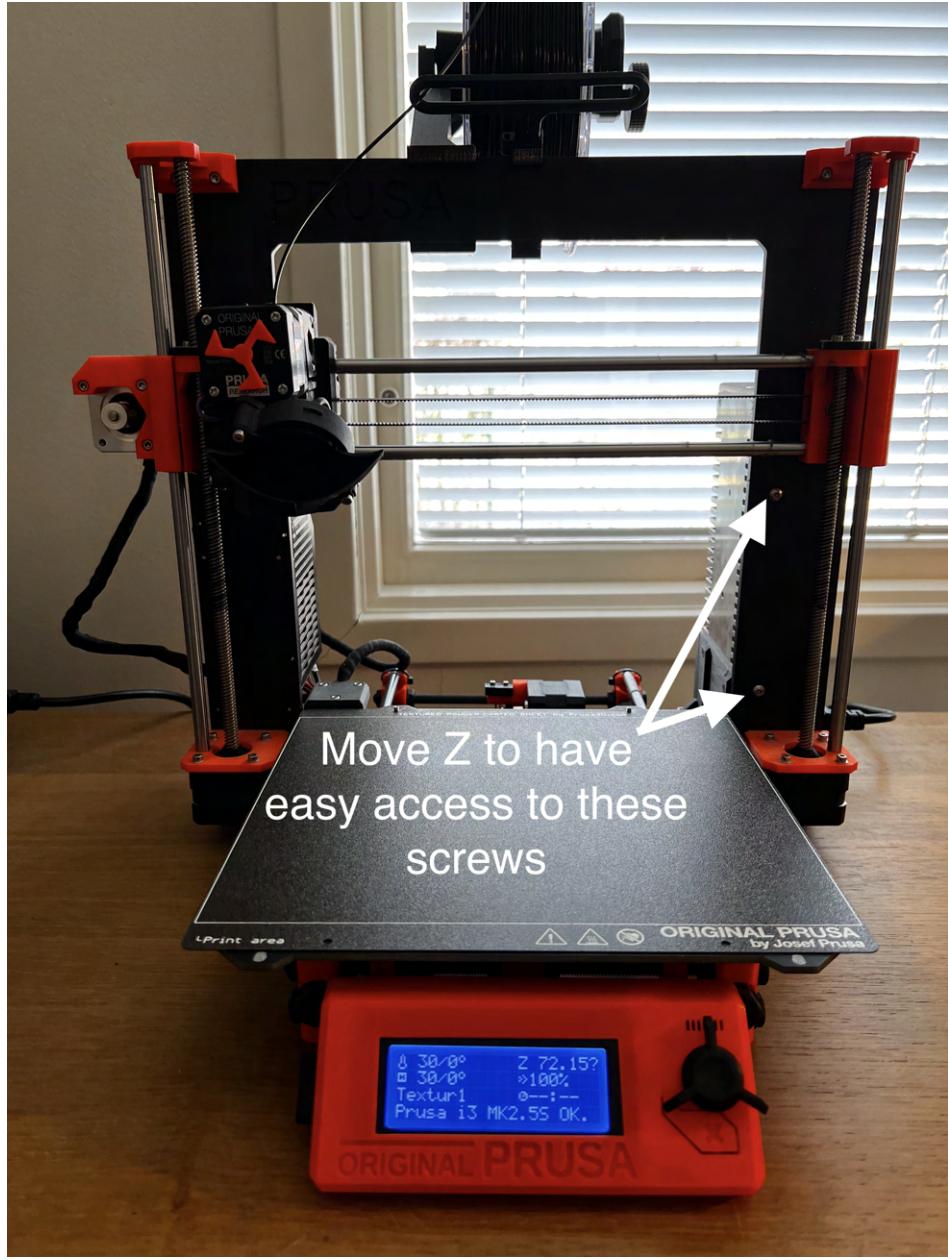


Figure 2: Recommended Z position.

To install the new power cables for the upgrade board, you will need to access the PSU's terminal. To do this, unscrew the screws marked in Figure 3. Next, lift up the PSU and position it as shown in Figure 4. Please note that depending on how tightly the cabling was done, you may need to unzip a few cable ties and/or unscrew the PSU holder from the printer to gain easy access. In some cases, it may be necessary to do both. Please note that your experience may vary based on who assembled your printer.

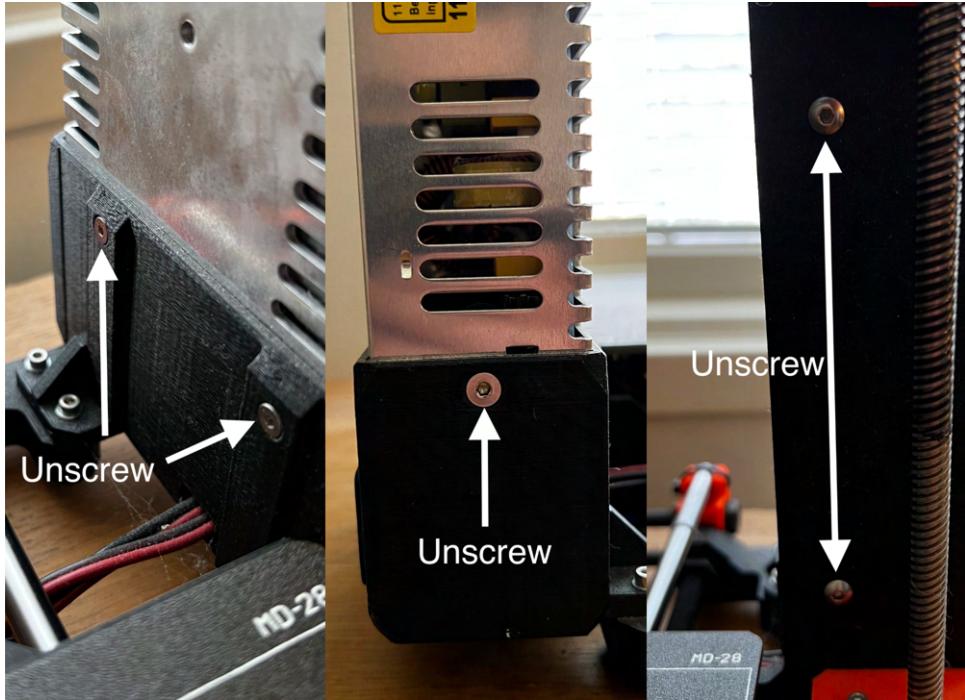


Figure 3: PSU mounting screws.

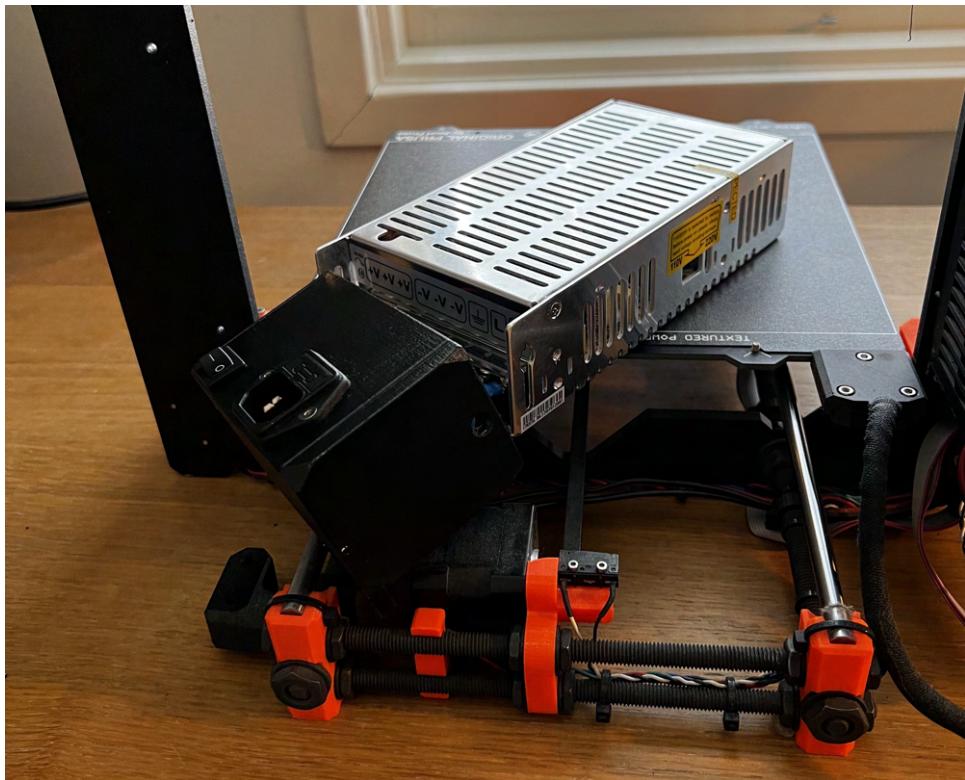


Figure 4: Recommended position for PSU.

Once you have gained access to the PSU terminal, take the provided pre-crimped wire and pull it through the opening in the PSU cover. Connect the red wire to the empty V+ terminal and the black wire to the empty V- terminal, as shown in Figure 5. Ensure that the cables are tightly secured to prevent any accidental disconnections. Then reassemble the PSU and its cover.

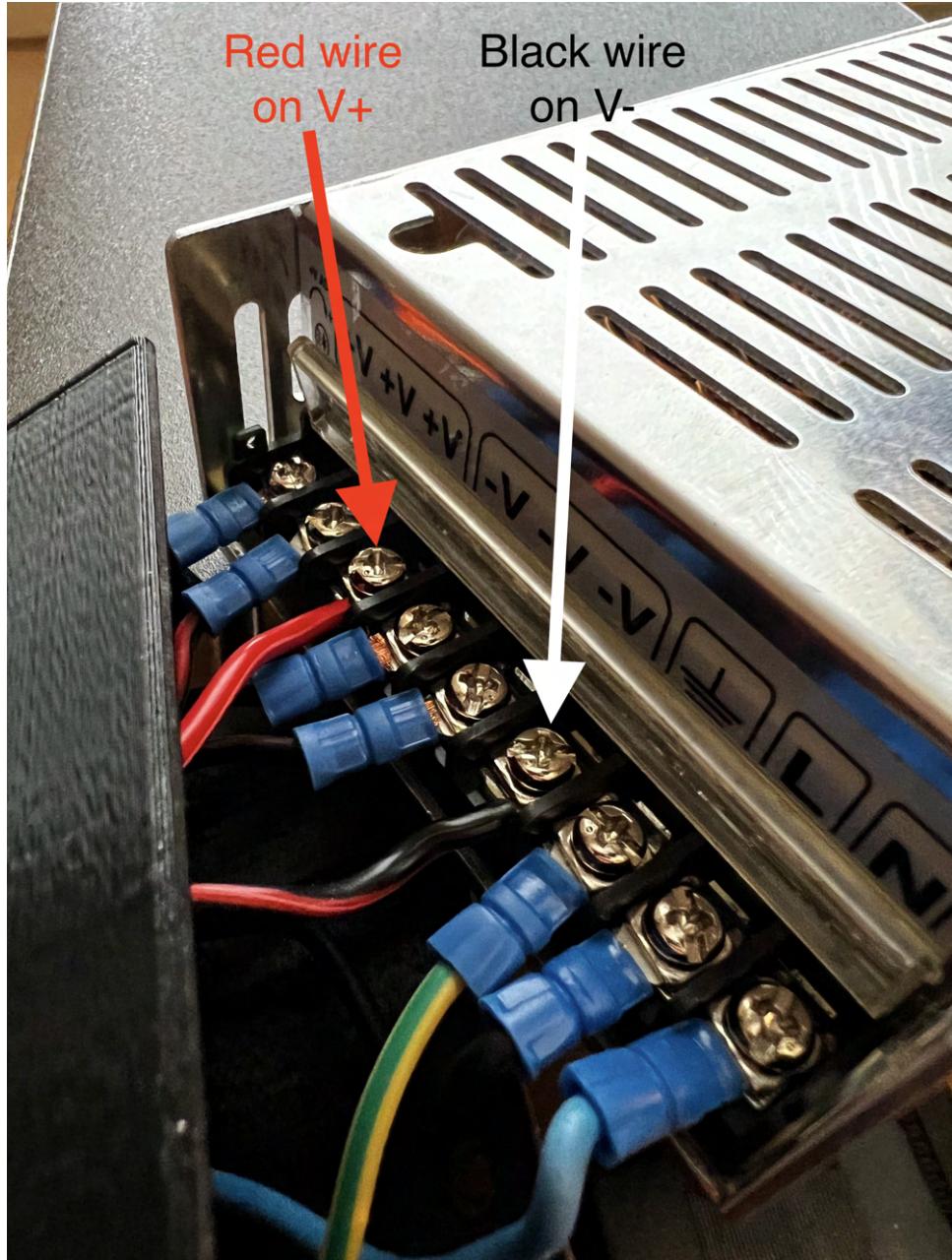


Figure 5: PSU terminal.

5 Rambo board

Moving on to the main board, I suggest that you only unscrew the board from the Rambo base while leaving all the wires connected. While you are free to approach this step as you see fit, I have found that this method makes soldering the data pins easiest. Begin by unscrewing the screw on the Rambo cover and opening it. Unscrew the screws marked in Figure 6, and move the Rambo board to the position shown in Figure 11. This will provide easy access to the pads that need to be soldered to the data pins on the ribbon cable.

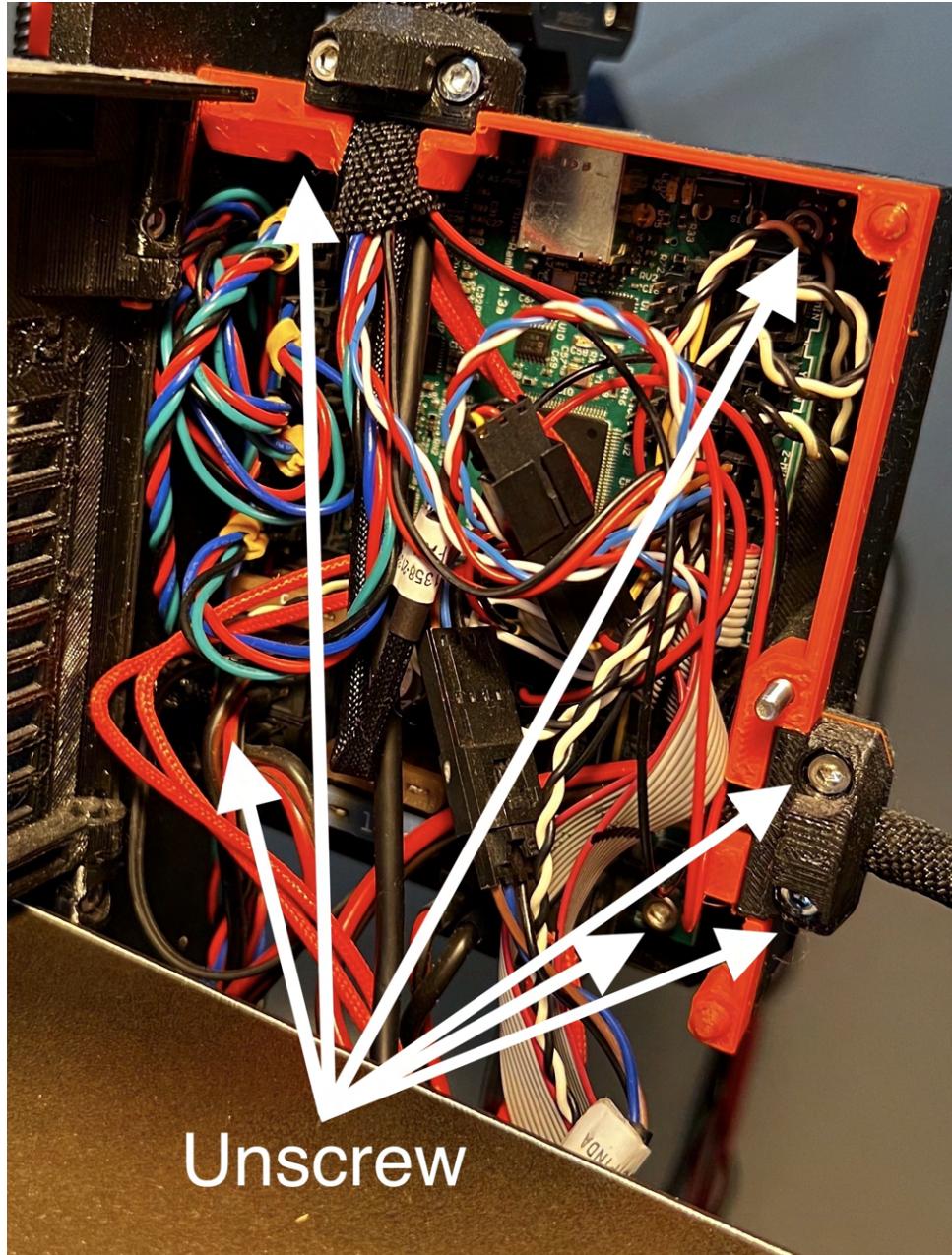


Figure 6: Front side Rambo control board.

IMPORTANT: before continuing the installation from here, note that there are two versions of the V1.1 board, one smaller board for upgrading the X, Y and Z called **XYZ** but there is also another board for X, Y, Z and E called **XYZE**. Follow the installation section below for your board.

5.1 XYZ board

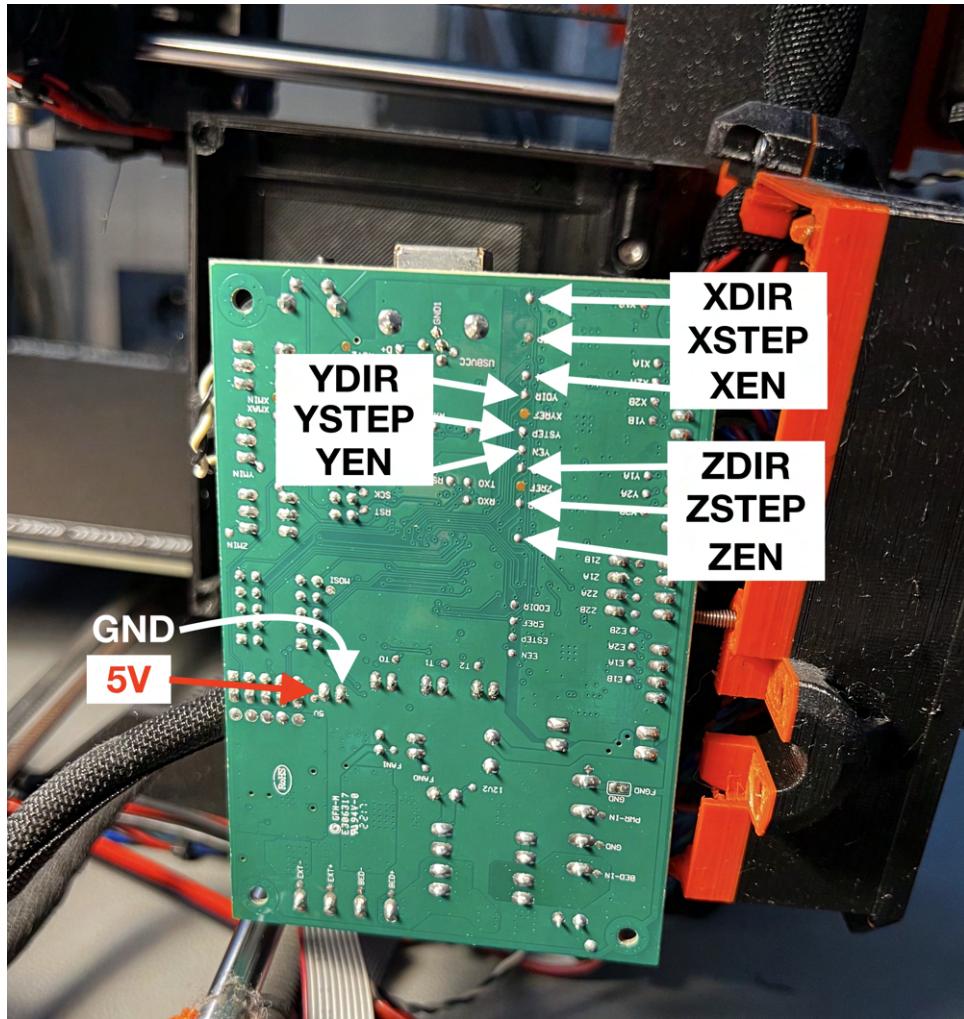


Figure 7: Recommended position for Rambo control board to solder data pins.

IMPORTANT: Before beginning with the soldering, it's important to note that the pads' names are marked on the Rambo board, as shown in Figure 7. It's crucial to watch out for the REF pins located close to the other pins and make sure you don't accidentally solder a data pin to one of those. Additionally, the data cable's orientation should be such that the red cable is located towards the right, ensuring the correct orientation of the connector to the upgrade board, as shown in Figure 8.

It is essential to solder the ribbon cable's data pins to the correct pads. The cable is ordered from the red cable, which is pin 1. The order in which the cables should be soldered is as follows for **XYZ** board:

Cable Nr	Pad	Cable Nr	Pad
1	5V	8	YEN
2	GND	9	ZDIR
3	XDIR	10	ZSTEP
4	XSTEP	11	ZEN
5	XEN	12	GND or Floating
6	YDIR	13	GND or Floating
7	YSTEP	14	GND or Floating

Note that you don't need to solder all pins; for example, if you don't plan to use an external driver for the Z-axis, you can skip soldering cables 9-11. However, I

I recommend soldering all cables in case you change your mind. It's easier to solder a few extra cables now than having to take out the board again.

After you have finished soldering to data pins the result should look like Figure 8. You can use some silicone or similar to glue the cables in place.

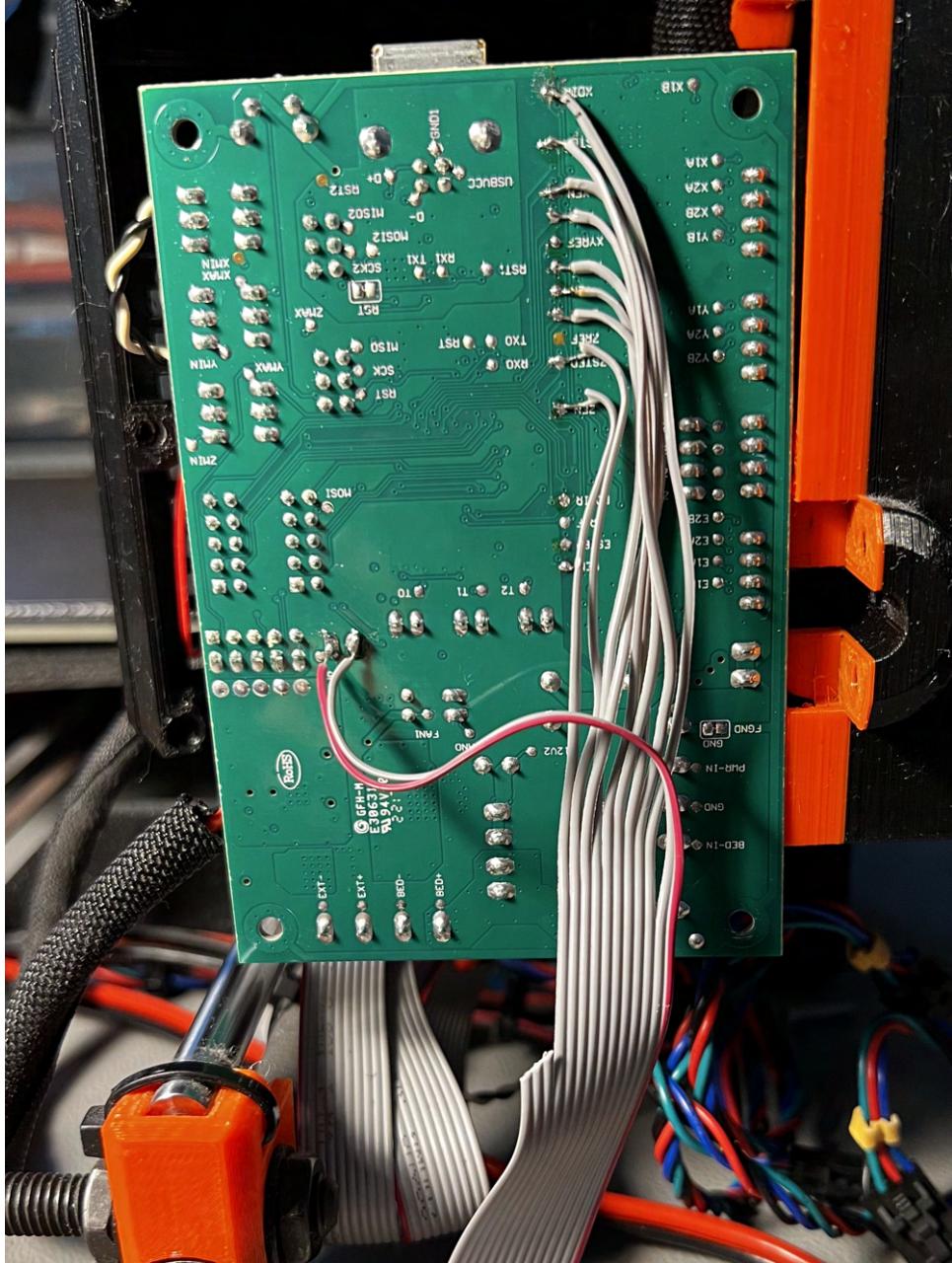


Figure 8: Data pins soldered to Rambo, pins 12, 13 and 14 left floating in this installation of a **XYZ** board.

With the data pins soldered and cables secured, you can proceed to reinstall the Rambo board in the base. Before doing so, remove the nuts marked in Figure 9 and place them in the printed holder, as shown in the same Figure. You'll also need to use the longer M3 screws included in the upgrade kit. It's important to note that if you want to use the X-axis motor with the new board, you'll need to unsleeve the X-axis motor cable slightly and have it on the same side as the upgrade board.

NOTE, if you are performing the 24V upgrade, refrain from connecting the power cables at this stage. However, if you are not performing the 24V upgrade, you may proceed to connect the power cables as instructed in the next paragraph.

You can now mount the upgrade board with 4 of the included threaded screws. You can then install the power cable in the correct orientation, motor cables, data cable (unless you are installing the Protection Addon), X-axis strain relief and stepper drivers. I suggest installing the drivers without heat-sink as it will be easier to adjust the Vref later. The result at this stage should look like Figure 10 except for the heat sinks.

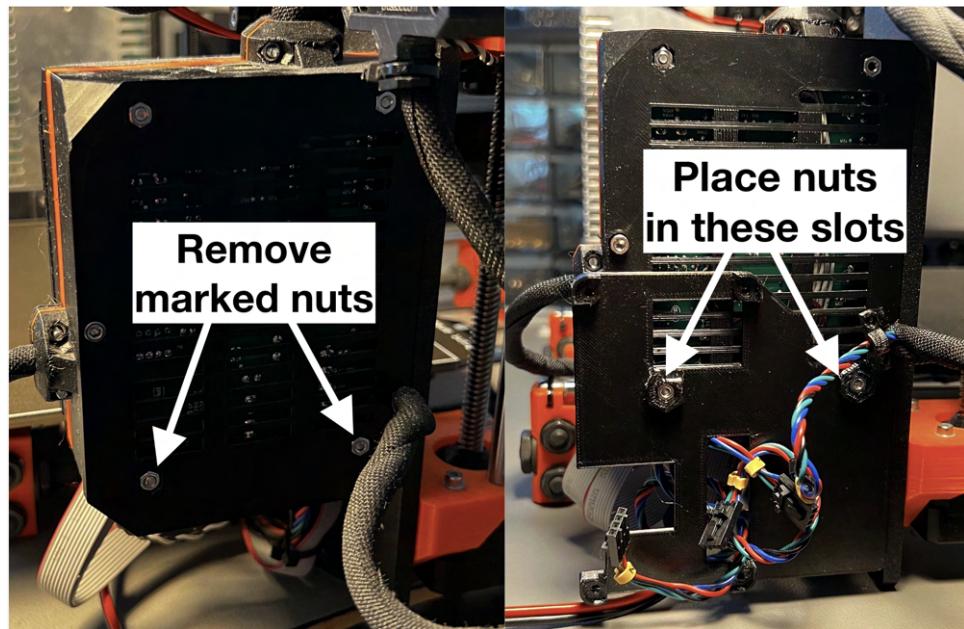


Figure 9: Rambo base, without and with the upgrade board holder-

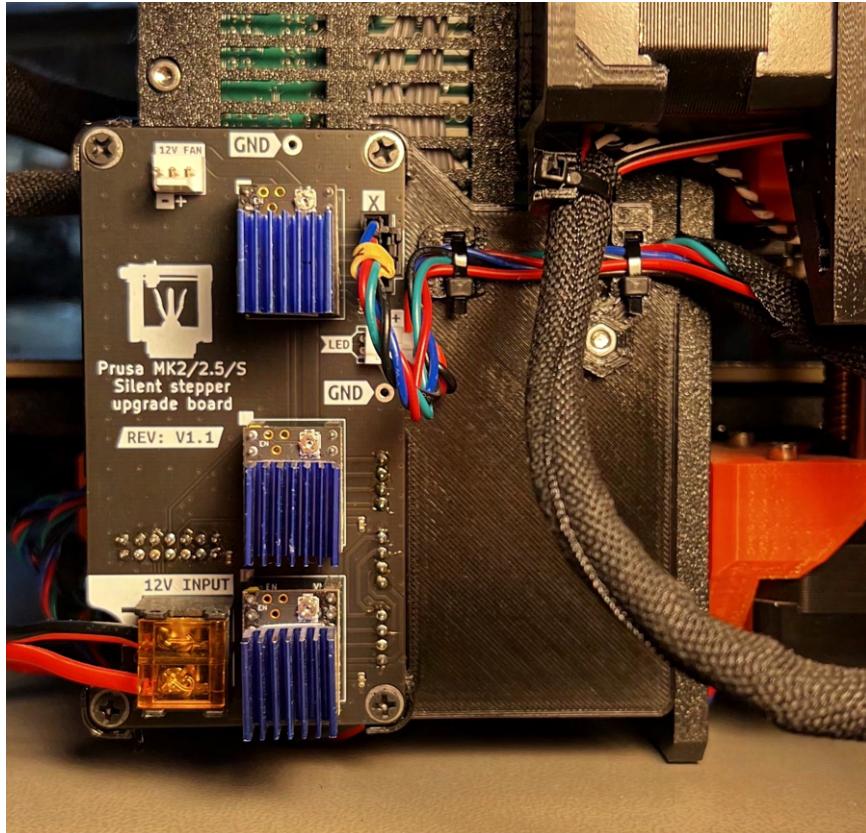


Figure 10: View of front of **X****YZ** upgrade board for X, Y and Z installation, with the optional X-axis LED light. Note the holder in this picture is the new zip tie version.

5.2 XYZE board

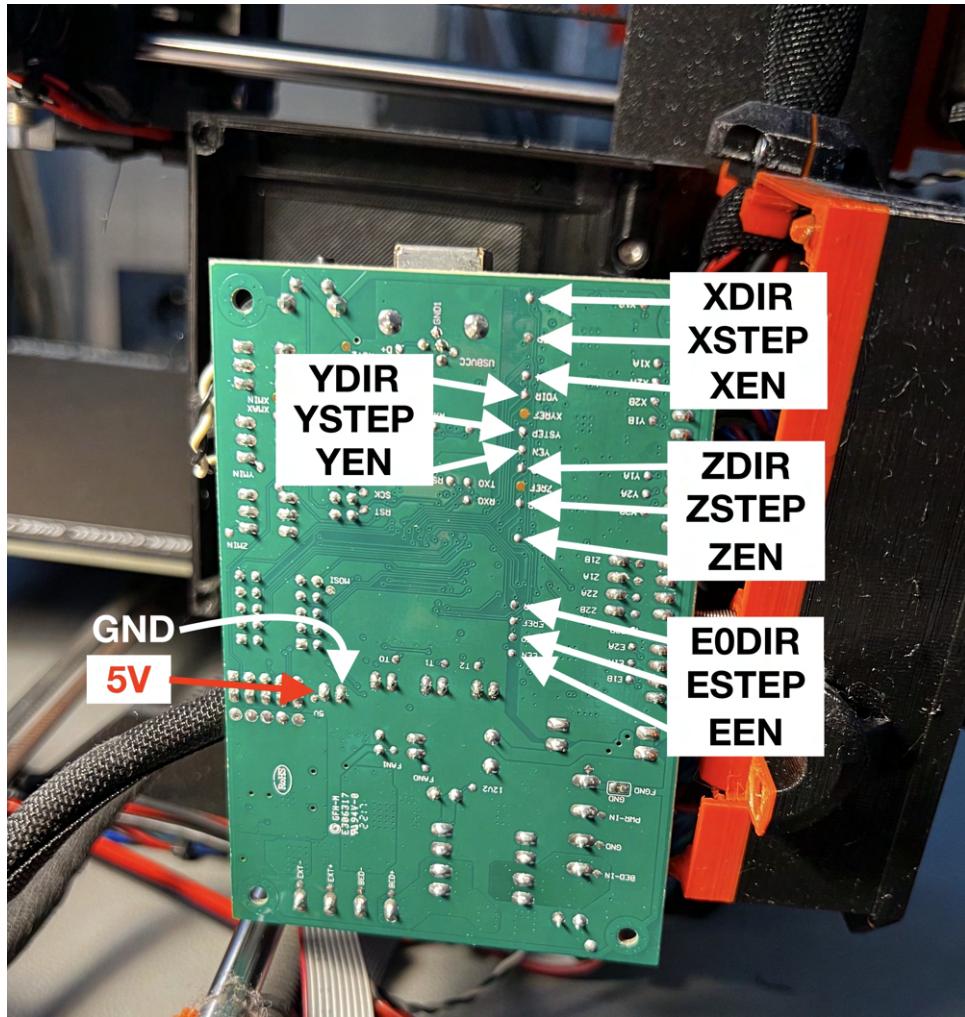


Figure 11: Recommended position for Rambo control board to solder data pins.

IMPORTANT: Before beginning with the soldering, it's important to note that the pads' names are marked on the Rambo board, as shown in Figure 11. It's crucial to watch out for the REF pins located close to the other pins and make sure you don't accidentally solder a data pin to one of those. Additionally, the data cable's orientation should be such that the red cable is located towards the right, ensuring the correct orientation of the connector to the upgrade board, as shown in Figure 12.

It is essential to solder the ribbon cable's data pins to the correct pads. The cable is ordered from the red cable, which is pin 1. The order in which the cables should be soldered is as follows for **XYZE** board:

Cable Nr	Pad	Cable Nr	Pad
1	5V	8	YEN
2	GND	9	ZDIR
3	XDIR	10	ZSTEP
4	XSTEP	11	ZEN
5	XEN	12	E0DIR
6	YDIR	13	ESTEP
7	YSTEP	14	EEN

Note that you don't need to solder all pins; for example, if you don't plan to use an external driver for the extruder, you can skip soldering cables 12-14. However, I recommend soldering all cables in case you change your mind. It's easier to solder

a few extra cables now than having to take out the board again.

After you have finished soldering to data pins the result should look like Figure 12. You can use some silicone or similar to glue the cables in place.

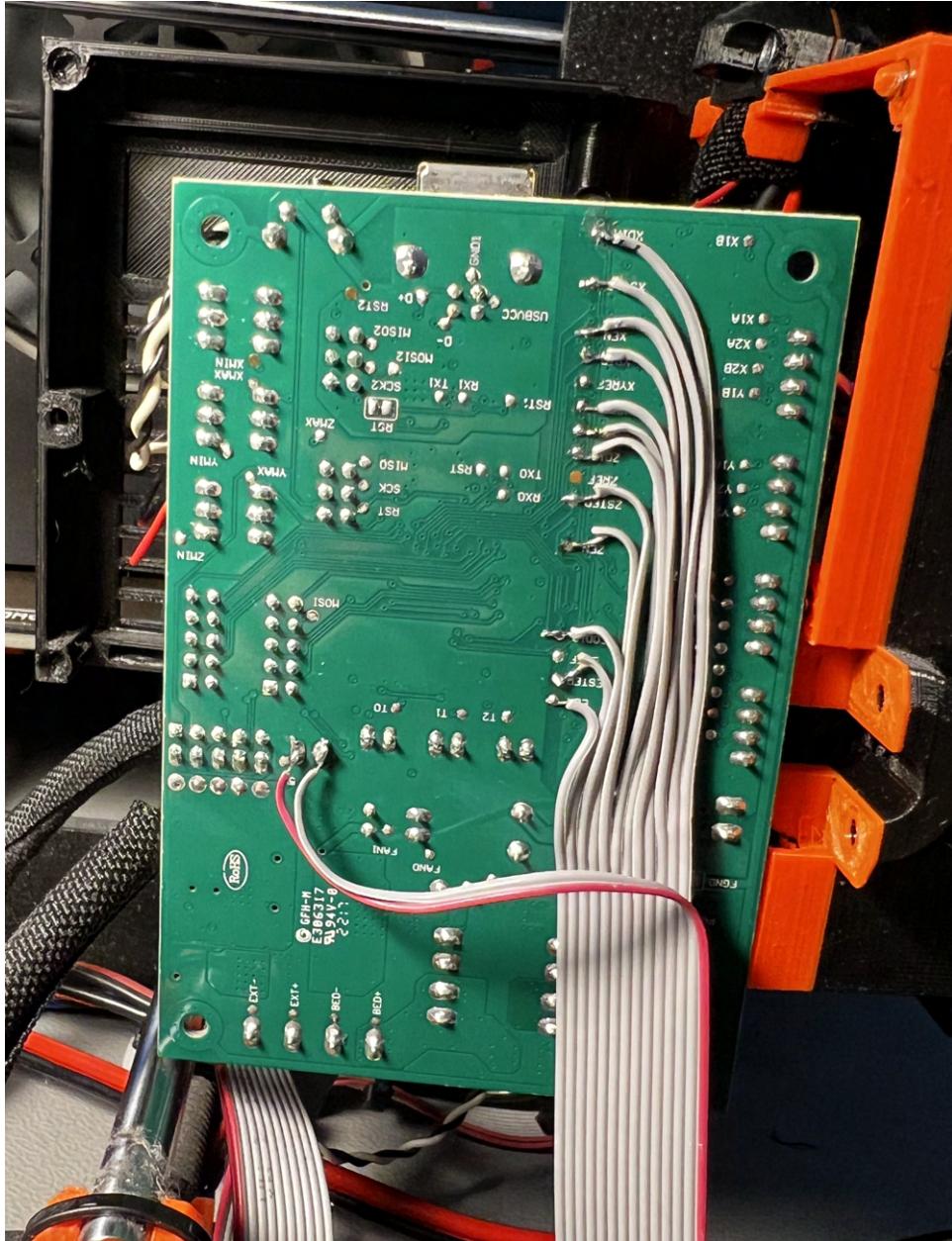


Figure 12: Data pins soldered to Rambo for **XYZE** board.

With the data pins soldered and cables secured, you can proceed to reinstall the Rambo board in the base. Before doing so, remove the nuts marked in Figure 13 and place them in the printed holder, as shown in the same Figure. You'll also need to use the longer M3 screws included in the upgrade kit. It's important to note that if you want to use the X-axis motor with the new board, you'll need to unsleeve the X-axis motor cable slightly and have it on the same side as the upgrade board.

NOTE, if you are performing the 24V upgrade, refrain from connecting the power cables at this stage. However, if you are not performing the 24V upgrade, you may proceed to connect the power cables as instructed in the next paragraph.

You can now mount the upgrade board with 4 of the included threaded screws. You can then install the power cable in the correct orientation, motor cables, data cable

(unless you are installing the Protection Addon), X-axis strain relief and stepper drivers. I suggest installing the drivers without heat-sink as it will be easier to adjust the Vref later. The result at this stage should look like Figure 14.

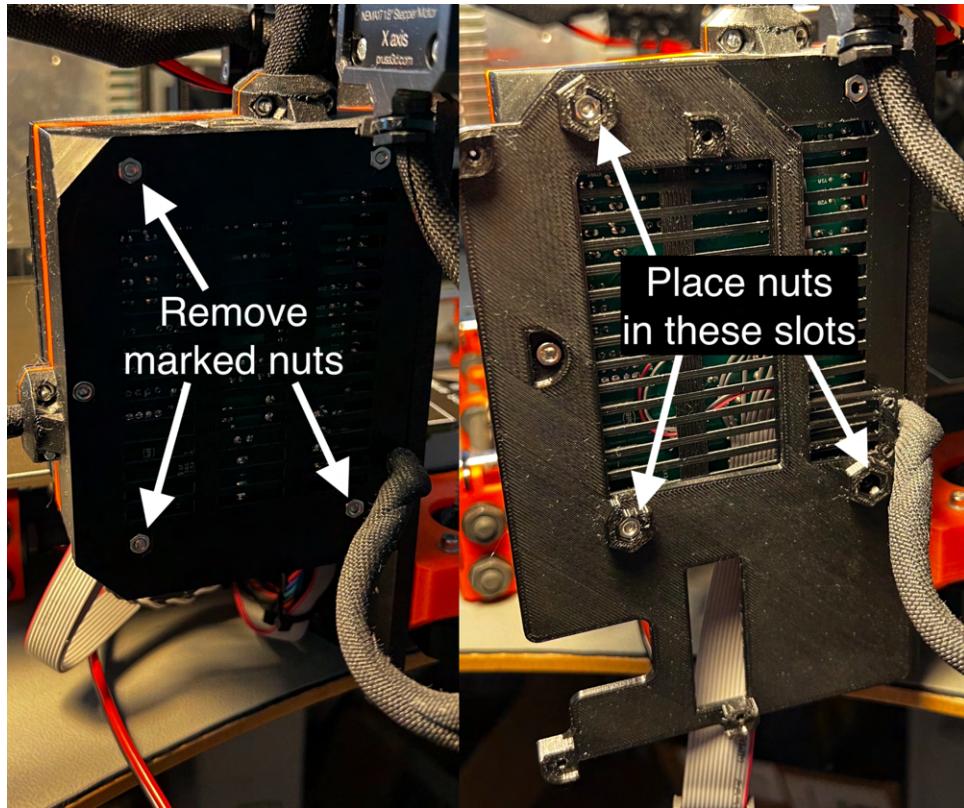


Figure 13: Rambo base, without and with the upgrade board holder-

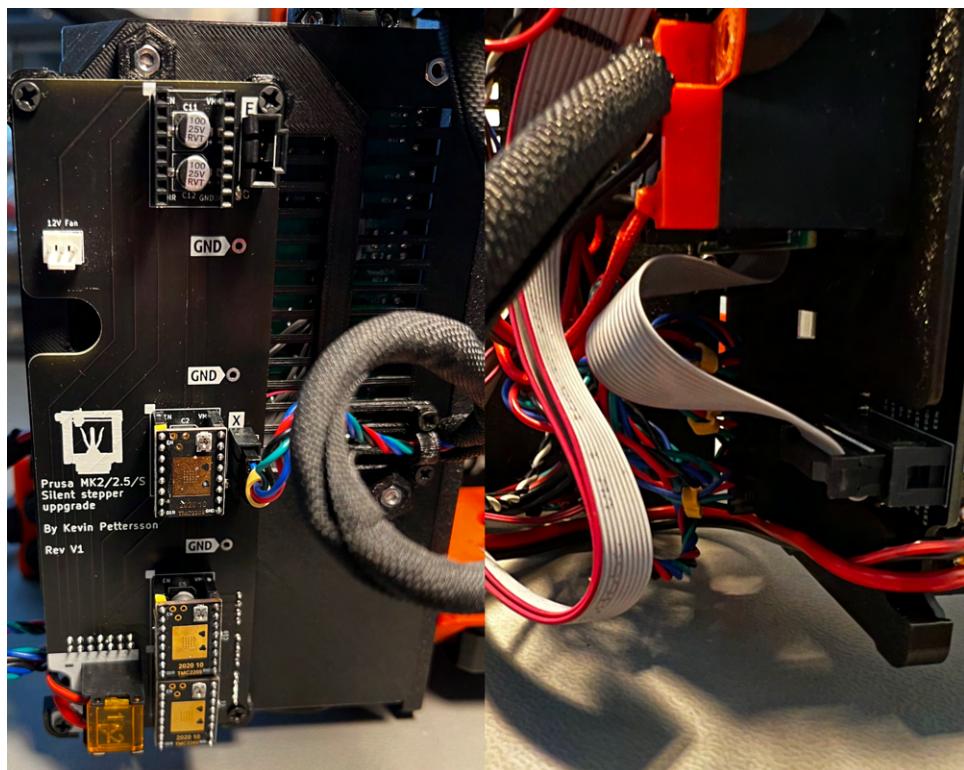


Figure 14: View of front and back of **XYZE** upgrade board for X, Y and Z installation, NOTE depicted image is of V1, V1.1 looks slightly different.

6 Protection Addon (Optional)

If you have purchased the protection addon board for your V1.1 or V1 board now is the time to install it. If you have a existing installation you can still follow along.

The installation is really simple, you take the upgrade board with the arrows pointing up towards the sky and push it into the data slot of the upgrade board as shown in Figure 15. NOTE, make sure that the female header is perfectly aligned with the data pins in the upgrade board otherwise you might damage your upgrade board and Rambo!

Lastly proceed to insert the data cable into the header on the protection addon, the installation is now complete.



Figure 15

7 X-axis LED light (Optional)

If you have purchased the optional light for the X-axis, now is the perfect time to install it. Here's a short step-by-step guide:

1. Start by sliding the wiring through the slot provided. Next, insert the LED light into the 3D printed holder, as illustrated in Figure 16. Slide it all the way in until it is flush with the end.

2. Proceed to install the end cap using one of the self-threading screws. Ensure that the ON/OFF switch remains easily accessible through the slot, similar to Figure 17.
3. Now it's time to install the strain relief for the wiring. Utilize a small zip tie, and slide it into the channel in the print like demonstrated in Figure 18. Then simply cut away the excess of the zip tie.
4. You are now ready to mount the light onto the printer. Simply take the M3 screw and attach it to the hole on the X-axis motor, as shown in Figure 19.
5. Lastly, add the cable to the cable sleeve and connect it to the LED port located next to the X-axis motor connector, as depicted in Figure 14. Please note that you should use the larger strain relief holder on the upgrade board and double check that the red wire is towards the + sign on the board.

By following these steps, you will successfully install the optional light for the X-axis.

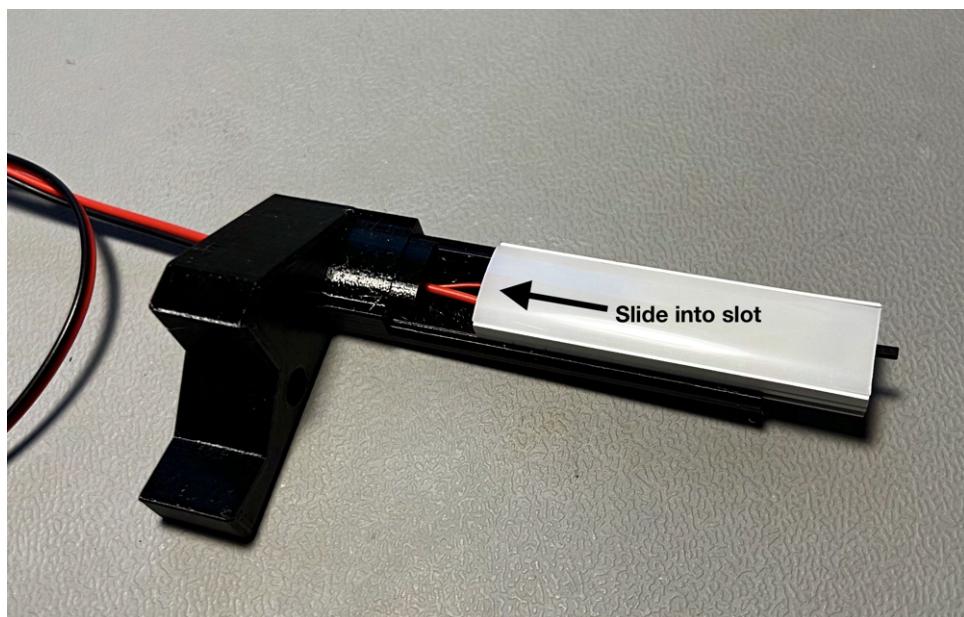


Figure 16: How to slide in the LED light into the 3D printed holder.

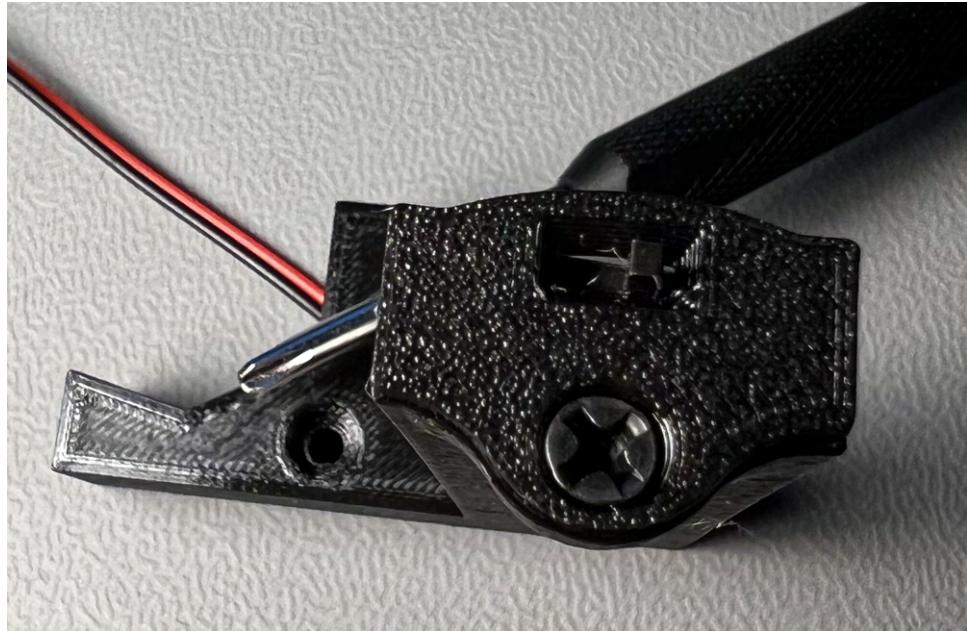


Figure 17: How to slide in the LED light into the 3D printed holder.



Figure 18: Strain relief installed on light holder.

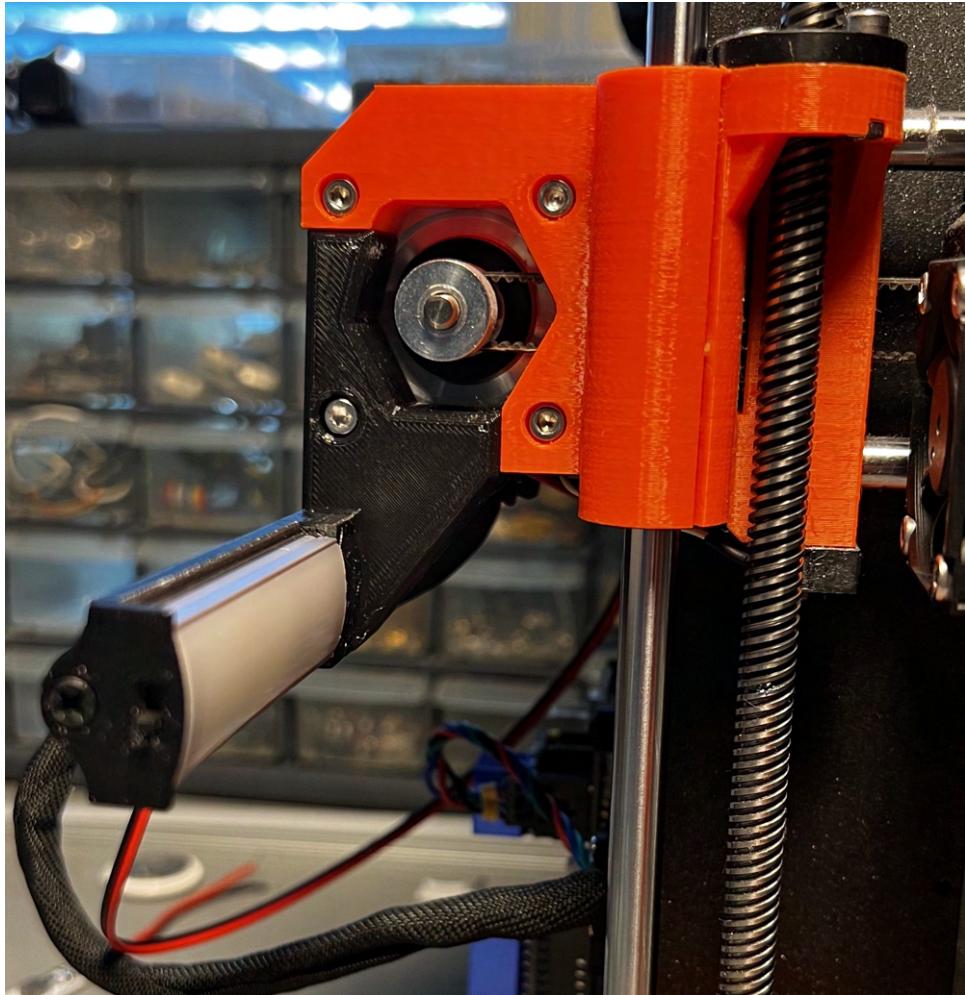


Figure 19: LED light installed on X-axis motor.

7.1 Adjusting LED light brightness (Optional)

If you want to adjust the brightness of the LED light you can follow this short guide:

1. Begin by unscrewing the end cap of the light, like shown in Figure 20.
2. Remove the cap by pulling it towards you, at this stage it should look like 21. Process to either (1) push off the diffuser where the arrow points or try to slide it off in the direction shown by (2) in Figure 21.
3. After the diffuser is removed you can adjust the brightness by turning a small potentiometer marked in the red circle in Figure 22. By turning the potentiometer clockwise you will reduce the brightness, turning it anti-clockwise will increase the brightness. **NOTE**, its recommended to use a plastic screwdriver to not shorten anything. If you use a metallic screwdriver you might experience a flickering in the light while adjusting if its turned on. This is not dangerous and is only a visual effect, the reason is you create a new current path for the feedback loop.
4. After you are satisfied with the brightness do steps 2 and 1 in that order to put it back together.



Figure 20: Illustration to show the screw that needs unscrewing for removing the end cap.

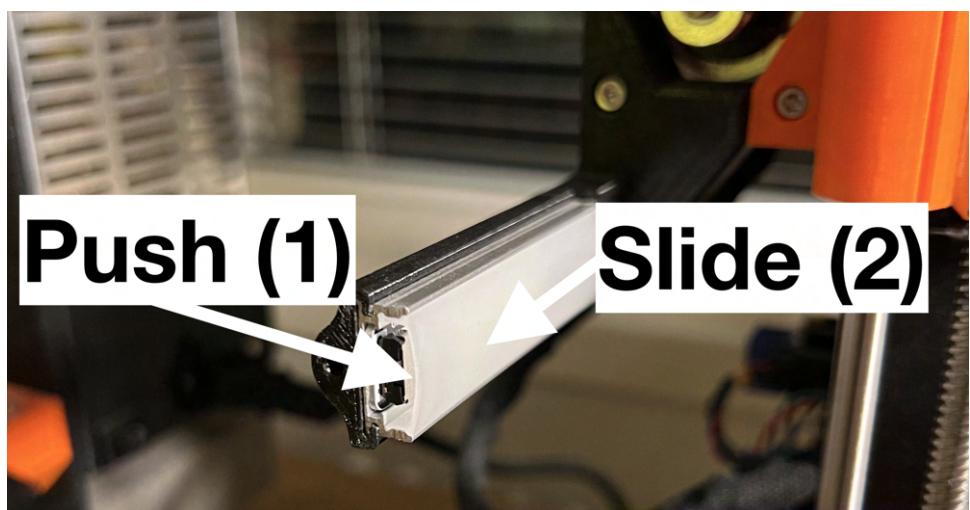


Figure 21: Illustration of two options marked by (1), (2), for how to remove the LED diffuser.

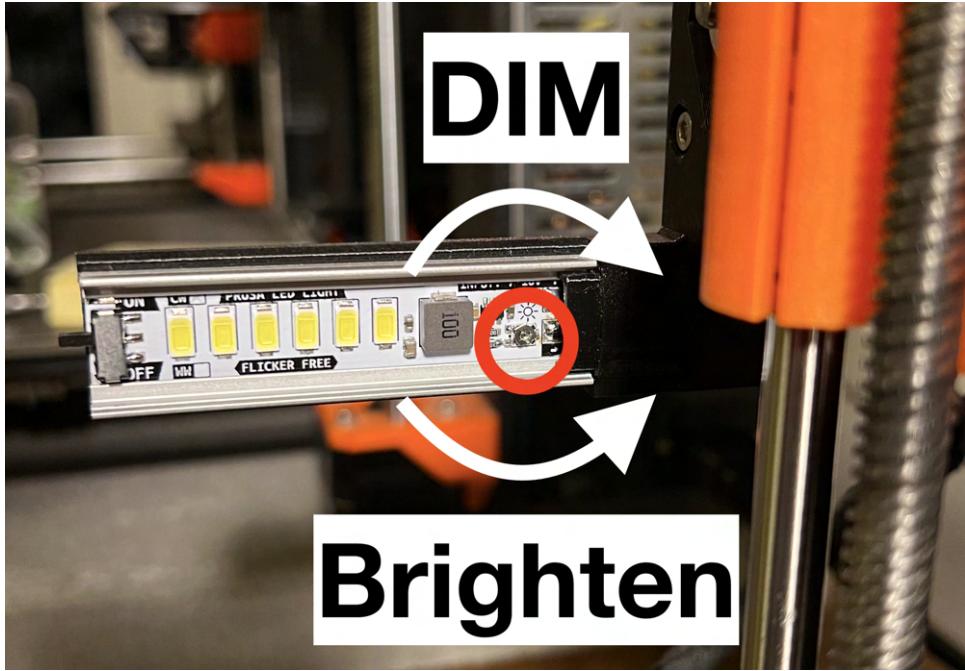


Figure 22: Illustration of how to dim and increase the brightness of the LED light.

8 24V Upgrade (Optional)

At this point, ensure that the upgrade board is securely mounted, and all cables are connected to the upgrade board, excluding the power cable.

IMPORTANT before proceeding further: If you have the initial version of the LED light (identifiable by checking the label inside the diffuser, indicating "INPUT: 7-16V" as illustrated in Figure 23), **DO NOT** connect it directly to the upgrade board. The same precaution applies if a 12V fan is currently connected to the fan connector on the upgrade board. Failure to disconnect these components may result in damage to both the components and the PSU. To still use them without causing harm, connect them to the 12V from the PSU using alternative methods such as splicing the cables or soldering them to the 12V input of the boost converter.

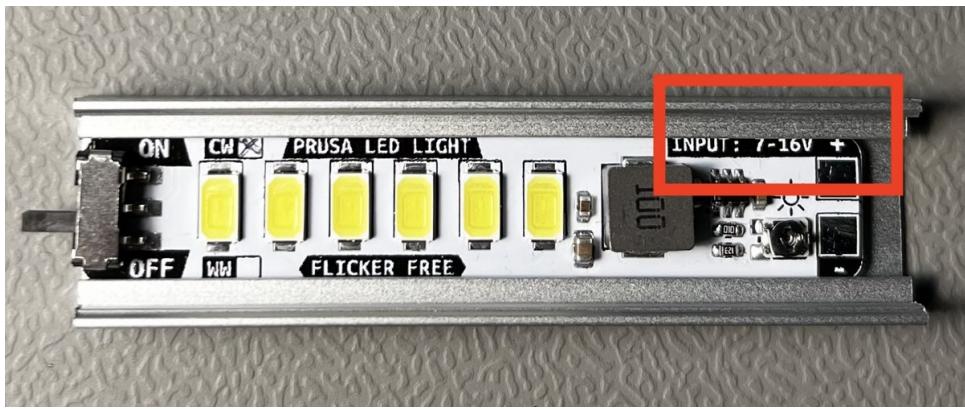


Figure 23: Version 1 of the LED light capable of 7-16V input.

Now that any 12V peripherals have been disconnected we can proceed:

1. Securely mount the boost module using 4 self-tapping screws, as depicted in Figure 24. Please note that if you have the 24V-capable version of the light, you have the option to route the cable underneath the boost converter (refer to the Figure). However, exercise caution in that case to prevent the cable from being pierced by any of the metal legs on the boost converter.

2. Retrieve the power cables from the PSU and connect them to the positive and negative inputs on the boost converter, as illustrated in Figure 25. **NOTE:** You may need to use a small plier to flatten the connectors of the cable to ensure a secure fit into the small screw terminal.
3. Now, it's time to adjust the output voltage of the boost converter.
 - (a) **IMPORTANT:** Before plugging in the printer, meticulously double-check all polarities and connections to avoid potential issues. Once you are confident that everything is correctly connected, proceed to turn on the printer.
 - (b) While the printer is powered on, adjust the potentiometer illustrated in 26, until the voltage measured between GND and OUTPUT measure around 24V. **NOTE:** Do not exceed 24V.
4. Turn off the printer, disconnect the power cable from the PSU, and wait until the red LED on the boost converter turns off before connecting the short 2-pin power cable from the output of the boost converter, marked in Figures 25, 26, to the input of the upgrade board.
5. Congratulations! The 24V upgrade is now complete. You can now proceed with the rest of the installation.

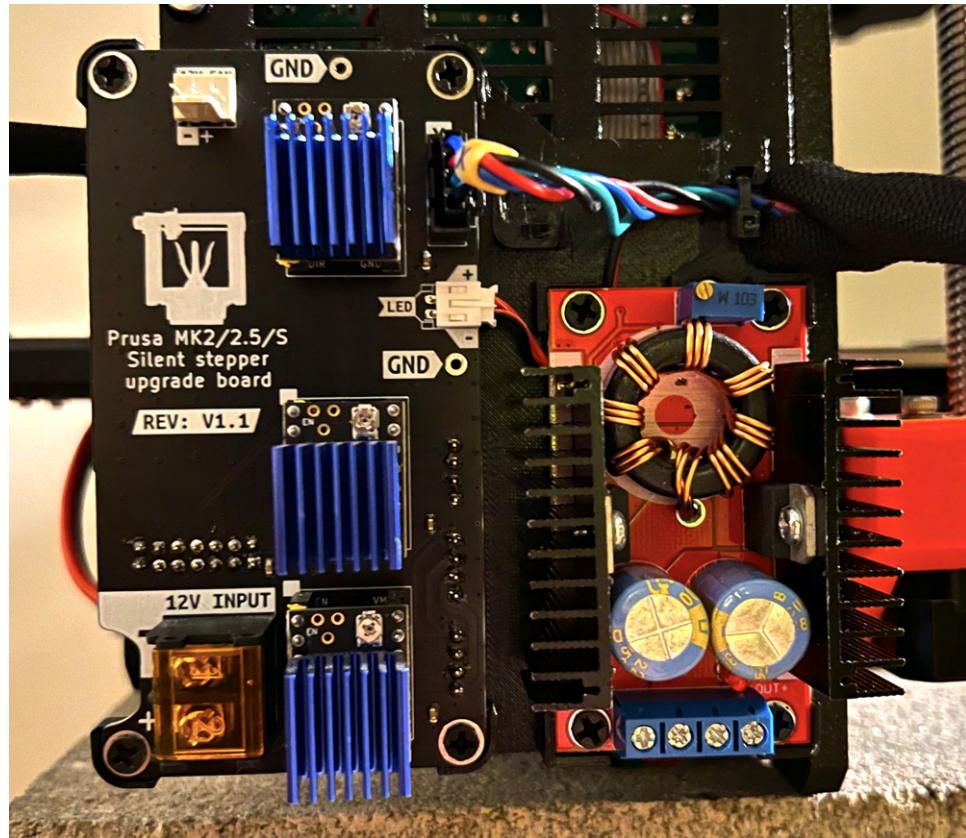


Figure 24: Boost converter mounted.

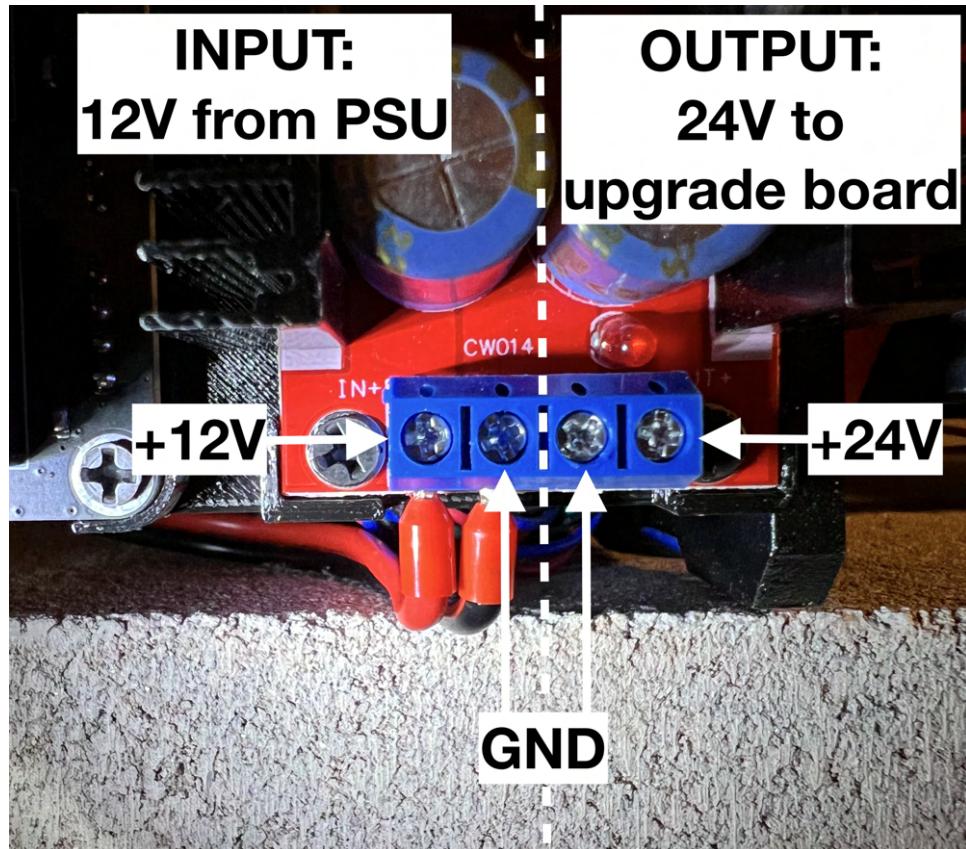


Figure 25: 12V power cables from PSU mounted to the input terminals on the boost converter. Boost converters terminals input and output connections marked.
NOTE, the +24V pin might not at first output 24V, it has to be adjusted.

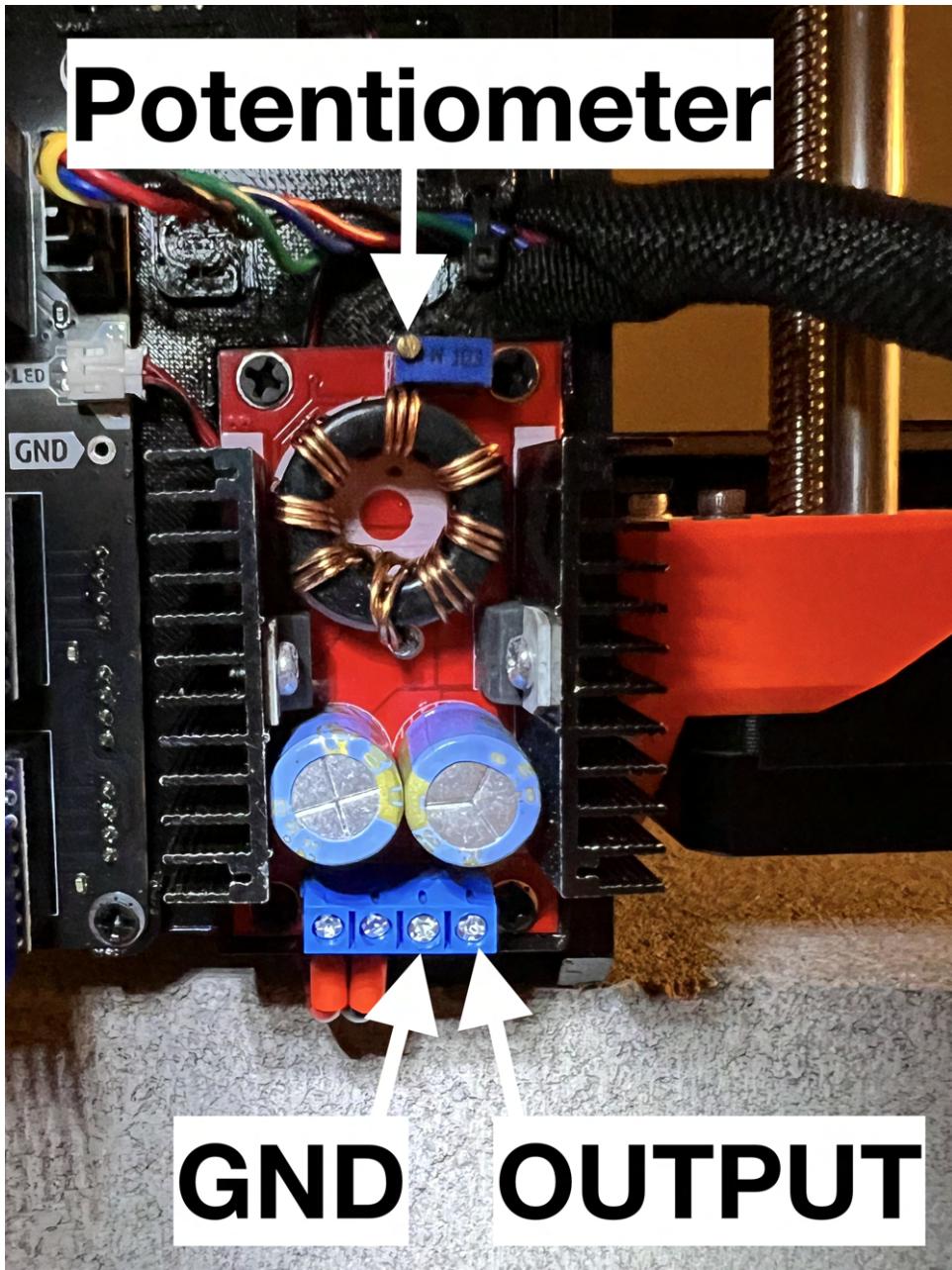


Figure 26: Potentiometer for adjusting the output voltage of the boost converter, and output pins marked.

9 Voltage reference

Before plugging in the printer, it's crucial to double-check all polarities and connections to avoid any potential issues. Once you're sure that everything is in order, go ahead and turn on the printer. The next step is to adjust the voltage reference (V_{ref}) to the stepper motors. It's best to use a plastic screwdriver to prevent any accidental short circuits. A good starting point for the V_{ref} is around 0.5V for X and Y, 0.8V for Z and E (extruder is more sensitive and might need more playing around with). These values typically work well for stock machines. Previously I recommended 0.8V for all axes but I have found that the X and Y motors get notably cooler by lowering to 0.5V and is closer to the stock equivalent V_{ref} values for the machine. However, if your printer has different rods or other custom components on the axis's, you may need to fine-tune the V_{ref} accordingly.

The V_{ref} is adjusted by turning the highlighted potentiometer in Figure 27, the

voltage is measured with a multimeter with the red positive wire on the Vref voltage pin and the black negative wire on GND. On the PCB I have created easy to use GND points for multimeter probes and are highlighted by the GND arrows.

Unfortunately my thermal camera has stopped working so this image hasn't been update to the new lower Vref values. Using a Vref of 0.8V, the temperature from the driver is notably cool. For instance, a thermal image captured during a 4-hour print with PETG, as shown in Figure 28, only shows a heatsink temperature of 40°C after 2 hours, when the room temperature is 22°C . As such, there's no need for active cooling, at least not under these conditions. In addition, the temperature of the X motor, also depicted in the figure, has remained well below the maximum recommended temperature of around $80^{\circ}\text{C} - 100^{\circ}\text{C}$, reaching only 60°C .

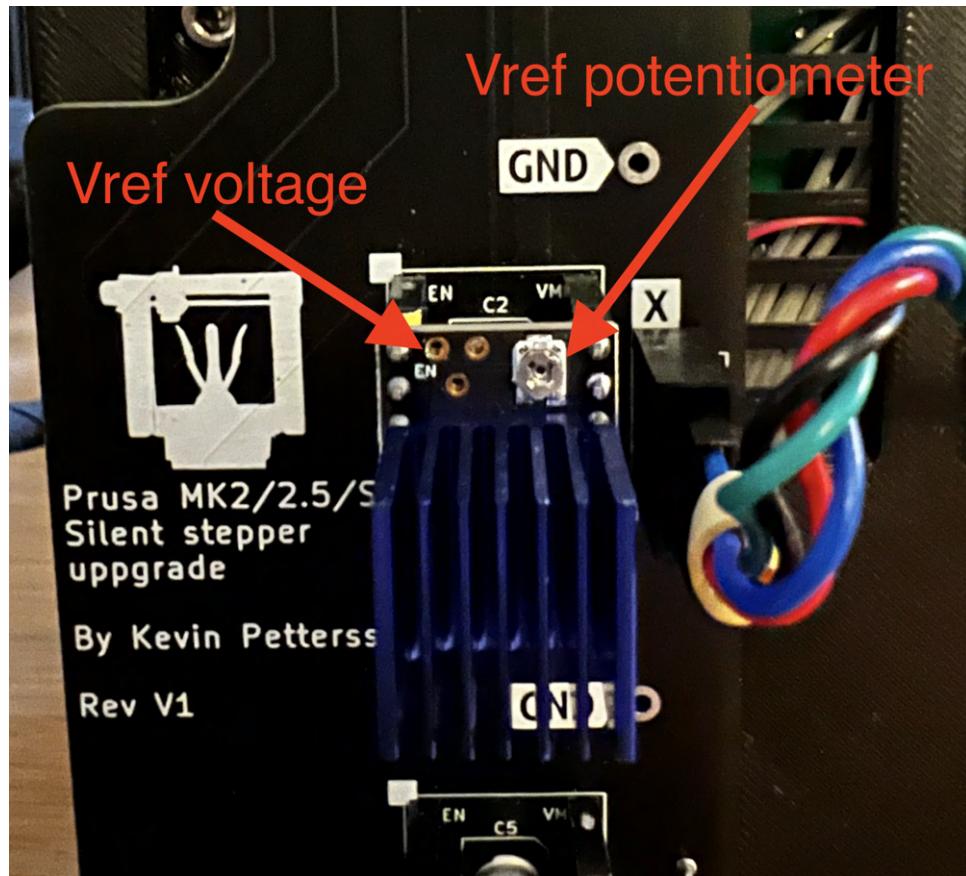


Figure 27: Vref potentiometer and measuring point illustrated on a TMC2209.

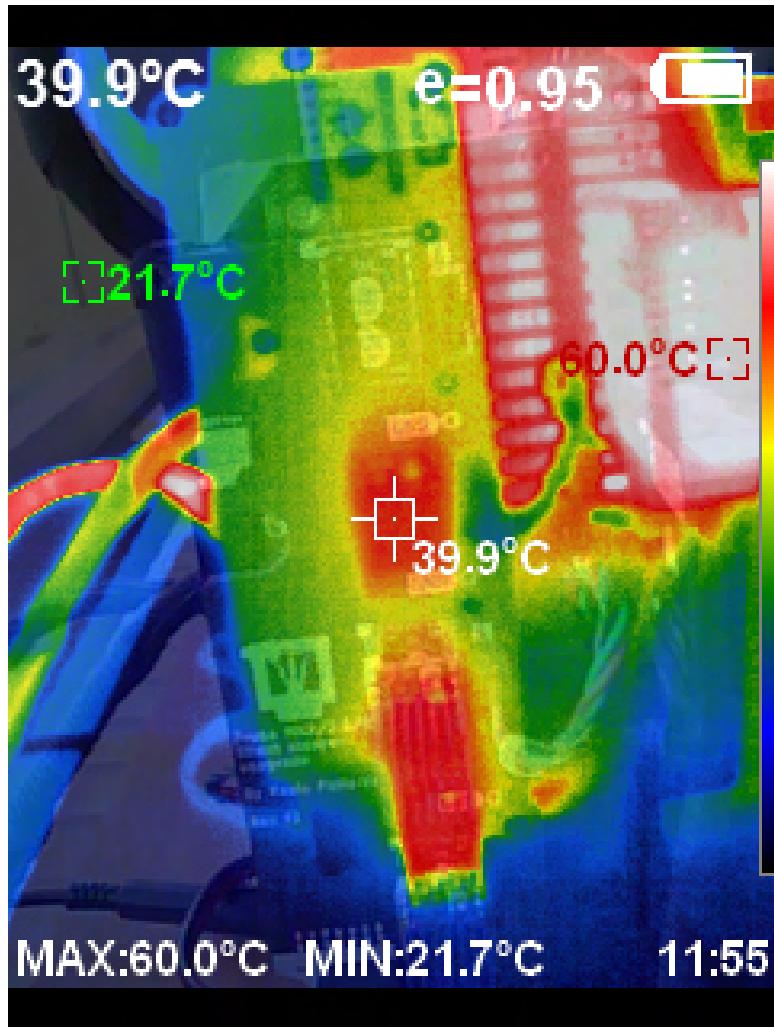


Figure 28: Thermal image of TMC2209's and X axis stepper motor 2 hours into a 4 hour PETG print with 0.8 Vref.

10 Verification

Now the only thing left is to verify that everything is working correctly.

- Try moving the axis's one by one manually in the Settings → Move axis menu.
- Next try the Disable steppers.

If both of these checks work correctly, the only thing left is to install the heatsinks on the drivers and complete a test print, but before doing that please read through the Software sections first. However, if something is not working correctly, please refer to the Troubleshooting section first.

11 Software

You are now done with the installation, so a congratulations is in order. However, before doing the test print I would suggest making a few small changes in your slicer first. The first thing is to reduce the acceleration to around $1000\text{mm}/\text{s}^2$ or slower, this will ensure that you don't experience any rubbing sound. I would also suggest reducing the print speed to a maximum of 100mm/s or slower to ensure that you get the most quiet printing experience possible.

12 Stepper driver cooling fan (optional)

To be added in the near future, models are, however, already available.

13 Performance

To hear the difference in noise check out my video. I have been running this upgrade (as of writing) now for over 4 months on both machines and it has been working flawlessly, without any layer shifts or other problems.

14 Troubleshooting

- A rubbing or weird sound emitting from the printer
 - Check Software section and reduce acceleration and or speed until sound is gone.
- One or more motors are not moving
 - Check if 12V is supplied to the upgrade board on the terminal, if not recheck power cables at PSU.
 - Double check the data pin connections to the Rambo board and check that 5V is supplied to the upgrade board.
 - If none of the above points solved the problem then the driver is most likely faulty.
- Disable steppers not working
 - Check the EN pins on the Rambo board.
- Layer shifts
 - Increase Vref to stepper drivers that are causing the layer shifts slowly (for example by steps of 0.05v) until problem disappears.
 - If the problem still persists it could be that the drivers are overheating, check heatsink connection and worst case scenario install a fan for the drivers (there is a connector on the PCB for a 12V DC fan).