

Whizoo

Controleo Reflow Oven Build Guide

Revision B



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Introduction

Revision History

Below is the revision history of this document. Please use the document revision that corresponds to the ship date of your build kit. For example, a kit shipped in December 2025 would use revision A of this guide. Click on your revision in the table to access the document.

Revision	Release Date	Description	Link
B	January 2026	Document rewritten in PDF format	n/a
A	December 2020	Document migrated to new website	Here

Overview

This guide documents how to build an incredible toaster reflow oven. It isn't difficult, and the results are often better than commercially available ovens. Building your own reflow oven teaches you how it works, what to look for, and how to tune your reflow process for excellent results.

The reflow oven build described here is capable of consistent, fine pitch lead-free soldering at temperatures up to 280°C. It's common to fill the entire 8" x 10.5" (200mm x 260mm) tray with PCBs that all reflow perfectly.

This oven was originally designed to reflow lead-free solder pastes with liquidus temperatures around 217°C (max temp around 250°C). This is what's typically used by contract manufacturers making commercial PCBs. Prototyping conditions should mimic the production environment to avoid mass-produced surprises.

Because this oven uses Controleo3, a programmable reflow oven controller, it can be programmed with custom temperature profiles to match any temperature curve that your oven is capable of. That means that this oven can reflow a wide variety of solder pastes including SAC305, Sn63/Pb37, and low-temperature bismuth pastes. It can also be configured to dry components, anneal 3D prints, or thermally expand metal parts.

Time Requirements

The average time needed to build this oven is around 8 hours (excluding glue curing time). One customer told us he did it in 5 hours, and another did it in 7 months. Build at your own pace!



Estimated Build Time

Building your own solder reflow oven usually takes 6 - 10 hours (excluding glue curing time).

Keep in mind that you will have to apply glue at two different stages in the build process. After applying glue, we recommend waiting at least 24 hours before continuing with the build.



Glue Curing Time

The kit's high-temperature RTV silicone glue has a set time of 1 hour and fully cures in 24 hours.

Over the years, we've received lots of feedback from customers. Thanks to you, we've been refining our kit contents and build methods to make the build easier, quicker, and better. Thank you!

The guide is written to get you through gluing quickly so that you can build some sub-assemblies while it dries. Do not run your oven through its learning cycle or do a reflow until the glue is fully cured.



Note

If you're planning a weekend build, then you'll probably want to get through the first glue step during the week.

Reference Images

Most of the images throughout the guide are sized to 350 x 350px to keep this document's file size down. Larger versions of the images are hosted on Whizoo's website. To view them, just click on the image you want to make larger!

Information Icons

We've built a lot of solder reflow ovens, and we've learned a lot over the years. Special icons will be used to call attention to important or clarifying information throughout this guide. The icons that will be used are described below.



Time Icon

The time icon indicates the estimated time for an operation.



Note Icon

The note icon indicates a useful tip or clarifying piece of information.



Attention Icon

The attention icon calls attention to an important piece of information.



Stop Icon

The stop icon indicates that the user should stop and read carefully before proceeding.

Safety Precautions

Throughout this guide, various icons will be used to call attention to safety hazards. When they appear, read the information beside them carefully and take appropriate precautions to prevent injury. The icons that will be used are described below.



Sharp Hazard

The sharp hazard icon indicates the presence of a sharp surface that can be harmful to the user.



Heat Hazard

The heat hazard icon indicates the presence of a hot surface that can be harmful to the user.



Electrical Hazard

The electrical hazard icon indicates the presence of a hot surface that can be harmful to the user.



Respiratory Hazard

The respiratory hazard icon indicates the presence of a respiratory hazard that can be harmful to the user.

Choosing an Oven

It's important to choose an oven that will meet your needs and will make the build a breeze. If you plan on using one of our recommended ovens, then check out the "Recommendations" subsection.

Recommendations

This guide uses and recommends the TO1313SBD toaster oven model from Black & Decker. Other ovens that are confirmed to work well are listed below.

- TO1313SBD
- TO1322SBD
- TO1332SBD
- TO1745SSG
- TO1750SB
- TO1760SS

These may have different controls, colors, or handle designs but their chassis are roughly the same. They have two quartz heaters and no convection fan. The top heater is roughly 600W and the bottom heater is roughly 550W for a total of 1150W. The internal volume is small at 10 liters, but the reflow area is a large 8" x 10.5" (200mm x 260mm).

Depending on your region, the ovens in this section may be unavailable or incompatible with your country's mains voltage and wall outlets. We currently don't have any specific oven recommendations outside of North America, but that doesn't mean there aren't any options! If you've successfully used an oven that isn't listed, then please let us know and we can add it to the list!

Other Regions

While we don't have specific oven recommendations outside of North America, we do have some tips.

- Look at the forum discussion [here](#) and this video [here](#).
- It's okay if two top heaters or two bottom heaters are in series because we'll still be able to control the top and bottom heaters separately. Don't use an oven that puts top heaters in series with bottom heaters!
- Do not connect 120V elements to a 240V supply! $P = V^2/R$ so wiring them this way will consume 4 times the power and likely burn out or melt the heating element.



Attention

If you're using 240VAC mains power, **do not** run a 120V oven through a 120V/240V converter! The power requirements are huge, as are the conversion losses. Your adapter may overheat and catch fire. Use an oven designed to run on 240V.

Convection Ovens

Convection ovens present some additional challenges that must be accounted for. Some advice is listed below.

- Most convection ovens have a much larger volume than their conventional counterparts (2 - 3x as large). That means that they will require **much** more power to heat up.

Consider buying two of the same oven, and using one to donate heating elements to the other. Make sure this will still work with your circuit's power limitations. You can wire 120VAC heaters in series to connect them to a 240VAC outlet.

- Consider making false wall(s) to reduce the internal volume. Eliminating the "pizza bulge" will help a lot.
- A boost heater should be added, but doing this will usually put the power draw beyond what a 15A circuit can provide. If you have access to a 20A circuit, then use it! If you don't add a boost heater then you'll want to double-down on the insulation.
- The highest wattage heaters are on the top. That means more hot spots. It's best to remove the heaters and reinstall them with the highest wattage heaters on the bottom. The top and bottom heaters might be different lengths, so this isn't always possible!
- The convection fan can be hardwired to be always on. Alternatively, you can switch it with a solid state relay. Keep in mind that your relay must be rated for the inductive kickback of a fan.
- If your SSR's are switching large loads, consider adding passive (heat sink) and/or active (fan) cooling to them.
- For the PCB tray, you can use a thin or copper tray resting on the wire rack. Remove as many of the cross-members as you can to reduce thermal mass.

- If you end up with an oven that is under-powered or under-insulated, consider using lead-free solder paste with a lower liquidus temperature (around 138°C) like Chip Quik SMDLTFP10.
- Read the blog posts [here](#) and [here](#).

Choosing Your Own Oven

A few key factors that will significantly affect your oven build are listed below.

Size

Smaller ovens have less metal and air to heat up (less thermal mass). That means that they will follow profiles better. Get the smallest oven that will work for you. The oven in this guide is just 10 liters.

Power

A lot of power is required to get the right rate-of-rise at high temperatures. The oven in the guide is rated at 1150W. We will add an extra heating element to bring the total power up to 1550W. This is plenty for a 10 - 12 liter oven.

Most outlets in the USA are rated at 15A @ 120VAC and accept a NEMA 5-15P plug. This means that $120V \times 15A = 1800W$ is available, but that should be derated by 20% if all the heaters are on continuously. Exceeding 1800W should trip a breaker.

The oven in this guide starts out at 1150W, but a 400W boost element is added for a total of 1550W. This is around 14% below the 1800W maximum and is acceptable because all the heaters will almost never be on at the same time.

Heater Type

Toaster ovens and commercial solder reflow ovens use a few different types of heaters.

- Resistive heaters are very slow to heat up and cool down, and make it difficult to follow a reflow profile.
- Infrared heaters heat up and cool down quickly, but they're usually a poor choice because their long-wave infrared light is readily absorbed by components. This can cause dark components to overheat while light/shiny components only partially reflow. Most commercial ovens use infrared heaters, but only to heat the air which is then blown onto the boards.
- Quartz infrared heaters are a subtype of infrared heaters that favor short/medium-wave infrared light. These wavelengths are less readily absorbed by components, so the PCB is less likely to suffer from hot/cold spots created by direct light during reflow.

For Controleo3 ovens, it's recommended to use mostly quartz infrared heaters with perforated shielding to limit direct radiation on the boards. Controleo3 supports heater biasing which can limit the top heater's duty cycle to further reduce uneven heating.

Independent Heater Control

Some cheap ovens wire the top and bottom elements together with no way to control them individually. Avoid those - you need to be able to control where the heat is coming from.

Convection Fans

Convection fans are undoubtedly a good thing. However, convection ovens are usually much larger and have less power for the volume. After performing a huge amount of testing on both convection and conventional ovens, we only recommend convection ovens if more PCB space is needed. The benefits added by the fan is usually outweighed by the lower power and higher volume.

Note



The thermally conductive aluminum PCB tray and insulation (Floor & Tunnel Shield II) are more effective at eliminating temperature differentials than most toaster oven convection fans.

Common Questions

Is a Boost Heater Necessary?

A common problem during reflow is hot and cold spots. When a spot doesn't get enough heat it is considered a "cold spot" and can result in flux failing to activate or the solder failing to liquify. When a spot gets too much heat it is considered a "hot spot." Hot spots can cause warped or blistered boards, component discoloration, and reduced mean-time-before-failure (MTBF) numbers for burnt components.

With this in mind, the boost heater adds a few benefits to the oven.

- The extra power allows for a higher maximum rate-of-rise during reflow.
- Heat comes from another location so heat sources are more distributed.
- Other heaters can run cooler, so the heat sources are less concentrated.
- It's installed at the bottom of the oven to keep heat away from sensitive components. The thermally conductive aluminum reflow tray helps distribute the heat from the bottom evenly throughout the oven.

Is a Resistive Boost Heater Bad?

The kit uses a resistive boost heater for its simplicity. Because it's used as a boost heater, it's biased to a lower duty cycle than the top and bottom heaters. Paired with its lower wattage, its effects on the oven's profile-following are insignificant.

A quartz infrared boost heater would be marginally better, but it comes with a much higher cost, added install complexity, and fragility during shipping. Buying a second toaster oven is usually cheaper than purchasing its quartz infrared heaters on their own. If you find a good way to add a quartz boost heater, then please let us know!

Is Insulation Necessary?

Good insulation is absolutely necessary when building your own reflow oven. It's almost impossible to have too much insulation. If you're using leaded solder paste (e.g. Sn63/Pb37) and only reflowing one small PCB at a time then it might be possible without insulation. However, we want to build an oven capable of reflowing an entire tray of PCBs using high-temperature lead-free paste (e.g. SAC305).

Quality insulation capable of withstanding high temperatures is expensive but worthwhile. We recommend using [Reflect-A-Gold](#), [Floor & Tunnel Shield II](#) and SuperWool Plus.

It's recommended to use the following types of insulation.

- Reflect-A-Gold and Floor & Tunnel Shield II inside the oven to prevent heat loss to the steel oven walls.
- Ceramic fiber blanket outside of the oven chamber (and inside the outer shell) to further reduce heat loss.
- High-temperature silicone glue to seal the air gaps between the oven panels.
- Nomex high-temperature gasket to reduce the air gap around the oven door.

Installing the insulation types recommended above will do a few things.

- Reduces the thermal mass of the oven, because less heat gets absorbed by the steel walls.
- Reflects and conducts heat to address hot and cold spots in the oven.

- Reduces the amount of energy needed to reach high temperatures. This means the heating elements can run cooler to prevent hot spots. In one test, the bottom element ran at a 95% duty cycle without insulation, but just 55% when insulated.

Use insulation and use a lot of it! Do it once, and do it right.

Should I Use More Thermocouples?

One thermocouple is enough for excellent results. More is unnecessary.

If you want an average reading of the temperature in the oven, then you can connect multiple thermocouples in parallel. Thermocouples generate a microvoltage that is read by the MAX31856 IC. Wiring them in parallel will average their microvoltages. You can purchase more thermocouples [here](#).

If you want to measure temperature variance around the oven, then the easiest method is to use [Temperature Test Labels](#), as shown [here](#). This will give you an accurate picture of the variance and let you know where the hot and cold areas are in the oven.

Non-convection ovens are inherently left-right temperature balanced. Top-bottom imbalance is expected (and desired). Front-back imbalance will occur because of the wattage and location of the heating elements, types of insulation, and the oven door. A convection fan may reduce front-back variation but will also introduce some amount of left-right fluctuation. In almost all ovens, the center will be hotter than the corners.

Getting Started

Inspect Your Kit

Before starting the build, it's a good idea to verify that the parts are in good condition. Ensure that the controller screen is undamaged and turns on when powered via USB. If you have any problems with your kit, then please don't hesitate to reach out!

Respiratory Hazard



Do not unpack the white ceramic fiber blanket until instructed to do so! Special safety precautions are required to prevent skin irritation and inhalation.

Step 1: Open the Oven

Disclaimer

Converting an oven to a reflow oven will probably invalidate the manufacturer's warranty on the oven. Ovens use high voltage electricity and potentially lethal electric currents. Whizoo Electronics LLC, Mitchell Herbert, and Peter Easton cannot be held liable or responsible or accept any type of liability in any event, in case of injury or even death by building and/or using or misuse of the information posted on this web site. By accessing, reading, and/or printing the articles presented here you agree to be solely responsible as stated in the above disclaimer and exempt Whizoo Electronics LLC and/or Peter Easton and/or Mitchell Herbert from any criminal and/or liability suit. Safety is a primary concern when working with high voltage circuits and high-temperature ovens. Play it safe!

Instructions



Estimated Time

5 - 15 minutes



Electrical Hazard

Make sure that the oven is unplugged before attempting to open or modify it.



Sharp Hazard

The sheet metal in the ovens is **razor sharp**. Wear work gloves, identify sharp edges, and place tape over them so you don't cut your hands! The kit includes a band aid for a reason!

1. Remove the oven from its packaging. Keep the box and styrofoam inserts to store the oven's lid while you work.



Note

The aluminum tray that comes with the build kit is recommended, but it may not be suitable for all ovens (especially larger ones). You may want to keep the trays that come with the oven.

Some ovens work well with a wire rack with cross members removed to reduce thermal mass. Keep in mind that these trays are usually steel, so they're less effective than aluminum at eliminating hot spots.



2. Remove the screws securing the oven lid to the enclosure. Put them in a plastic bag and store them in the oven box for later use.



Note

Some ovens use Torx or tamper-resistant Torx screws to secure the lid. It's recommended to use the appropriate driver. If you don't have one, then a small flathead screwdriver might work.



3. Remove the oven's feet. The screws securing the feet are usually hidden below rubber foot inserts. Put the feet in a plastic bag and store them in the oven box for later use.



4. Remove the oven's lid and store it in the oven box with styrofoam inserts to prevent it from getting scratched during the build.



Step 2: Remove the Controller



Estimated Time

5 - 10 minutes



Stop and Read Ahead

Read the following steps carefully before proceeding. Cutting the wrong wires at this step may be irreparable.

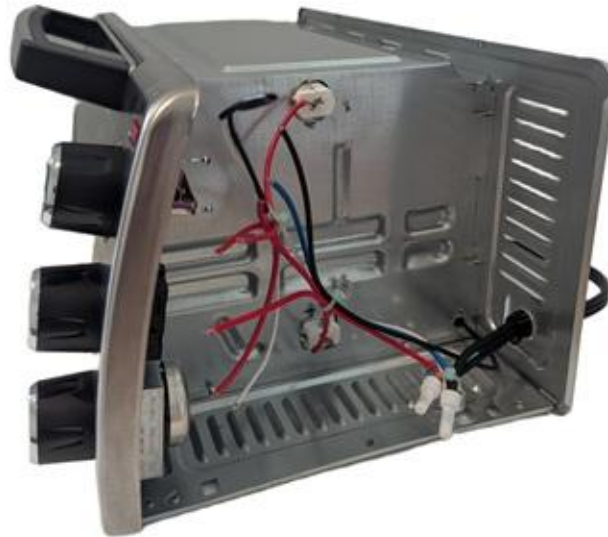
To make room for the new controls, you're going to dismantle the oven's existing controls. The top control knob is removed because that's where the wires to our controller will be fed through.

1. Cut the wires connected to controls on the oven's front panel. Leave them as long as possible. You will need the length later to reach the SSRs.

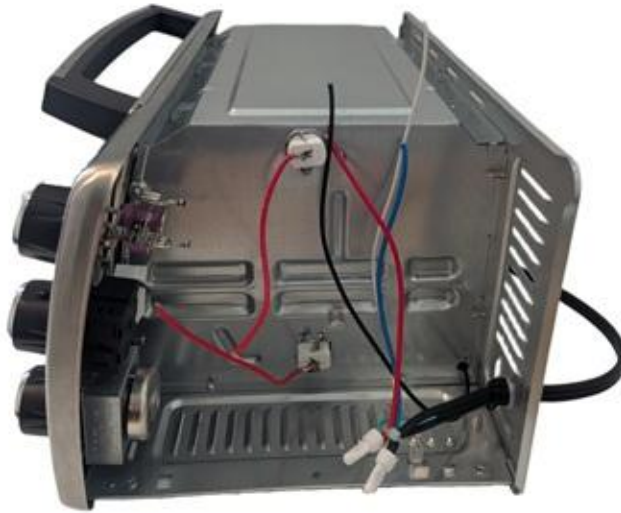


Attention

Do not cut the ends attached to the chassis, the heaters, or the power cord.



2. Remove heat shrink, zip ties, and other loose parts from the wires. Some ovens may have an inline resistor for the LED indicator light. Remove it.



3. Remove the top control knob. The easiest way is to heat the back of the knob with a heat gun until the glue (or plastic) securing it softens. Alternatively, you can try prying it off with a screwdriver. Be careful not to scratch or dent the front of the oven!



Heat Hazard

If you use a heat gun, then the knob and surrounding metal parts will become **very hot**. Wear gloves when removing the knob.



4. Remove the screws securing the controller for the top knob. Remove the knob and discard it.



5. If you haven't already, cover sharp edges of the oven with tape. You're going to remove your gloves for the next step.



Step 3: Glue



Estimated Time

15 - 45 minutes



Stop and Read Ahead

Read through this entire step before proceeding. Set aside around 45 minutes of uninterrupted time. Do not stop until you reach the end of the step. Otherwise the glue will set.



Respiratory Hazard

The glue releases fumes that can cause mild respiratory irritation. Work in a well ventilated area. These fumes are mostly acetic acid (vinegar), hence the strong vinegar smell.

The glue is classified as non-hazardous and non-carcinogenic.

Regardless, it's still recommended to wear gloves (e.g. latex gloves). For more information refer to the [material safety data sheet](#).

Most toaster ovens come with huge air gaps that will allow hot air to escape. In this step you'll remove the rear panel of the oven, install a false wall, and seal all of these gaps.

Glue **will** get everywhere. It doesn't matter how hard you try. Take some time to lay out some cardboard or paper and change into clothes that you don't care about. Have a full roll of paper towels and a trash can nearby.

Remember - it won't look perfect. Fortunately, most of it will be hidden once you finish the oven. Even so, we still have a few tips to make your glue look great.

- Clean your finger between each smear.
- If glue gets on the outside of the tube, then clean it off.
- The glue bead should always trail behind the tube. Don't run the bead of glue over with the tube as you go.

- Longer smears are better. Short smears will make your glue look lumpy or spikey. Don't dabble!

Make sure that you have the false oven back on hand before starting.

1. Open the tube of glue. The nozzle opening should be trimmed to around 4mm diameter.



2. Stand the oven on its handle with the roof facing away from you.
3. Remove the screws securing the rear panel. Place the screws in a safe place - you'll need them shortly. Set the rear panel to the side of the oven. It may still be connected to the oven chassis via wires.

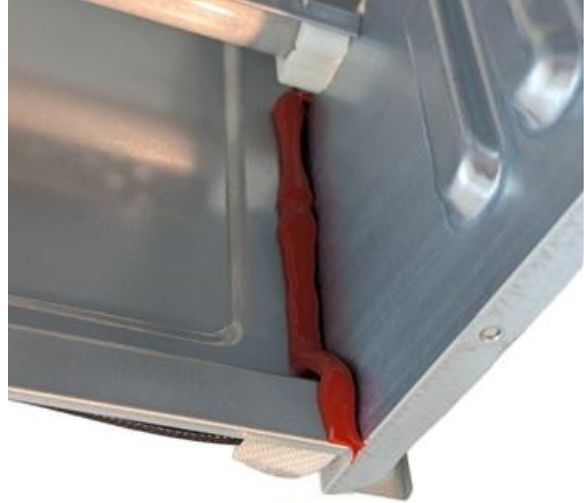
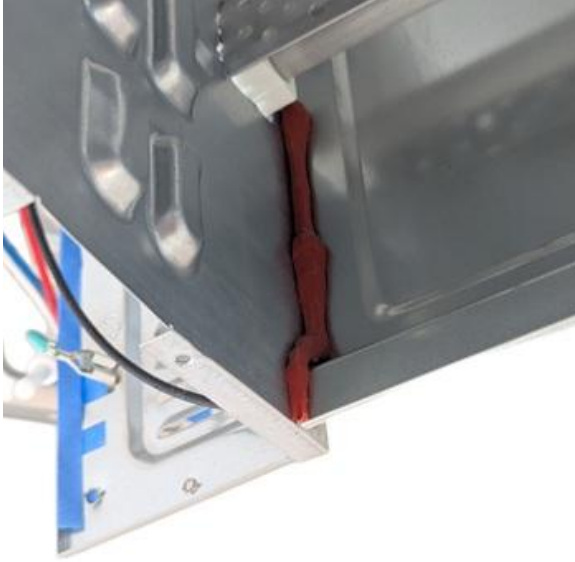


4. On the left and right sides of the oven, create beads of glue that extend from beneath the bottom heater to the back of the oven.



Attention

Start squeezing the tube of glue from the bottom and roll it up as you go. If you aren't careful, then the bottom of the tube will burst open and get glue everywhere!



5. On the left and right sides of the oven, create beads of glue long enough to cover any air gaps in the roof near the back of the oven.

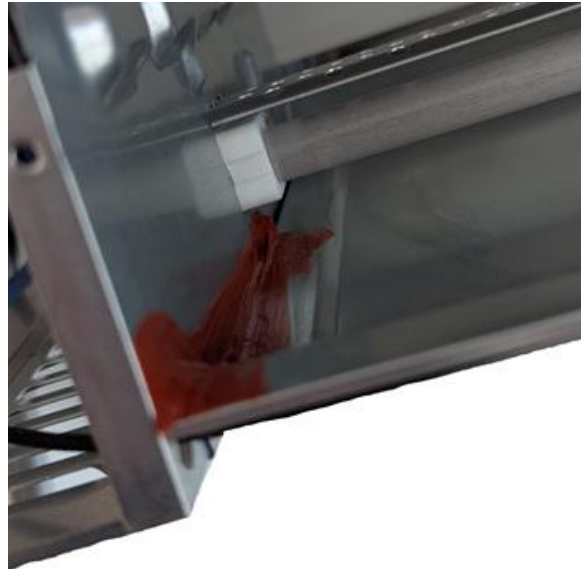


6. Smear all four beads of glue using your finger.



Sharp Hazard

When smearing the glue with your finger, be careful of sharp edges.



7. We will now add glue to seal the gaps between the oven chamber and rear panel. Starting in the top-left corner of the back of the oven chamber, make a bead of glue moving right and down to the bottom-right corner. Then, starting in the same top-left corner, make a bead of glue moving down and right to the bottom-right corner.



Note

Try to keep the bead close to the inside of the oven chamber so that it spreads inwards when you put the back on. Don't cover the screw holes with glue or it will be harder to put the back on.



8. Place the aluminum false wall in place. It should be centered and should not cover any of the screw holes used to secure the back of the oven. It's sized just right - don't let it fall into the oven!



9. Line the rear panel up on the oven's back-bottom edge. Lever the rear panel down into place such that the screw holes align. Reinstall the screws.

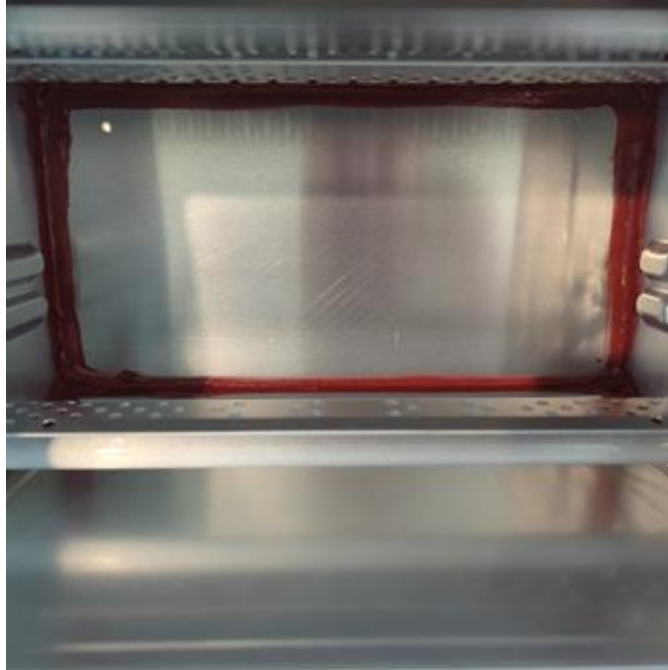


Note

If you slide the rear panel around too much, then the false wall will fall into the oven. Try installing screws on different sides of the rear panel first so that it can't move around too much. Don't tighten the screws until you've gotten all of them in place!



10. Double-check that all of the screws made it through the intended holes.
11. In one continuous motion, smear the glue that was pushed onto the front of the false wall. The smear should traverse all four sides of the rectangle. If there are any gaps in the smear, then add more glue and smear again.

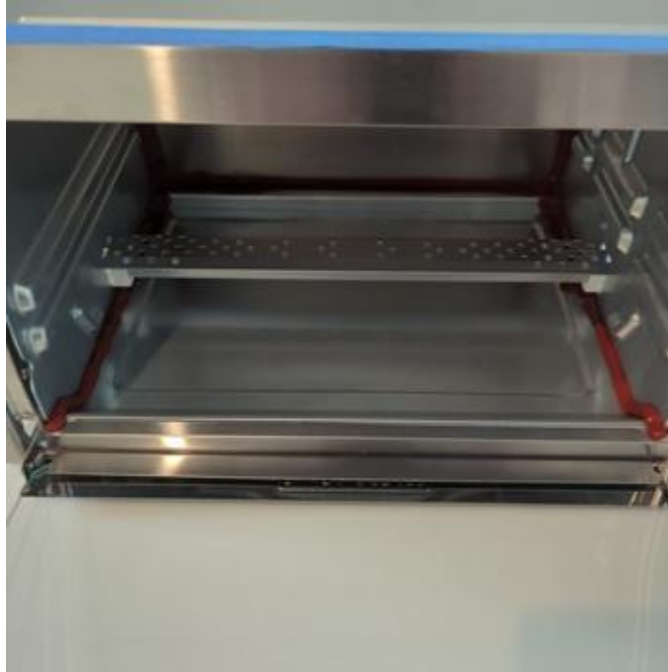


12. On the left and right sides of the oven, create beads of glue that extend from beneath the bottom heater to the front of the oven. They should connect with the glue that you placed earlier.



Attention

Do not get glue on the door glass. It's extremely difficult to remove.



13. On the left and right sides of the oven, create beads of glue long enough to cover any air gaps in the roof near the front of the oven.



14. Smear any remaining unsmearred beads of glue using your finger.



Note

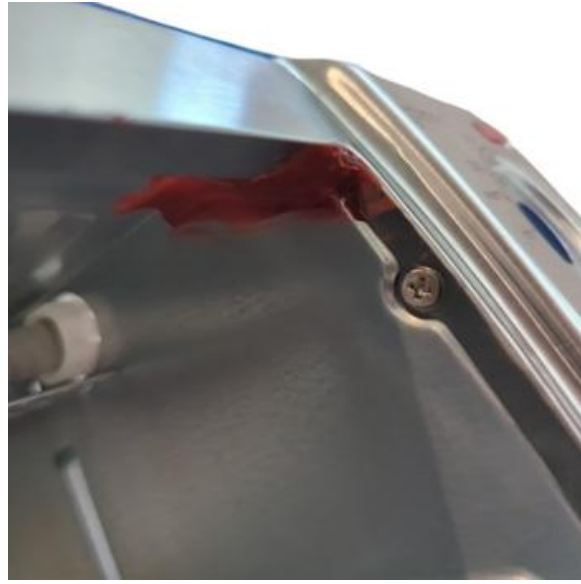
Do not leave lumps of glue beneath the heaters. This will make installing the insulation much more difficult.



15. If you got glue in places that you didn't intend, then clean it up with a paper towel before it sets.

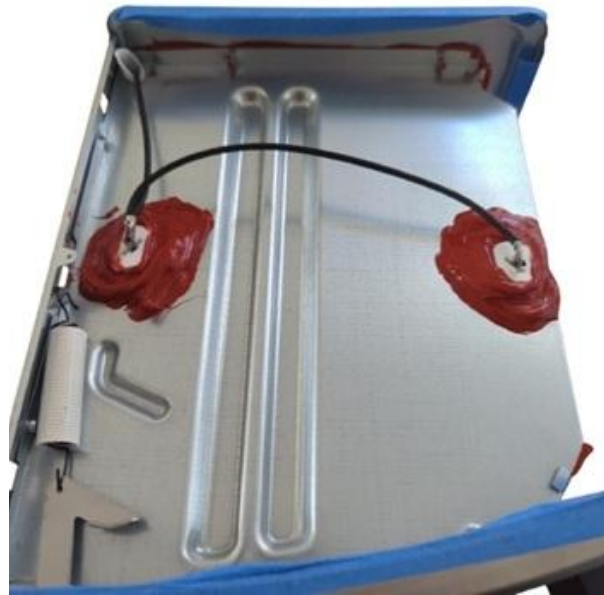


Before Cleaning



After Cleaning

16. On the outside of the oven, add and smear glue around the four heater terminals. Remember, longer smears are better - don't dabble. Completely cover all metal tabs and gaps around the heater terminals. Do not allow glue to touch the wiring.



17. Verify that all gaps have been sealed. You can use a light inside the oven to help identify where the gaps are.
18. Set the oven outside or in a well ventilated space to dry.



Attention

Don't throw the tube of glue away yet! You'll need to use it later!

Congratulations! You've finished the tougher of the two glue steps! While the oven dries, let's prepare some sub-assemblies.

Step 4: Prepare the Relay Assembly



Estimated Time

10 - 15 minutes

Controleo3 can work with both mechanical relay modules and solid state relays (SSRs), but it's strongly recommended to use SSRs for Controleo builds.

Mechanical Relays

Mechanical relays tend to be much cheaper than quality SSRs, but they have a lot of disadvantages. They have mechanical contacts that wear out over time and can be affected by impacts, vibration, and altitude. They also produce a fairly loud "click" sound every time they're turned on, so you'll hear hundreds of clicks per profile.

Most importantly, mechanical relays require high coil currents and cause voltage spikes that Controleo3's outputs aren't able to handle. Controleo3 can only supply

around 23mA per output, so you'll need a circuit to drive the coil if you want to use a mechanical relay. This circuitry is built into some relay modules.

Solid State Relays

Solid state relays solve most of these issues. They have no mechanical parts, so they have less trouble with impacts, vibration, altitude, and noise. They also have lower current requirements and no inductive kickback, so you won't need a separate relay driver. However, they cost quite a bit more than most mechanical relays.

When choosing SSRs for your oven, it's important to keep in mind the environment they'll operate in. Without active cooling (fans), the electrical chamber of the oven gets fairly warm (around 40 - 60°C). The SSRs should be derated to allow for this. The build kit includes [Opto 22 240D10 SSRs](#) which are rated for 10A of **continuous** current. For the build in this guide, you can derate them to around a **peak** of 6 - 7 amps for a few reasons.

- The SSRs are rated for around 3 amps of continuous current at 60°C with no heat sink at all. You have an aluminum heat sink.
- Controleo3 rotates the heaters to balance heat throughout the oven. That means that the SSRs are not conducting power continuously.
- If you insulate your oven well, then the duty cycles for maintaining temperature are much lower than for ramping quickly. The SSRs will have a low duty cycle during an overwhelming majority of the profile.

This means that with a 120VAC circuit you can switch around $6.5A * 120VAC = 780W$ of power per SSR. For example, you could switch two 375W heaters in series or one 600W heater. With this approach, we've measured the SSRs and aluminum plate to get slightly warm (around 50 - 60°C) during consecutive high-temperature lead free reflows.



Note

Without insulation, the bottom heater's duty cycle was recorded around 95% during ramping. With insulation, that dropped to around 55%.
Insulate your oven!



Note

The SSRs power dissipation won't increase if you increase the mains voltage. A 240VAC circuit will allow us to switch twice as much power with the same amperage and heat dissipation.



Note

If you're building a larger oven, then your relays might be carrying more current at higher duty cycles. If the convection fan gets in the way, then your relay plate might also be smaller. Consider adding active cooling (a cooling fan) and/or passive cooling (a heat sink). Controleo3 profiles support cooling fans, but you'll need a relay to switch the fan.

The relays are mounted to a thermally conductive aluminum plate to dissipate the heat. Copper and aluminum both have great thermal properties. That's why these metals are used as heat sinks for computers. Stainless steel's thermal conductivity is around 1/10th that of aluminum, so **do not** mount your relays to the oven walls! The SSR's in this guide are mounted on a 6 x 6" (152.4 x 152.4mm) aluminum sheet that is 1/16" (1.58mm) thick.

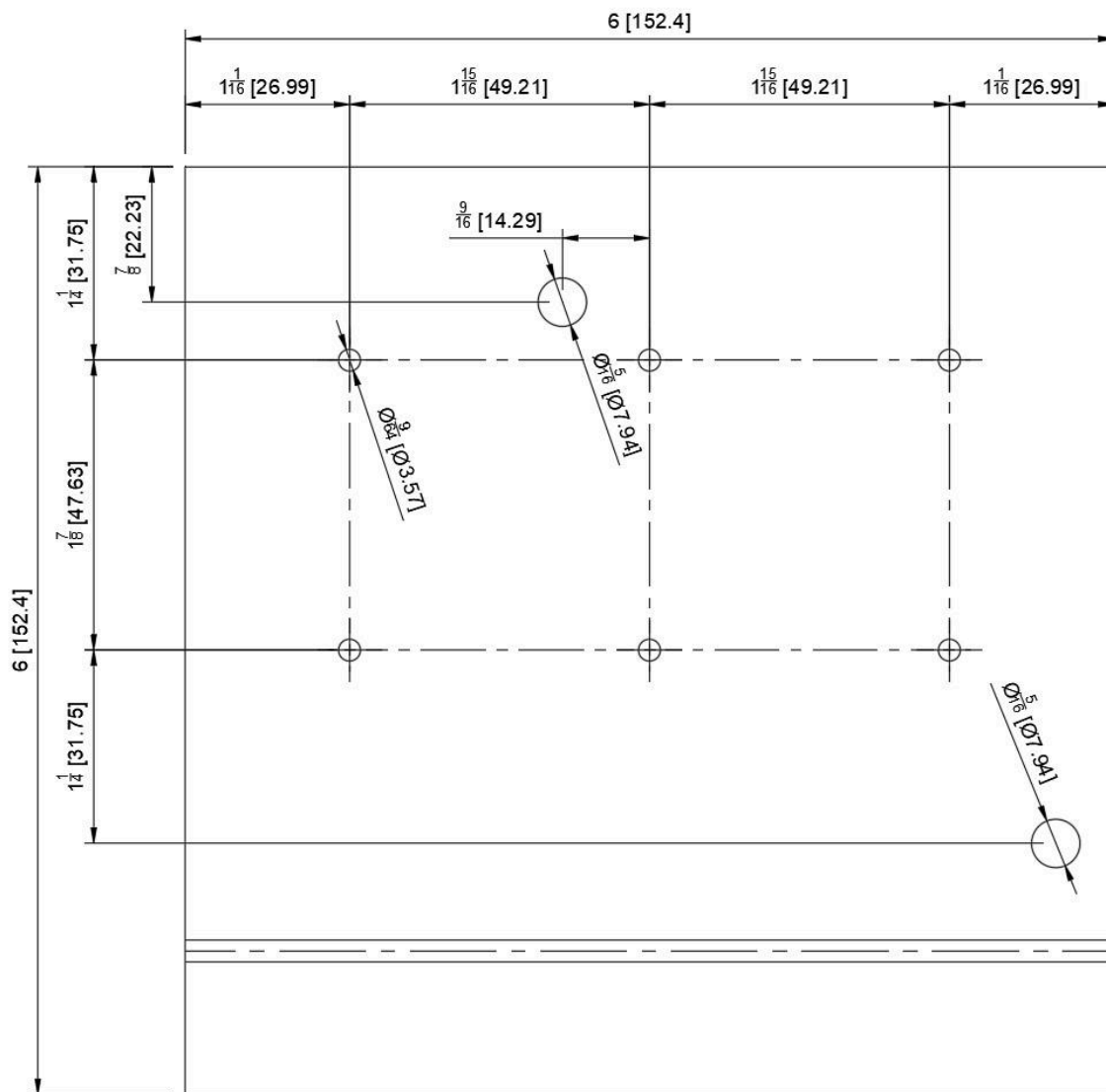
1. Unbox all of your SSRs and set the screw terminal hardware bags in a safe place. You'll use them later.
2. Using a marker, mark where you'd like the holes in the 6 x 6" (152.4 x 152.4mm) aluminum plate. It's recommended to drill them as shown. There are six 9/64"

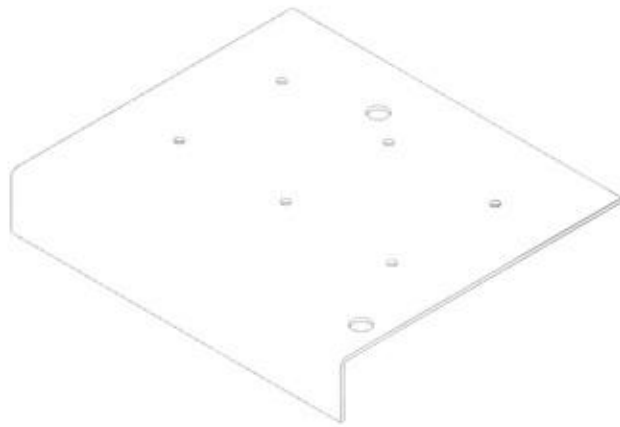
(4mm) holes to mount the SSRs and two 5/16" (8mm) holes for wire and zip tie routings.



Note

This piece doesn't come pre-drilled to make your build flexible. You can mount fewer or extra components without your plate looking like swiss cheese.





3. Punch and drill the holes.
4. Remove burrs. This can be done using a countersink bit.



5. Cut the thermal pad in half two times, making four equal sized squares.
6. For three of the squares, trim one dimension to 1.75" (44.5mm) so that it matches the width of the SSR.
7. Flip each SSR face down so that its metal heat sink is exposed.



- Place one of the three trimmed squares onto each SSR flush against three edges of the SSR.



Attention

Remember to remove the backing from **both** sides of the thermal pad!
For best performance, avoid getting dirt and fingerprints on the thermal pad.



- Use the remaining square to fill in spots without a thermal pad.



10. Using nuts and bolts, mount all of the SSRs to the relay plate with the AC (~) side facing away from the bend. Make sure they're secure - you don't want loose parts rolling around near mains voltage.



Step 5: Prepare the Power Supply



Estimated Time

5 - 10 minutes

Next, you need to attach some wires to the power supply's AC prongs. For this, you'll use quick-connect crimps and some heat shrink.



Note

Before installing the power supply, it's a good idea to check that it works with your Controleo3. Strip some wire off of the power supply's 5VDC output and connect it to the Controleo3's adjacent terminals labeled "+" and "-". The controller's screen should turn on and the pre-flashed software should show.

1. Cut 12" (300mm) of the 18ga (1.0mm²) blue silicone wire. Larger ovens may require more wire.
2. Strip 1/4 - 3/8" (6 - 10mm) of wire from both ends.
3. Using a proper crimping tool, secure 18ga 6.3mm quick-connect terminals to the wire.



Electrical Hazard

Use a proper crimping tool! We recommend a ratcheting crimper. Using pliers isn't worth getting electrocuted or starting a fire!



4. Slide two pieces of 1.5 - 2" (40 - 50mm) long 6mm heat shrink over the crimps.
Don't shrink it yet!



5. Connect the quick-connect terminals to the power supply's AC prongs.



6. Slide the heat shrink over the power supply's AC prongs and quick-connect crimps such that there is no exposed metal.



7. Shrink the heat shrink with a heat gun or lighter.



Heat Hazard

Heat guns and lighters may be capable of melting the plastic enclosure on the power supply. Direct heat away from the power supply to prevent damaging it.



Step 6: Prepare the Enclosure



Estimated Time

5 - 15 minutes



Stop and Read Ahead

This method works well for the TO1313SBD and ovens of a similar design. Your unique oven may require a different approach. Before drilling holes, read ahead and make sure that this mounting method will work for your oven.

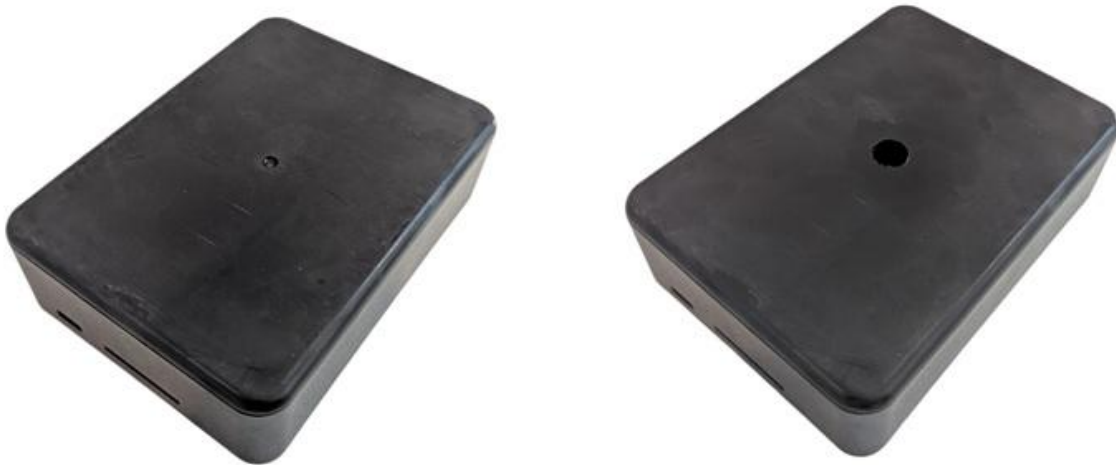
Next, you will prepare the enclosure for the controller. The enclosure will be secured to the outside of the oven and will serve as a mounting point for the door servo.

1. In the enclosure base, drill a 7/16" (11mm) hole through the center of the enclosure. Use the injection gate mark (lowered spot) as the center.



Note

7/16" (11mm) is a large, irregular drill size that might not be found in your drill bit set. A 3/8" (10mm) hole might work as a tight fit.



2. Line the controller bracket up as shown. The right edge of the bracket should line up with the seam in the plastic. This helps guarantee that it's straight.



Attention

Don't underestimate the spatial perception needed to figure out where the aluminum plate goes! It could go on the left or the right, facing up or facing down. Only one combination is correct!



3. Drill $9/64$ " (3.5mm) holes to mount the controller bracket. After the first hole, install a #6 machine screw and double-check that the bracket is straight.



4. Secure the plate using #6 machine screws and nuts.



5. Install the servo into the servo bracket using the #4 x $5/16$ " screws as shown.



Attention

The servo can be installed in four different ways, but only one of those is right!



6. Line the servo bracket and enclosure up as shown. Make sure of the following.

- The servo arm will be able to make a full arc without colliding with the door or oven roof.
- The servo arm sweeps over the door handle where you will mount a bracket.



Note

Don't mount the servo arm to the servo just yet! The servo isn't guaranteed to be in its home position (90° out of 180°), so installing it now might prevent the arm from reaching far enough to open the door.



7. When you're happy with the servo mounting bracket's position, drill three holes measuring 1/16" (1.5mm) through the bracket. Install three #4 x 5/16" sheet metal screws to secure the bracket.



Step 7: Drill Holes



Estimated Time

15 - 25 minutes



Stop

Wait for the glue to dry before proceeding. Otherwise, you'll end up with metal filings stuck in your glue.



Sharp Hazard

Burrs created by drilling through metal can be sharp, but **do not** wear gloves while drilling! Gloves can get caught in the power drill and cause serious injury. Just keep away from the burrs until you've removed them!

Next, you're going to drill all the holes in the oven chassis. The table below summarizes the holes you'll make in this step. Check them off as you go along.

Hole Description	Qty	Diameter (in)	Diameter (mm)
Thermocouple routing	1	9/64"	4mm
Grommet plate mounting	2	9/64"	4mm
Top insulation bolts	4	9/64"	4mm
Controller chassis bolt	1	9/64"	4mm
Controller bracket mounting	2	9/64"	4mm
Power supply zip tie routing	2	3/16"	5mm
Eye bolt mounting	2	3/16"	5mm
Boost heater wire routing	1	5/16"	8mm



Note

Mark all holes with a marker and a center punch before drilling. Otherwise, your bit might slip and cause damage to the oven.



Note

The drill bits are very sharp! Go slowly, drill perpendicular to the surface, and handle the drill with a firm grip. If you push too hard, the drill can tear through the sheet metal instead of cutting it.

1. Drill a 9/64" (4mm) hole for the thermocouple to enter the oven chamber. It's recommended to do this near the top-back-right corner as shown.



2. Widen the two screw holes in the front of the oven that were previously used to hold the top knob. Use a 9/64" (4mm) bit.



3. Drill four $9/64$ " holes to secure a small cut of Floor and Tunnel Shield II to the roof of the oven. You'll want holes on either side of the top heater so that the insulation won't fall onto the heater if the adhesive fails. For the TO1313SBD, these holes are spaced in a rectangle measuring roughly 3.5×8.5 " centered about the top heater. Refer to Step 8 for more information about Floor and Tunnel Shield II.



4. Drill a 9/64" (4mm) hole in the oven chassis where you will install a bolt securing a ground wire for the controller. The best place to do this is atop the existing ground symbol punched into the chassis.



Note

The ground wire should be kept away from the inner walls of the oven. The wire's insulation and crimp aren't rated for reflow temperatures.



5. Drill two 9/64" (4mm) holes to mount the controller enclosure to the oven. Make sure of the following.
 - The door can open without colliding with any part of the enclosure.
 - The servo arm will sweep over the door handle where you will mount a bracket.

- The servo arm will be able to make a full arc without colliding with the door or oven roof.

Don't mount the controller enclosure just yet! You're just drilling the holes to mount it in this step.



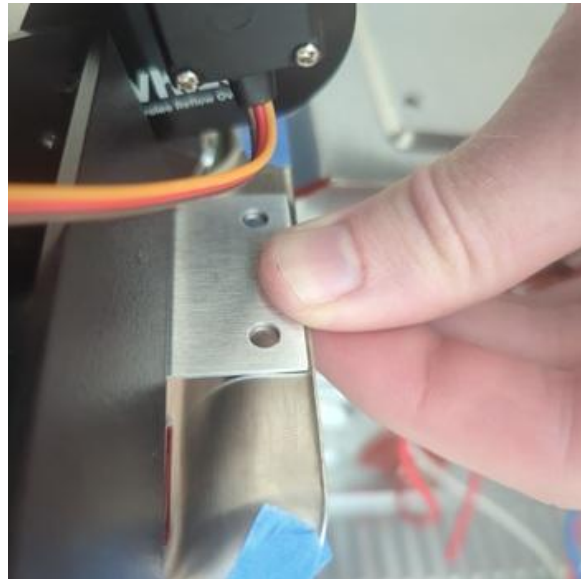
Note

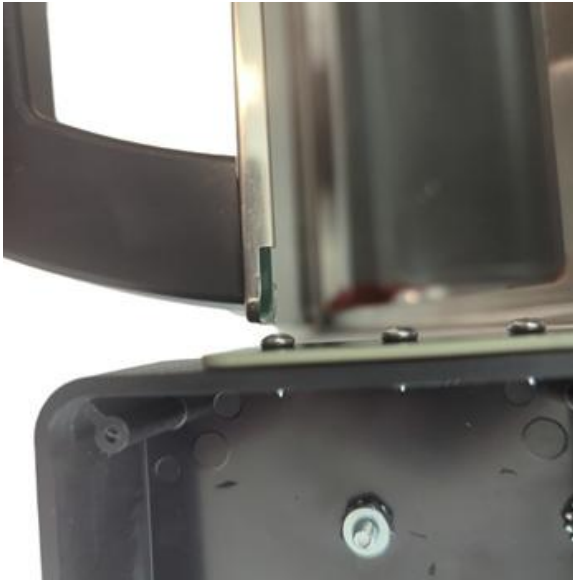
It's a good idea to remove any protective tape from the area before drilling. Otherwise your drill bits will dull quickly.



Note

It helps to use a marker to color in the holes in the controller bracket. Then punch and drill in the middle of the circular marks.





6. Drill two 3/16" (5mm) holes on the vent on the back of the oven. These holes will accommodate a zip tie holding the 5VDC power supply in place.



Attention

Don't drill too close to the vents! If you're too close to the vents, then the power supply zip tie will tear into the vents the moment you tighten it.



Note

On some ovens there's a vent on the bottom of the oven that looks almost identical to the one on the back. You'll want the holes in the vent on the **back** of the oven.

Make sure that there's clearance to mount the power supply once the relay plate is installed. For the TO1313SBD and similar, they should be drilled between the third and fourth vents.



7. The boost element will be held up by $\frac{3}{16}$ x $1\frac{1}{2}$ " unwelded eye bolts. Drill two $\frac{3}{16}$ " (5mm) holes in the front-bottom of the oven to mount them.

The boost heater measures approximately $7\frac{1}{8}$ " (180mm) long, so the holes should be closer together than that. A good spacing is around $6\frac{3}{4}$ " (170mm) apart.



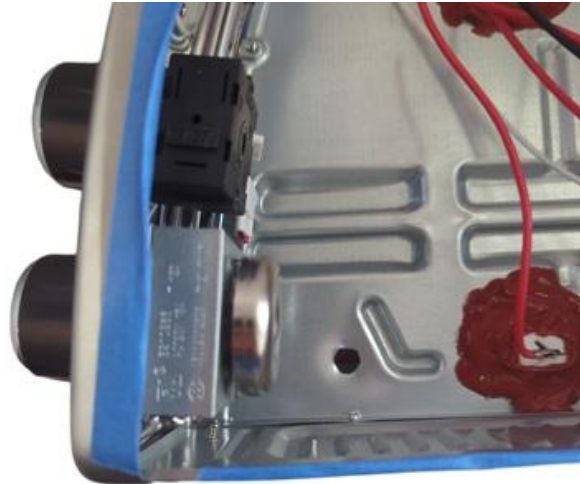
Note

The ends of the boost heater are much cooler than the center, so you want to hold the boost heater by its ends.

The front-back spacing will determine heat distribution throughout the oven. You don't want the heaters too close together or you'll get hot spots. A good distance is around 2 - 2.5" (50 - 65mm) from the bottom heater. If you have a larger oven, then the distance may need to be larger.



8. Drill a 5/16" (8mm) hole in the oven chamber for the boost heater wires. It should be roughly in line with the boost heater mounting holes you already drilled and about 3/4" (20mm) from the bottom of the oven.



9. Use a countersink bit to deburr the holes. This is especially important for the thermocouple and boost heater wire holes.



Note

If you have one, then a right-angle adapter for your drill will be very helpful for this.

10. Take care to ensure that no metal filings are left inside of the oven. This can be done by shaking out the oven or picking up the filings using tape.

Step 8: Floor and Tunnel Shield II



Estimated Time

10 - 15 minutes

Floor & Tunnel Shield II from Design Engineering, Inc. is used to cover most of the interior of the oven. It can handle continuous temperatures up to 950°C (1750°F) and has lots of thermally conductive aluminum that helps move heat evenly throughout the oven.

However, Floor and Tunnel Shield II's adhesive can only handle continuous temperatures up to 232°C (450°F). The insulation that goes on the roof of the oven chamber is at the greatest risk of adhesive failure. If it fails at high temperatures, it can fall onto the top element and catch fire (we tested this). As a precaution, we do four things to prevent this problem.

- Use a large piece so if the glue directly above the heater fails it will still be held in place.
- Make sure the insulation is firmly pressed down, to ensure the adhesion of the glue and maximize the space between the element and the roof of the oven.
- Secure the insulation to the roof with bolts.
- By default, the power to the top element is intentionally limited to 75%. This can be overwritten by the reflow profile file if necessary.



Note

A lot of things have to go wrong to encounter this problem, but we take precautions regardless. During normal reflow, the hottest you'll ever go is 285°C for short periods of time. Thanks to the insulation and low thermal conductivity of steel, we've measured the oven chamber's roof at a cool 120 - 150°C during peak reflow temperatures.

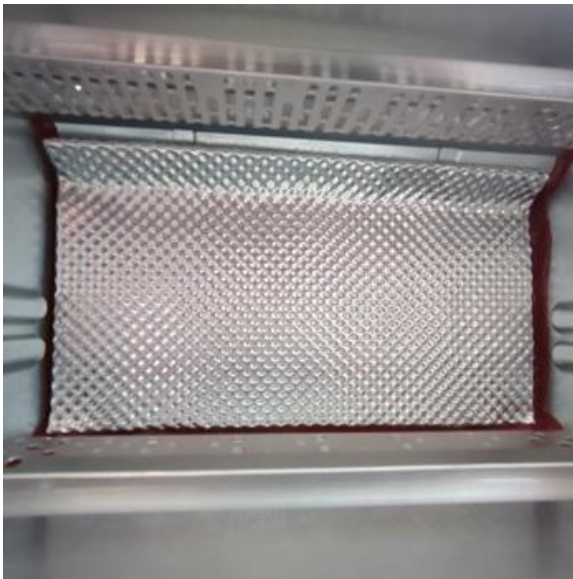
We'll start by insulating the back wall of the oven, then the roof, then the bottom. The larger piece goes on the bottom of the oven.



Note

For larger ovens, you may need to place two or more pieces of Floor and Tunnel Shield II next to each other. Keep in mind that the aluminum helps distribute heat throughout the oven. The pieces should stretch from hot spots (heaters) to cool spots (corners).

1. Without exposing the adhesive, place one of the smaller pieces against the back wall of the oven. Bend an angled flange near the top of the oven so that it fits flat against the back wall. Remove it from the oven.



2. Cut the adhesive backing in half (lengthwise) with a razor blade. Peel both halves off and reattach them about 3/4" (20mm) away from the center. This will leave pull tabs on either end of the material to be used later.



Attention

The adhesive backing is **not reversible**. Keep track of which side came stuck to the adhesive. If you stick down the wrong side, it will never come back up.

3. Stick the middle of the piece onto the back wall. Fold the tabs over on themselves and gently pull off the backing.



Attention

Once the adhesive is down, it's **never** coming back up! Keep it away from the walls until you're ready to stick it down!

4. Inspect the pieces of backing you removed to make sure that you removed all of it. If anything is left behind then it may catch fire.
5. Press down on the insulation to secure it in place.



6. Grab the remaining small piece of insulation and cut the adhesive backing in half (lengthwise) with a razor blade. Peel both halves off and reattach them, this time about 1/2" (13mm) away from the center.



Note

In tight spaces (like under the top element) it helps to have less adhesive exposed.

7. Slide the piece above the top heater, taking care not to let the adhesive touch the ceiling by forming an upside down "U" shape. Once the piece butts up against the piece on the back wall, stick down the middle. Fold the tabs over on themselves and gently pull off the backing.



8. Inspect the pieces of backing you removed to make sure that you removed all of it. If anything is left behind then it may catch fire.
9. Press down on the insulation to secure it in place.

10. Grab the large piece of insulation, and without exposing the adhesive, place it against the bottom of the oven chamber. Make two bends so that it sits flat against the bottom of the oven throughout. Remove it from the oven.



Note

Avoid leaving big air gaps below the bend. Make sure that the bend follows the metal.



11. Cut the adhesive backing in half (lengthwise) with a razor blade. Peel both halves off and reattach them about 3/4" (20mm) away from the center.

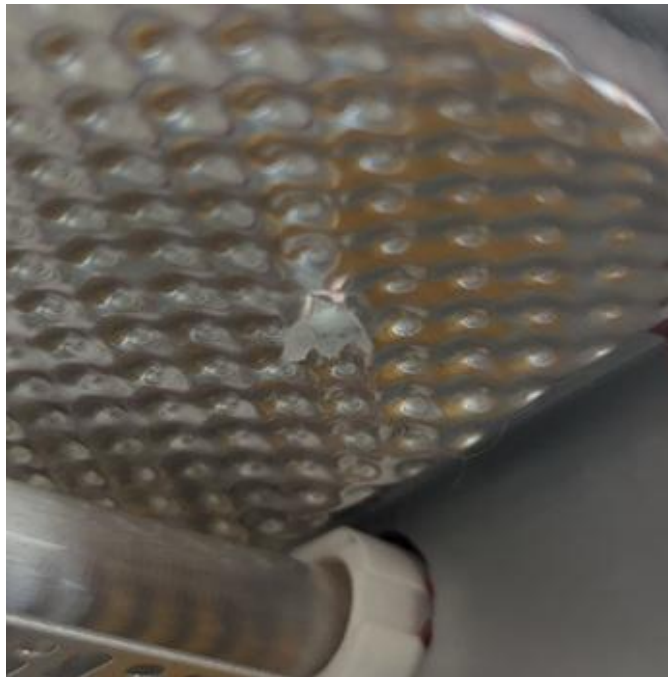
12. Slide the piece under the bottom heater, taking care not to let the adhesive touch the bottom by forming a "U" shape. Once the piece butts up against the back wall, stick down the middle. Fold the tabs over on themselves and gently pull off the backing.

13. Inspect the pieces of backing you removed to make sure that you removed all of it. If anything is left behind then it may catch fire.
14. Press down on the insulation to secure it in place.
15. Make four holes through the top piece of Floor and Tunnel Shield II using the 9/64" (4mm) holes in the oven roof as a guide. An awl is the right tool for this, but any hard, pointy object will work. Support the Floor and Tunnel Shield II with your other hand while you make the hole.

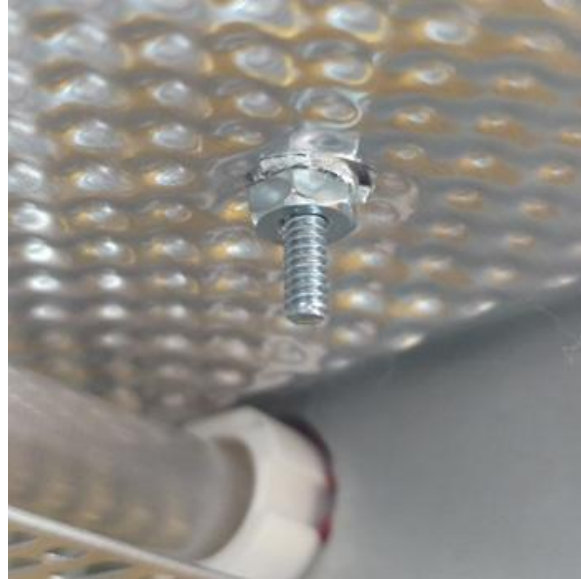
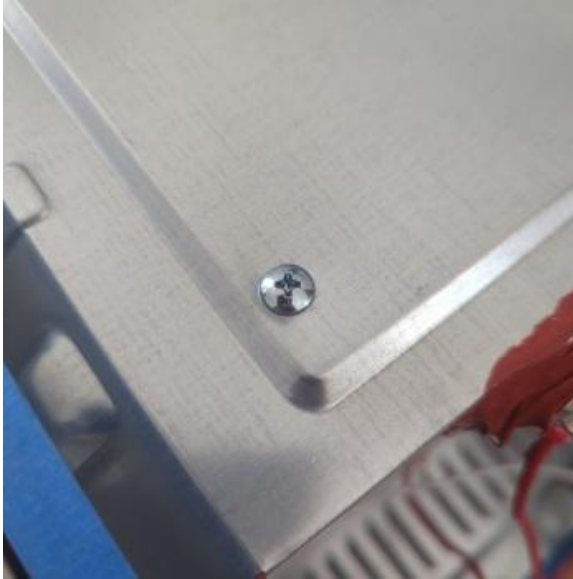


Sharp Hazard

The pierced Floor and Tunnel Shield II is **very** sharp, so wear gloves.



16. Install and tighten #6 bolts into the newly made holes. It's recommended to have the nut inside of the oven to make it easier to install the Superwool Plus later.



Step 9: Reflect-A-Gold



Estimated Time

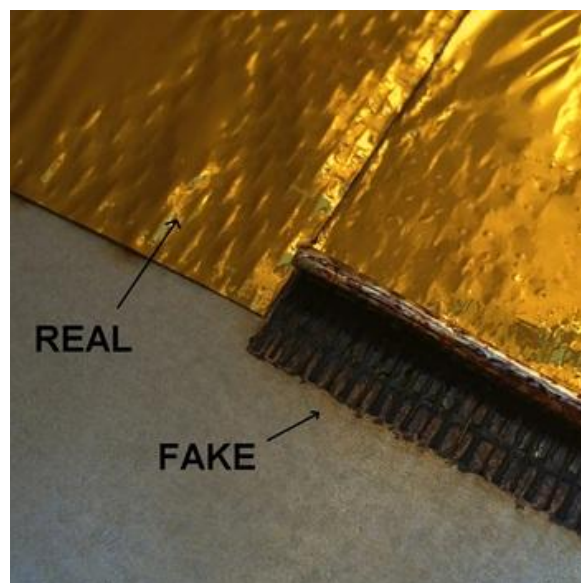
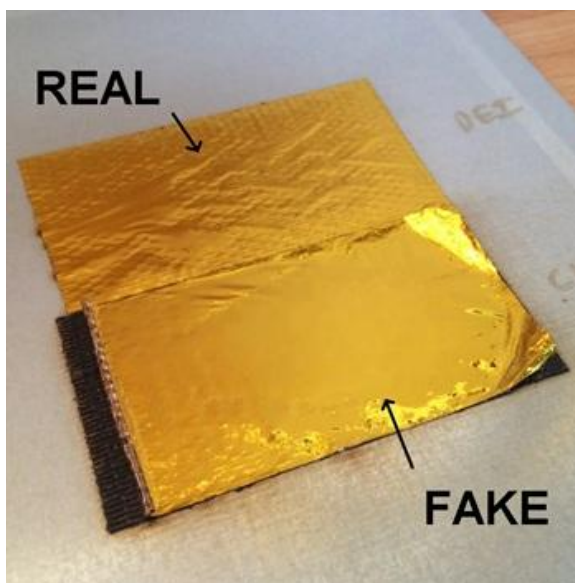
10 - 15 minutes

Next, you'll apply Reflect-A-Gold insulation from Design Engineering, Inc. to the remaining exposed walls inside the oven. This insulation is capable of handling continual temperatures up to 450°C (850°F). The goal of this insulation is to minimize heat loss through the oven walls and door. Reflect-A-Gold works by reflecting heat back to where it came from.

Reflect-A-Gold's adhesive is only rated for 162°C (325°F), which is much lower than peak reflow temperatures. Thanks to the low thermal conductivity of steel, we've

measured the oven walls at a cool 120 - 150°C during peak reflow temperatures. However, it's possible to exceed Reflect-A-Gold's limits during long profiles like high-temperature baking. For this reason, we don't recommend baking above 160°C.

Make sure to use genuine Reflect-A-Gold, not an "equivalent" available from eBay or AliExpress. The insulating properties are very similar but the adhesives on alternatives don't survive reflow (see below).



Note

You'll be tempted to use a lot more Reflect-A-Gold than needed. It's expensive, so use it sparingly! The loss through the uncovered steel walls is minimal due to their low surface area and thermal conductivity. The Superwool Plus will be installed later to catch any escaping heat.

1. Cut pieces of the following lengths. Try to make straight cuts. It's important that the two long cuts are precisely the same length.



Note

The required lengths may differ depending on your oven. These are recommendations for the TO1313SBD.

Cut Description	Qty	Length (in)	Length (mm)
Long door cut	2	10-1/2"	267mm
Short door cut	2	3"	76mm
Left wall	1	6-7/8"	175mm
Right wall	1	6-1/8"	155mm

2. Clean the inside of the oven door using isopropyl alcohol and a lint-free cloth. If you don't have lint-free cloth, then do your best to clean the surface without leaving lint behind.
3. Once the alcohol has fully evaporated, apply the first long door cut as shown below.



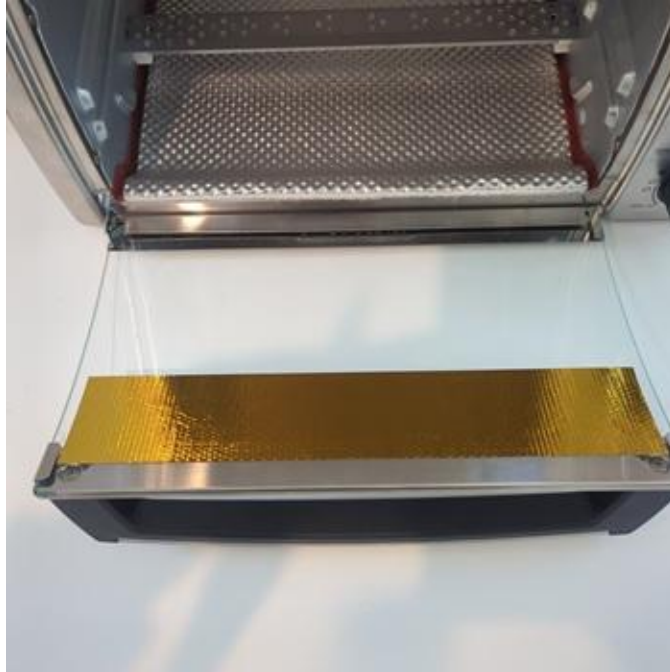
Attention

Avoid air bubbles in the Reflect-A-Gold! Try to avoid uneven surfaces and debris.

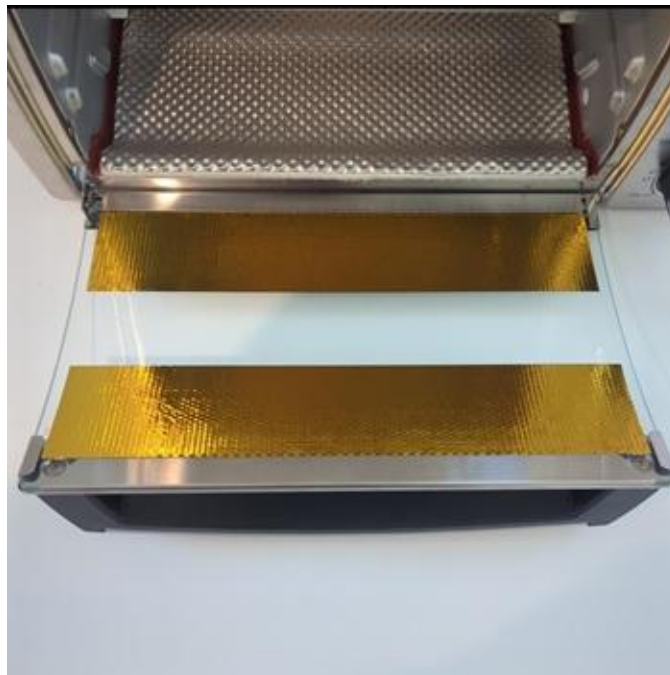


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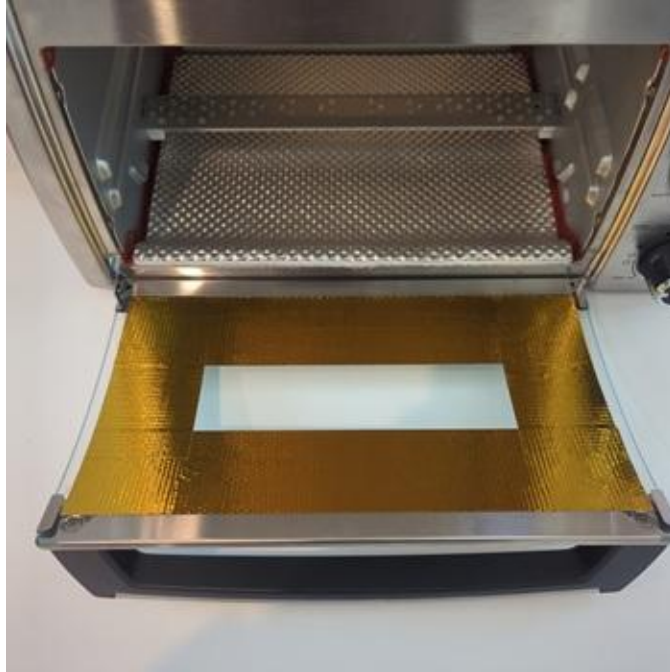
Keep in mind that the door is not necessarily centered on the oven chamber! Your insulation should be centered on the oven chamber. Some ovens have doors that stretch an inch or more to the left/right of the oven chamber.



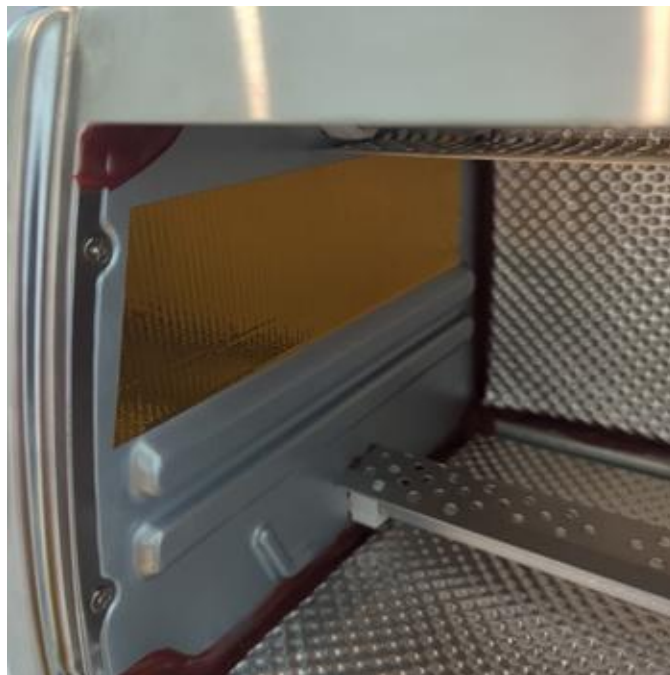
4. Apply the second long door cut on the opposing end of the door, parallel and in line with the first long door cut.



5. Apply the two short door cuts as shown.

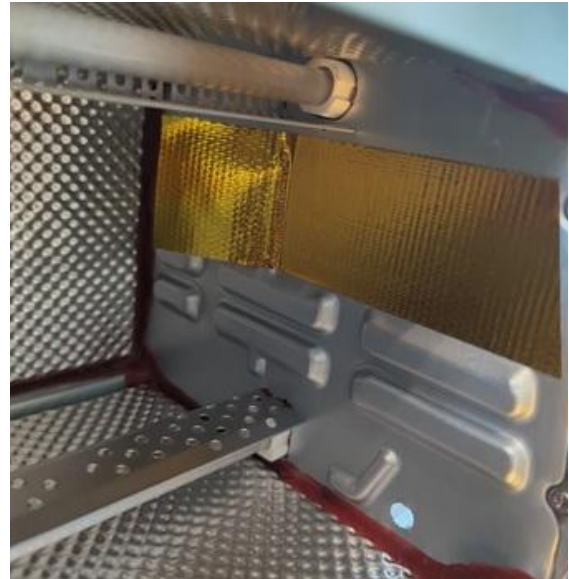


6. Make an angled cut to the end of the left wall piece so that it appears as shown. Apply it to the left wall above the ridges used to hold the tray. It should be as close as possible to the front of the oven without covering uneven surfaces.



7. Make an angled cut to the end of the right wall piece so that it appears as shown. Apply it to the right wall above the ridges used to hold the tray. It should be as close as possible to the front of the oven without covering uneven surfaces.

About halfway through this piece you will encounter a large bump. Before securing the back half of the piece, press the tape down along the ridge's surface as you go up and over it. Don't leave air gaps, and don't cover the thermocouple hole!





8. Feel free to apply any leftover Reflect-A-Gold to better insulate your oven! You should still have roughly half the roll left.

Step 10: Tray Spacers



Estimated Time

5 - 10 minutes

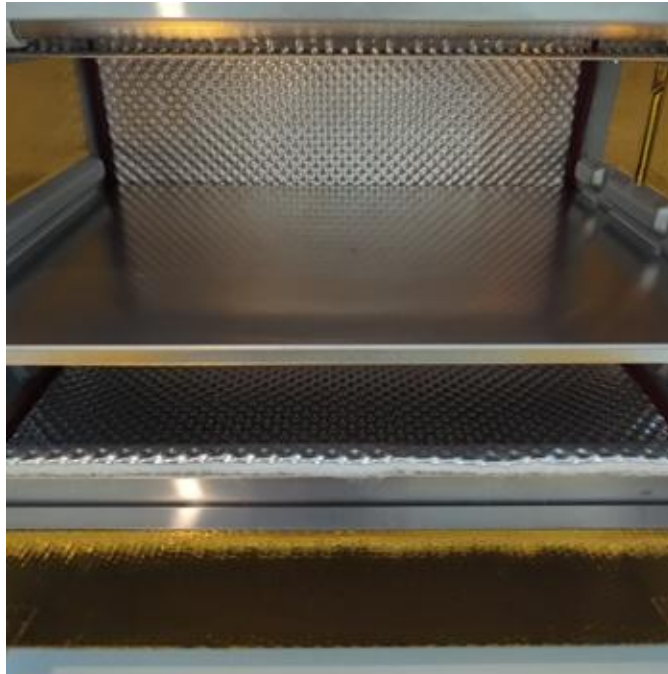
In this step you will install spacers into the back wall of the oven. These spacers will make a space for airflow between the tray and the back wall of the oven, allowing for natural convection and improving heat distribution.

1. Place your tray in the oven as shown.

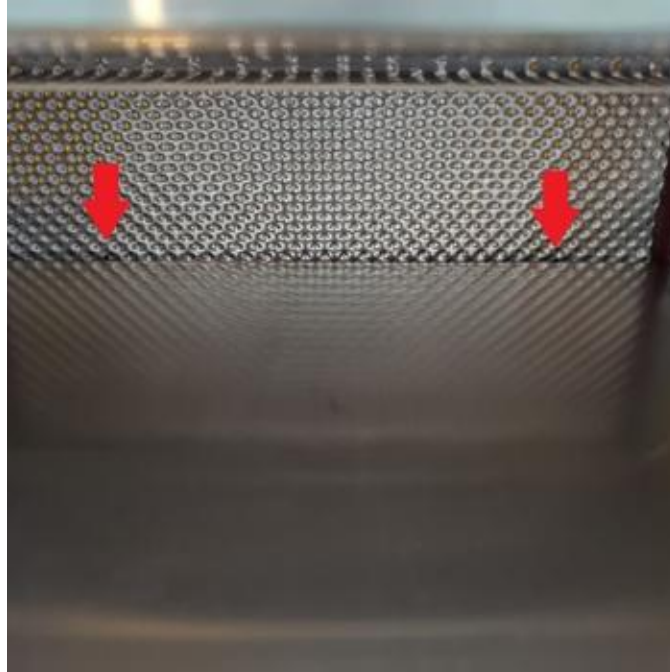


Note

In most cases, it's a good idea to use the lower ridge to hold the tray. This keeps the components further from the top heater.



2. Using a marker, mark two evenly-spaced dots where the tray makes contact with the Floor and Tunnel Shield II on the back wall.

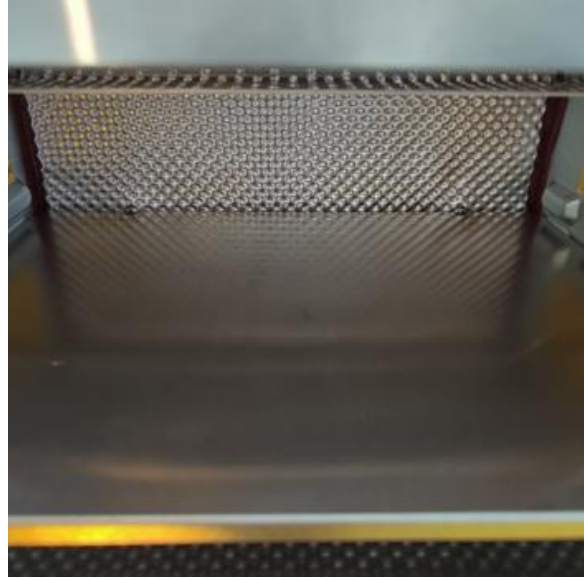


3. Using a screwdriver, drive the spacer screws into the Floor and Tunnel Shield II.
This may take a little force.



Attention

Go slowly! Don't overtighten the spacer screws or the material won't be able to hold them in place!



Step 11: Boost Heater



Estimated Time

5 - 10 minutes

Next you will install the resistive boost heater. We use a 400W resistive heating element that is normally used for heating molds. It will be held up by eye bolts on either end, and the wires will exit the oven chamber through a hole you made in a previous step.

1. Set the oven on its left side.



2. Make holes through the bottom piece of Floor and Tunnel Shield II using the 3/16" (5mm) holes for the boost heater as a guide. An awl is the right tool for this, but any hard, pointy object will work. Support the Floor and Tunnel Shield II with your other hand while you make the hole.



Sharp Hazard

The pierced Floor and Tunnel Shield II is **very** sharp, so wear gloves.



3. Remove the hex K-lock nut from each eye bolt. Leave the regular hex nut in place.



4. Put the heater through the eye bolts, thread its wires through the 5/16" (8mm) boost wire hole, and put the eye bolts through the holes you just made.



5. Secure a hex K-lock nut to the end of each eye bolt on the outside of the oven.
6. Tighten the eye bolts in place. Adjust the two nuts until no more than 1/8" of threads protrude from each nut on the bottom of the oven.



7. Straighten the eye bolts and heater on the inside of the oven until they are to your liking. Make sure that the boost heater is centered in the eye bolts.



Note

The boost heater can be temporarily secured in place by rotating both eye bolts. This may require a bit of force.



Crooked Heater and Eye Bolts



Adjusted Heater and Eye Bolts

Step 12: Install the Thermocouple



Estimated Time

5 minutes

We will use a fiberglass insulated "K-type" thermocouple probe that can measure up to 550°C. This particular probe is used because it has a low-mass tip so it responds very quickly to changes in temperature.

Ideally, the thermocouple should measure the temperature experienced by the solder. Our first thought was to use aluminum tape and tape it to the board being reflowed. However, this method falls short in practice. It's difficult to place the probe on the PCB and get consistent results. The thermocouple could be over a via or there can be a tiny air gap between it and the PCB. It's also easy to accidentally bump components when trying to place the thermocouple.

We've found that the best approach is to place the thermocouple in a location that approximates the board temperature, but doesn't rely so heavily on direct contact. This will improve consistency because the thermal mass of the oven is largely unchanged between runs. We have built ovens and reflowed boards using both placement methods and we recommend this method without reservation.



Attention

Don't place the thermocouple near any of the heaters or oven walls! This will cause significant overshoot/undershoot.

1. Insert the thermocouple into the oven through the 9/64" (4mm) hole you drilled earlier. You should have 3" or 4" of the thermocouple inside the oven.

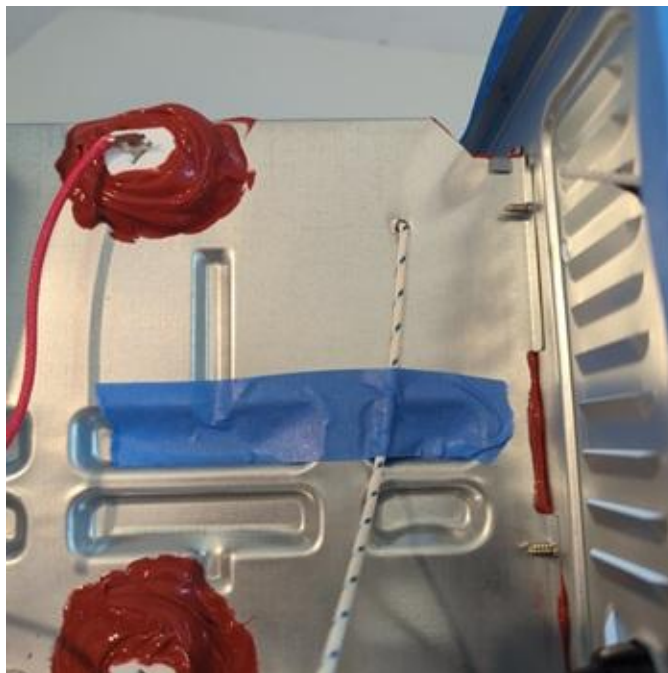


2. Route the thermocouple downwards. Secure it with a piece of masking tape, leaving around 2" of wire against the oven for us to cover in glue.



Attention

The masking tape **must** be removed before closing the oven otherwise it will burn!



Step 13: Glue (again)



Estimated Time

5 - 15 minutes



Stop and Read Ahead

Read through this entire step before proceeding. Set aside around 15 minutes of uninterrupted time. Do not stop until you reach the end of the step. Otherwise the glue will set.



Respiratory Hazard

The glue releases fumes that can cause mild respiratory irritation. Work in a well ventilated area. These fumes are mostly acetic acid (vinegar), hence the strong vinegar smell.

The glue is classified as non-hazardous and non-carcinogenic.

Regardless, it's still recommended to wear gloves (e.g. latex gloves). For more information refer to the [material safety data sheet](#).

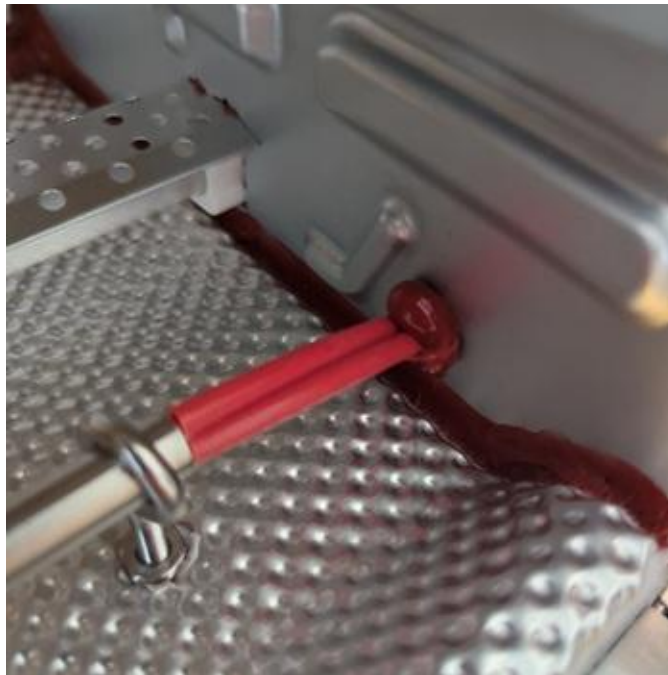
Congratulations! You've made it to the last glue step. Now you're going to seal the holes for the thermocouple and boost heater wires.



Attention

For this step, it's crucial that the boost heater stay in the right position (secured by the two eye bolts). Take care not to let it move or it will dry in the wrong place!

1. This step is much shorter than the last one, but you'll still want to get set up for glue. Lay out cardboard or newspaper and change into clothes that you don't care about.
2. Route the wires from the power cord through the 3/16" (5mm) holes for the power supply zip tie to keep them out of the way.
3. On the inside of the oven, apply a small amount of glue around the boost heater wires against the oven wall.



4. Smear the glue around the boost wire hole, taking care not to get it on the Floor and Tunnel Shield II insulation.

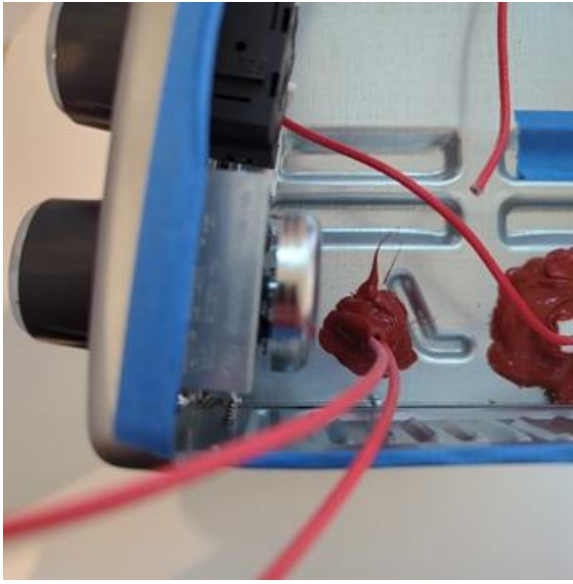


5. On the outside of the oven, apply glue to the boost heater wires and thermocouple. Smear until it is to your liking. Make sure that there are no air gaps left (including under the thermocouple).



Note

Remember, longer smears are better! Don't dabble or the glue will look spikey. Clean your finger after each smear.



6. Clean any glue that got onto the Floor and Tunnel Shield II, wires, or glass door with a paper towel.
7. Set the oven on its base and let it dry undisturbed. This will prevent the boost heater from shifting and drying in the wrong position.

Step 14: Grommet Mounting Plate



Time

5 minutes



Stop

Wait for the glue to dry before proceeding. Otherwise, the boost heater might shift positions and ruin your hard work.

In this step you'll secure the grommet mounting plate to the oven. This plate holds the grommet that the low voltage wires will exit the oven through. It's installed on the backside of the hole where the top oven knob used to be. We supply a plate to hold the grommet because not all ovens use the same diameter hole for the knobs.

1. Secure the grommet plate to the oven as shown.



Step 15: Install the Relay Plate



Time

10 - 15 minutes



Sharp Hazard

While they look blunt, the edges of the relay plate can cut your hands with enough force. Be careful!



Note

Resist the temptation to put the Superwool Plus in the oven at this time. It's easier to install it now, but you'll end up fighting it for a long time.

In this step you'll install the relay assembly in the oven.

1. Lengthen any heater wires that are too short to reach their relays (see Step 17). Usually only the bottom heater wire needs to be lengthened by around 4 - 6" (100 - 150mm). Use butt connectors and 18ga (1.0mm²) silicone wire to accomplish this.

Strip roughly 1/4" (6mm) from each wire that will need a butt connector and insert it halfway through the butt connector. Then, crimp that half of the butt connector. Repeat the process with the blue silicone wire on the other end of the butt connector. Finally, heat the butt connector with a heat gun or lighter to activate the heat shrink.



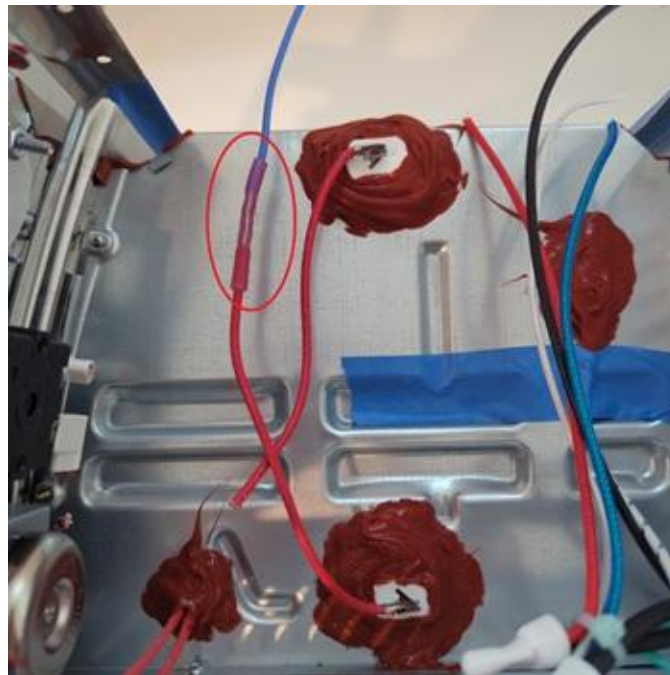
Electrical Hazard

Use a proper crimping tool! We recommend a ratcheting crimper. Using pliers isn't worth getting electrocuted or starting a fire!



Attention

The butt connectors are only rated for around 125°C. That means that they shouldn't be touching the oven chamber walls! When installing the Superwool Plus, make sure to put it between any butt connectors and the oven walls.

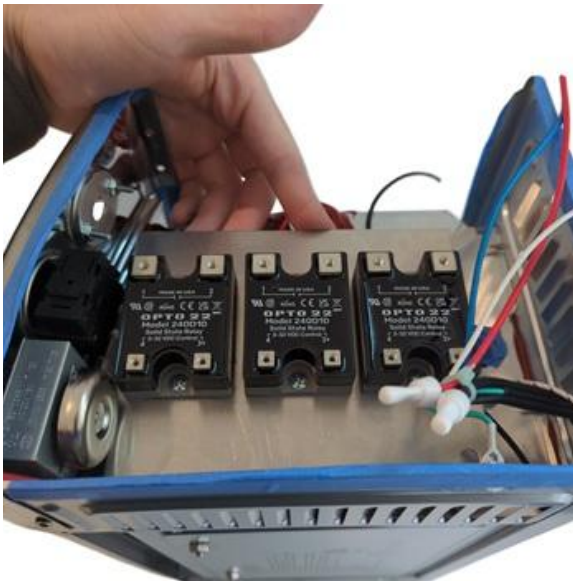


2. Hold the relay assembly in the oven as shown. It should be as far towards the bottom-left corner of the electrical chamber as possible to make room for the power supply. Some ovens have screws or rivets that get in the way. Remove them.



Note

Rivets can be removed by drilling them out with a 9/64" (4mm) drill bit. Center the bit in the head of the rivet.



3. Mark and punch hole(s) in the bottom of the oven where you'll install bolts to mount the relay assembly. Ideally, the holes will be staggered to prevent the plate from wobbling.



Note

If you removed screws/rivets that were in the way, then you'll want to use them to mount the relay assembly. Otherwise, the oven chassis will become flimsy.

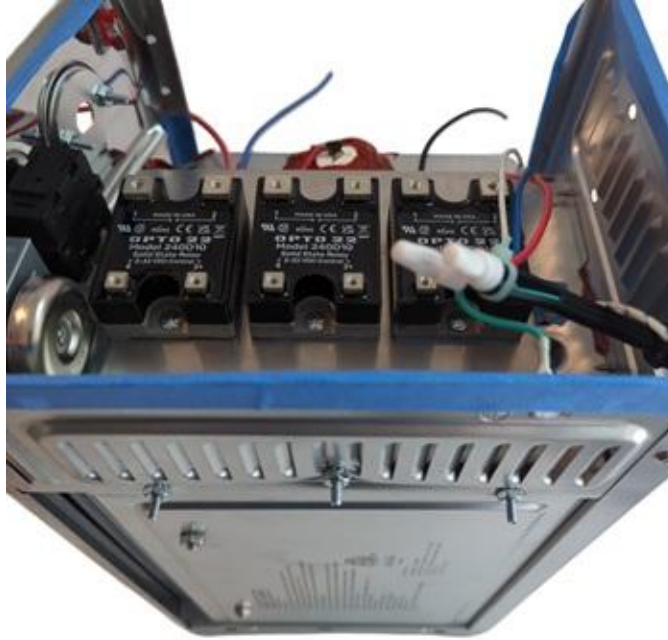


4. Holding the relay assembly in place, drill 9/64" (4mm) holes through the chassis and relay plate where you punched. Install bolts to hold the relay assembly in place as you go.



Note

Installing the bolts is difficult. Putting the nut on the outside of the oven makes it a lot easier.



5. Take care to ensure that no metal filings are left behind. This can be done by shaking out the oven or picking up the filings using tape.

Step 16: Install the Power Supply



Time

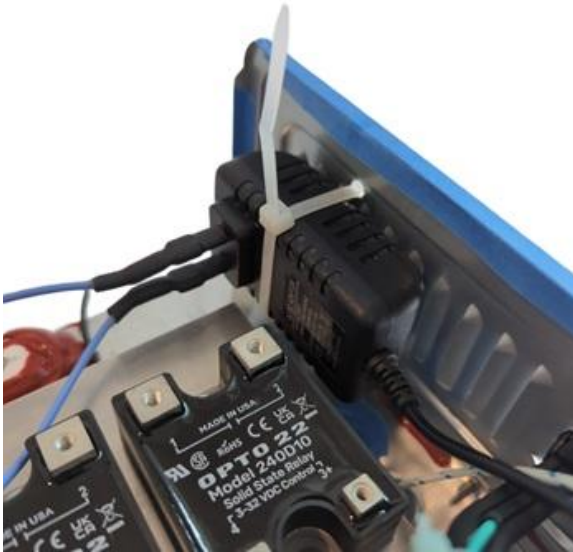
5 minutes

In this step you'll secure the power supply inside the oven chassis.

1. Place the power supply assembly as shown. Ideally the power supply's AC prongs will be above the relay plate to allow room for wire routing.



2. With a zip tie, secure the power supply using the two 3/16" (5mm) zip tie holes. Don't cut the zip tie too close or it might come loose when it warms up.



Step 17: Mains Voltage Wiring



Time

15 - 30 minutes



Electrical Hazard

It's important to get your high-voltage wiring right! This step uses mains electricity. Depending on your circuit, this can range from 110VAC to 240VAC. These voltages can kill!

If you're not confident, then please stop the build and/or consult an electrician. Your safety should be your top priority.

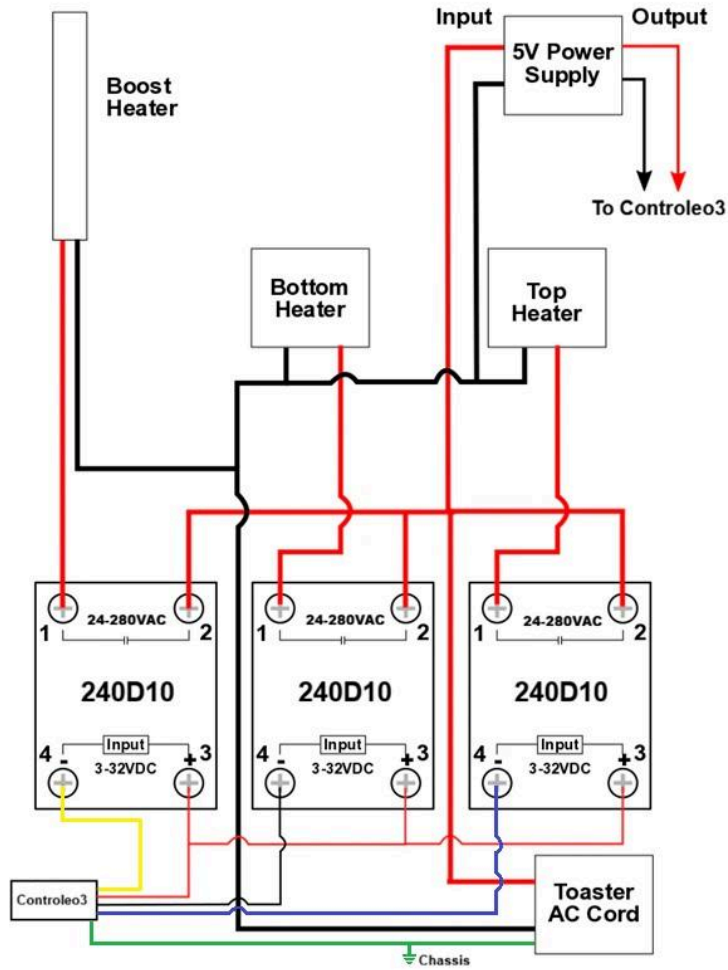


Stop And Read Ahead

We've written this step for the TO1313SBD, but different oven models may have mains voltage wiring that looks very different. Read ahead and decide the best way to wire up your unique oven.

In this step, you'll do all of the mains voltage wiring for the oven. This includes the AC power to the relays, heaters, and 5V power supply.

We'll route a hot wire to each of the SSRs and the 5V power supply. Neutral wires will go to one end of each heater and the other terminal of the 5V power supply. The remaining end of each heater should be connected to the SSR that will switch it.



Each SSR can control a single heater or a group of heaters. Heater groups can be set up in a few different ways.

- When wired in parallel, two or more heaters will draw their normal load current. That means that two 550W heaters in parallel will draw 1100W, which is more than our 10A relays can handle after derating.
- When wired in series, two or more heaters will split the voltage between themselves. For an even split, the heaters must have the same resistance.



Electrical Hazard

Never run a 120VAC heater using 240VAC! This will cause the heater to use **four** times as much power and burn out or melt down.

If you must use 120VAC heaters with 240VAC, then you'll need to put two heaters of the same resistance in series. This will halve the voltage experienced by each heater.



Attention

Read the following instructions for connectors thoroughly. Improper use of the connectors can be very dangerous.

Throughout this step you'll use a few different types of connectors. There's a few things to keep in mind while using them.

- Use a proper crimping tool. We recommend a ratcheting crimper.
- After every connection, give it a gentle tug to see if the wire is secure.
- Don't leave any wire hanging out of the crimps or Wago 221 connectors.
- Wires should bottom out in the Wago 221 connectors.
- The Wago 221 connectors shouldn't be gripping the wire's insulation. Check through the clear back to see where the wires are being held.
- Wago 221 connectors have a maximum continuous operating temperature of 105°C and butt connectors have a maximum continuous operating temperature of 125°C. They'll be fine in the free air, but not if they're pressed against the oven chamber walls. Keep them away from the oven walls!

The table below summarizes the correct strip lengths for each mains voltage connector.

Connector	Strip Length (in)	Strip Length (mm)
Ring Terminal, 22 - 16 AWG, #8 Stud, PVC	1/4 - 3/8"	6 - 10mm
Butt Connector, 22 - 16 AWG, Heat Shrink	1/4"	6mm
Wago 221, 24 - 12 AWG, 5 Position	7/16"	11mm

1. Set the oven on its side so that you can access the electrical chamber easier.



2. Determine which wires on the power cable correspond to hot, neutral, and ground. This can be done using a multimeter's continuity test mode. Touch one lead of your multimeter to a prong on the cable and the other to each wire until continuity is detected.



Note

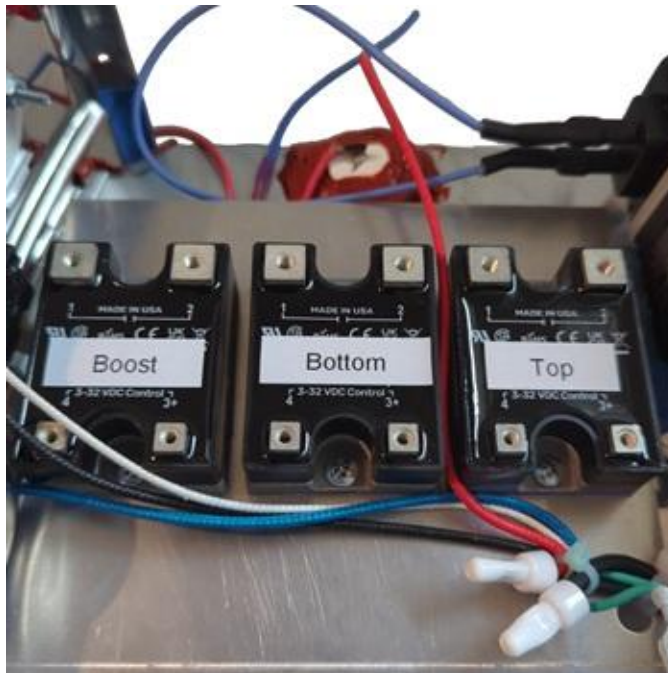
It's not uncommon for there to be multiple hot or neutral wires coming from the power cable. The ground/earth wire is usually already secured to the chassis.



3. Secure the power cable to the relay plate using a large zip tie as shown. If your oven has a return path for the heaters (see black wire in photo), then zip tie it with the power cable.



4. If you have a label printer, then label the SSRs so that you know which SSR controls which heater. For the oven in this guide the relays are boost, bottom, and top from left to right.

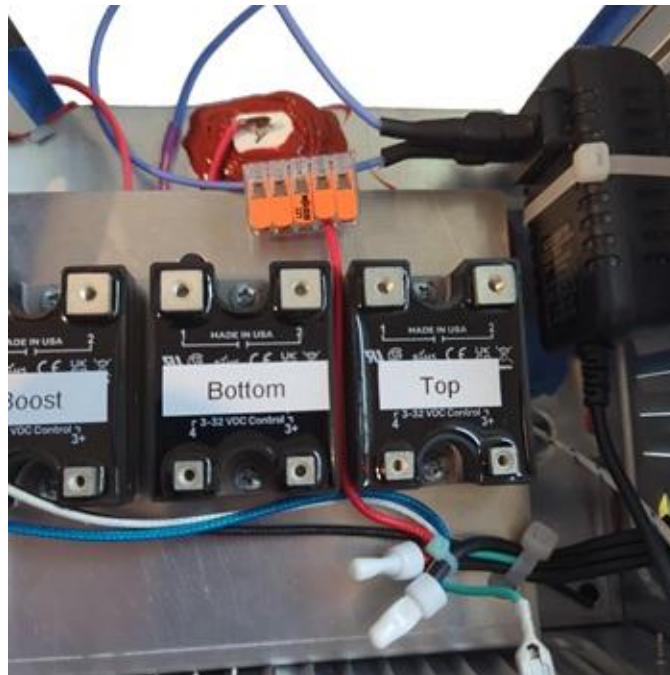


5. Route the hot wire between the second and third relays from the left. Trim the wire such that it ends slightly above the top of the relay plate. Secure a Wago 221 connector to it. For this build, the best wire routing is achieved by placing the hot wire in position 4 from the left.



Note

It's uncommon to have multiple hot wires, but if you do then you'll want to connect one of them to one of the SSRs (e.g. "Top") while the other wire goes into the Wago 221 connector described here.



6. Size three pieces of blue silicone wire to connect the Wago 221 to the right AC terminal of each relay. Secure an 18ga #8 ring terminal crimp to each. Connect the remaining end of each to positions 2, 3, and 5 from the left of the Wago 221 connector. Using the screws and washers from the relay hardware bags, secure the ring terminals to the right AC terminal of each relay.



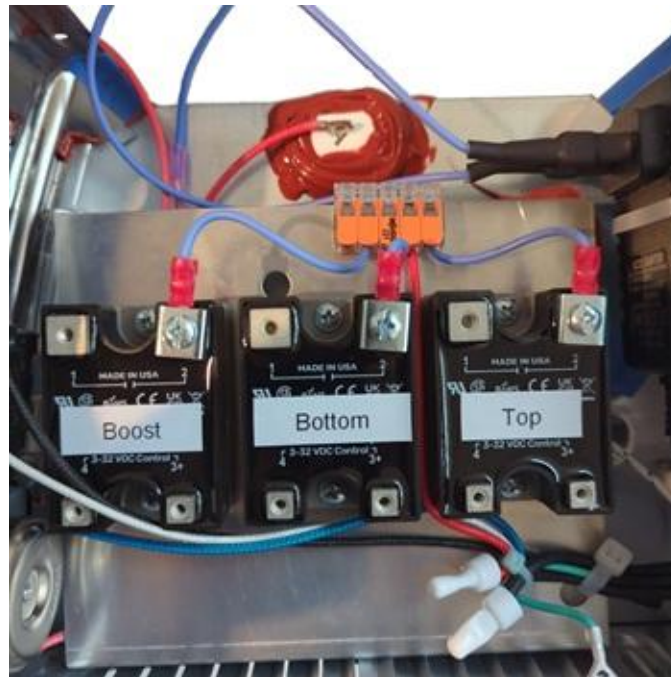
Electrical Hazard

Use a proper crimping tool! We recommend a ratcheting crimper. Using pliers isn't worth getting electrocuted or starting a fire!



Note

The #8 and #6 ring terminals look **very** similar. Make sure you're using the ones sized for the #8 stud.

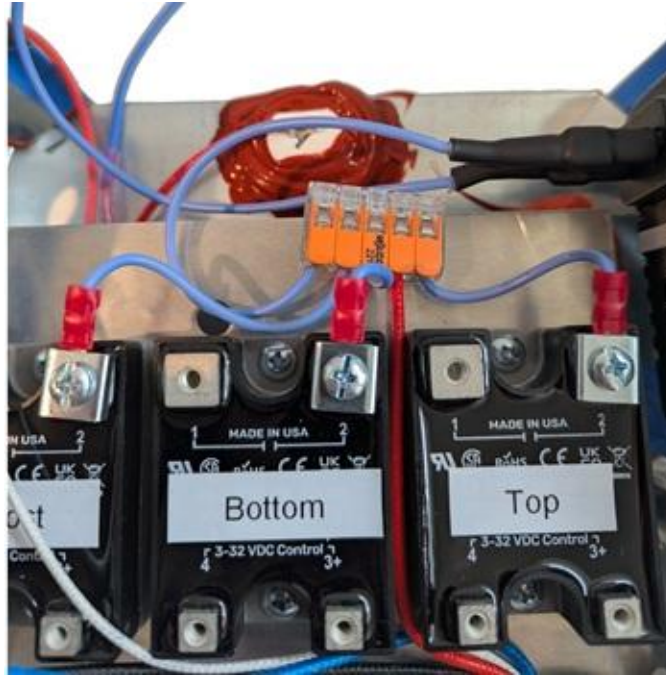


7. Cut the power supply AC wire roughly in half. Connect one of the halves to the remaining position in the Wago 221 connector.

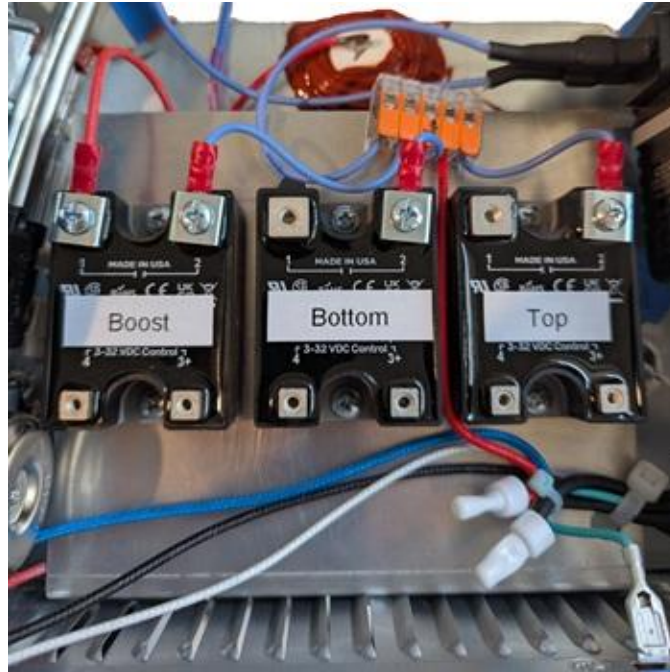


Note

It doesn't matter which of the power supply wires you use here. AC current flows in both directions, so the circuit will function the same either way.



8. Route one wire from the boost heater beneath the relay plate, over the top, and to the left terminal of its relay. Secure an 18ga #8 ring terminal crimp to the end. Using the screws and washers from the relay hardware bags, secure the ring terminal to the relay.

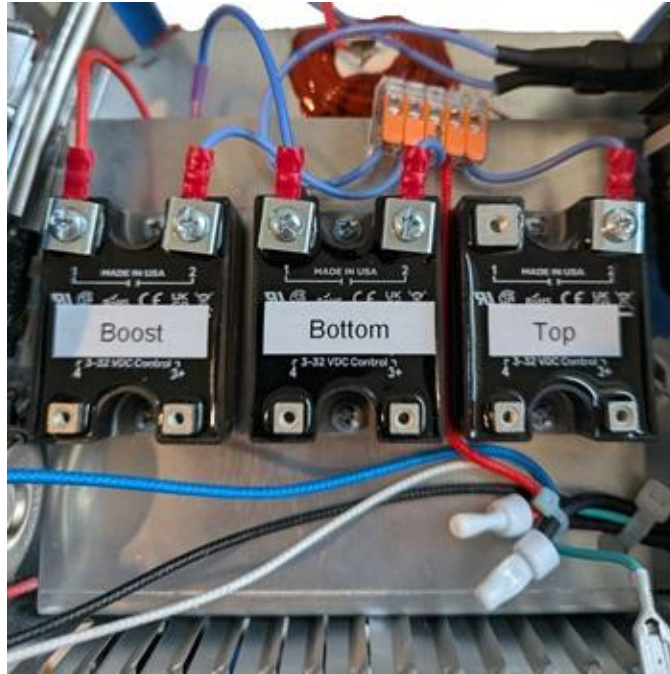


9. Route the wire from the bottom heater through the hole you made or over the top of the relay plate to the left terminal of its relay. Secure an 18ga #8 ring terminal crimp to the end. Using the screws and washers from the relay hardware bags, secure the ring terminal to the relay.

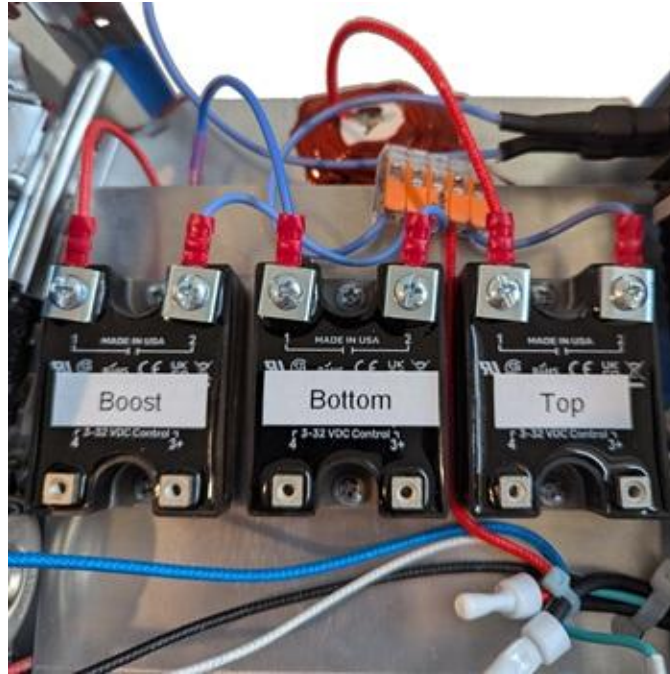


Note

This wire is usually short. If you didn't lengthen it with a butt connector earlier, then you may find yourself wanting to do so now. This may involve removing and reinstalling the relay plate.



10. Route the wire from the top heater over all of the other wires to the left terminal of its relay. Secure an 18ga #8 ring terminal crimp to the end. Using the screws and washers from the relay hardware bags, secure the ring terminal to the relay.

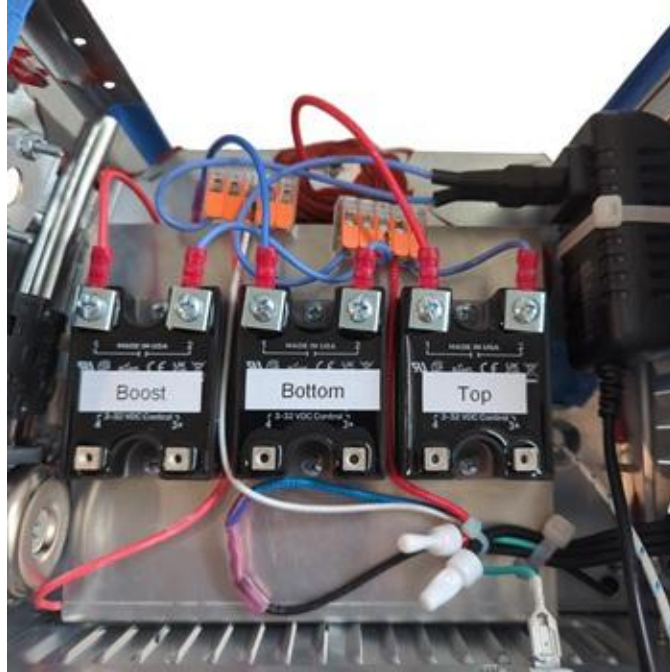


11. So far you've connected the hot wire to the relays and power supply. You also connected the relays to their heaters. It's time to complete the loops by connecting the other end of the heaters and the power supply to neutral.

For this, you're going to use a Wago 221 connector. Route the following wires into a new Wago 221 connector. The following wires should be connected together.

- Neutral wire
- Remaining power supply wire
- Remaining boost heater wire
- Return path(s) for top and bottom heaters

If you have two or more neutral wires (like this oven), then don't connect them to the same Wago 221 connector! Use one to terminate the loop for power supply and one or two of the heaters. Use the other to terminate the loop for the remaining heater(s) with a butt connector.



12. Double-check that you've connected all of the loose wires in your oven. You should have no unterminated wires left; leftover wires can cause arcing and pose a safety hazard.



Attention

Review this step and make sure that everything is connected properly! Mistakes in this step can be dangerous!

Step 18: Low Voltage Wiring



Time

20 - 45 minutes

In this step, you're going to finish the low voltage wiring inside of the oven. This includes connecting low-voltage wires to the SSRs and routing the thermocouple and power supply wires.

The thermocouple generates a microvoltage that increases with the temperature of the oven. Running the thermocouple close to high-voltage AC wires will induce noise into the temperature reading. Keep as large a gap as possible between the high and low voltage wires.

In the past, a small percentage of ovens experienced static buildup on the thermocouple. This would cause the thermocouple IC on Controleo3 to report an error, so it wouldn't display the oven's temperature. Touching the tip of the thermocouple with your finger would remove the static and fix the issue for that reflow session. However, it wasn't a long term fix; the problem could recur the next time the oven was plugged in.



Note

After investigation, we found that grounding the negative thermocouple lead through a 100k Ω resistor would discharge the static and preserve the common mode voltage at zero. More information is available [here](#).

We solved this by connecting a 100k Ω resistor between the power supply negative and the oven chassis, and we've incorporated this resistor onboard in Controleo3 version 3.7 and later. The board version is printed on the silkscreen. To take advantage of this, just connect the chassis wire as outlined in the steps to follow.



Note

For Controleo3 version 3.6 and older, you'll route the chassis wire as shown in this step. In the next step, you'll affix a 100k Ω resistor to the controller end and route it to the power supply negative terminal of the controller.

Controleo3 is designed to act as a low-side switch; its outputs switch the connection to power supply negative. That means all of our relays will share a common positive that's always on. Turning on an output will complete the path to ground, triggering the relays.

Wire Color	Description
Red	Common positive
Black	Bottom heater relay negative
Blue	Top heater relay negative
Yellow	Boost heater relay negative
White	Convection fan negative (not included in regular kit)
Brown	Cooling fan negative (not included in regular kit)
Orange	Not used
Green	Chassis (earth)
Bare copper	Not used



Note

We've seen Controleo3's outputs used to control oven lights, bells, and more. Some ovens include lights and bells that are designed to be

driven by mains voltage. The unused orange wire has a lot of potential, but, for the moment, Controleo3's software can only configure the outputs as heaters or fans.

The table below summarizes the correct strip lengths for each low voltage connector.

Connector	Strip Length (in)	Strip Length (mm)
Ring Terminal, 22 - 16 AWG, #6 Stud, PVC	1/4 - 3/8"	6 - 10mm
Wago 221, 24 - 12 AWG, 5 Position	7/16"	11mm

1. Install the grommet into the grommet mounting plate as shown. Make sure that both sides of the grommet aren't caught on the plate.



2. Strip away 19-3/4" (400mm) of the outer insulation of the white multi-conductor cable as shown. Pull the string out of the bundle.



Note

This guide will only cover how to use the red, black, blue, yellow, and green wires. The white, brown, orange, and bare copper wires will not be used. If you're not using them to control a fan, light, bell, or other device then you can remove them. Otherwise you'll need to terminate them.



3. Untangle the power supply and thermocouple wires. They shouldn't cross each other. Using masking tape, secure them to the white multi-conductor cable as shown.



4. Using a screwdriver, open one end of the braided sleeving. Install it over the wire bundle as shown. Don't let the wires cross or you won't be able to get the bundle through the grommet.



5. Insert the wire bundle through the grommet as shown. Don't pull the braided sleeving all the way through the grommet.

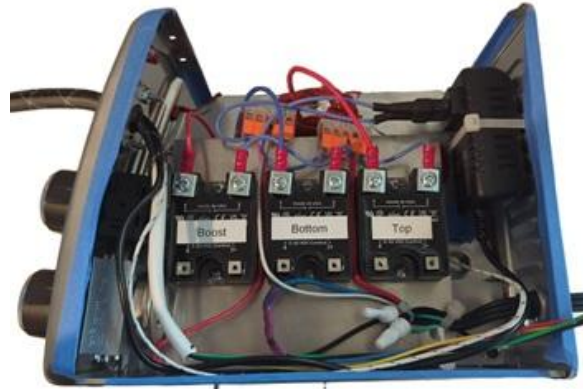


6. Adjust the wires such that there are approximately 10" (254mm) of white multi-conductor cable and 6" (152mm) of braided sleeving protruding from the oven. Adjust the thermocouple and power supply wires lengths such that they form a loop passing over the power cord, along the bottom of the oven, and over the oven controls.

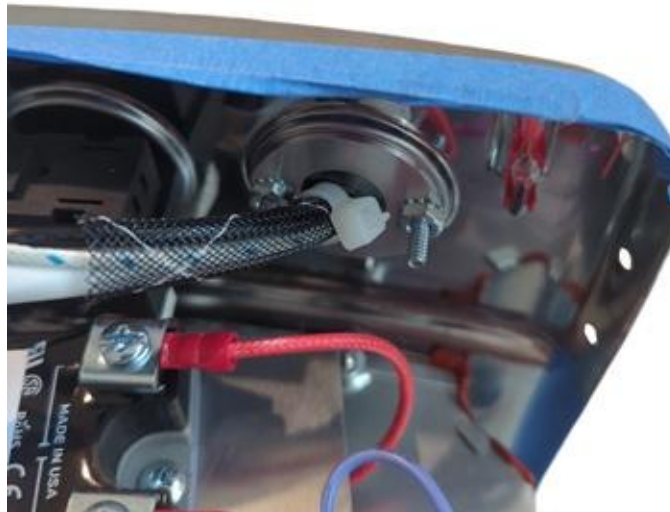


Attention

Keep the thermocouple away from the power cord! Leave some extra slack so that it forms a loop up and over the power cord. Just in case, Controleo3's MAX31856 IC has built in 50/60Hz noise rejection filtering to help reduce noise induced by the AC wires.



7. Install a large cable tie around the black braided sleeving inside the oven next to the grommet. Pull it tight! This will prevent the wires from being pulled out of the oven.



8. Install two large cable ties securing the wire bundle to the oven controls. Don't trim them too short or they might come loose when the oven heats up!



9. Route the chassis wire (green) to the chassis hole you drilled in the bottom of the oven. Cut it to length and install an 18ga #6 ring terminal crimp to the end. Secure it in place with a bolt.



Note

We're using 18ga #6 ring terminal crimps for the low voltage wiring! These are different from the 18ga #8 ring terminal crimps you used in the mains voltage step.

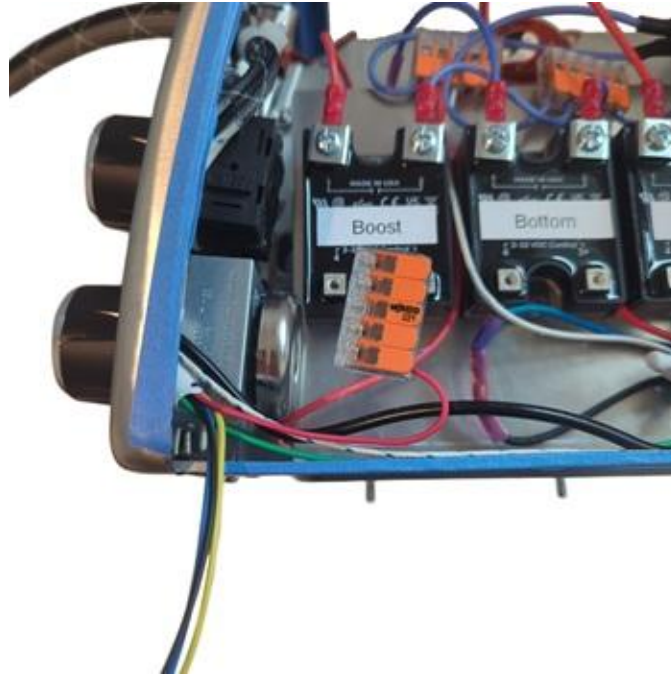


10. Route the red wire to a new Wago 221 connector as shown. You'll need to cut and strip the red wire.



Attention

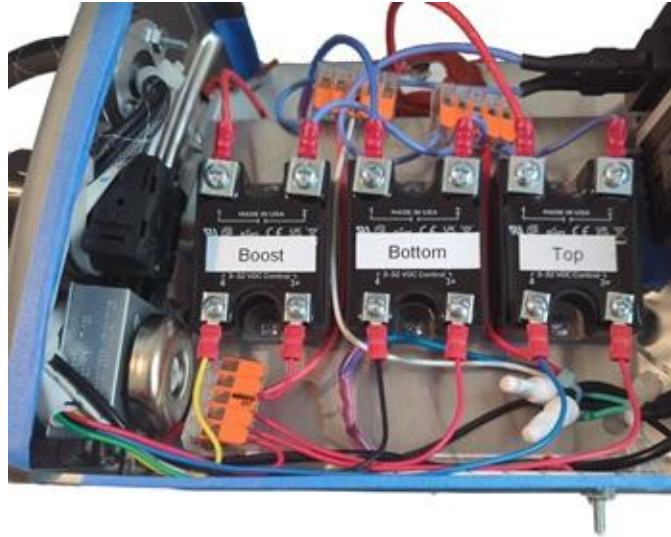
Don't throw away the scrap red wire! You're going to use it to connect Controleo3's common positive to the three relays.



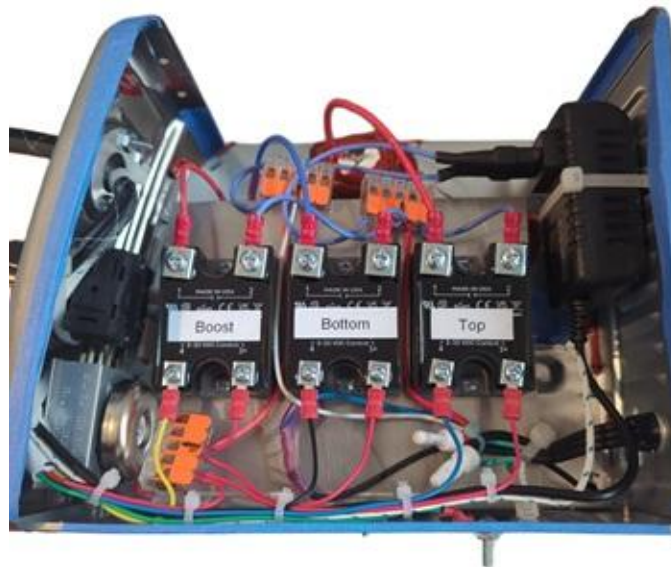
11. Now you'll use the scrap red wire to branch Controleo3's common positive to each relay. Cut a piece for each relay spanning from the Wago 221 to the relay's "+" DC terminal. Wires should be routed along the bottom of the oven where possible. Connect one end of each to the Wago 221. Install 18ga #6 ring terminals on the remaining ends. Using the screws and washers from the relay hardware bags, secure the ring terminals to their relays.



12. Now you'll connect Controleo3's outputs to each relay. Route the yellow, black, and blue wires along the bottom of the oven to the "-" DC terminal of each relay. Yellow connects to boost, black connects to bottom, and blue connects to top. Cut each wire to length and install an 18ga #6 ring terminal on the end. Using the screws and washers from the relay hardware bags, secure them to the relays.



13. Install small cable ties onto the low voltage wire bundle to keep the wires together. Make sure that the wires are kept away from the holes for the oven feet.





Note

At this point, a few bolts protrude from the bottom of the oven. If desired, you can trim them using bolt cutters or a grinder. You'll be putting the feet back on later, so the bolts protruding a bit won't affect functionality.

Step 19: Controleo3 Wiring



Time

15 - 30 minutes



Respiratory Hazard

In this step you'll strip fiberglass insulation from the thermocouple. The process will make fiberglass dust, so wear respiratory protection and gloves when doing so. We recommend an N95 mask or a respirator with a particulate filter.

Next, you're going to wire up the power, thermocouple, and signal wires to Controleo3.

1. Trim the power supply cable and thermocouple to 3 - 4" (75 - 100mm) longer than the white multi-conductor cable.



Note

The wires in this step can be difficult to strip. Leaving yourself the extra 3 - 4" will help if you mess up.

2. Stretch the braided sleeving so that there are no bulges or slack. On the outside of the multi-conductor cables, draw a line at the end of the braided sleeving with a marker.



3. Using the line as a guide, strip the outer layer of insulation off of the white multi-conductor cable and the power supply cable.



4. Strip $3/16$ " (5mm) from each of the wires inside of the white multi-conductor cable.



Note

We'll only use the red, yellow, green, blue, and black wires for this guide. No need to strip other colors in the white multi-conductor cable if you're not using them.

5. Strip $3/8$ " (10mm) from each wire inside the black multi-conductor cable. Twist each and fold it in half without overlapping the insulation.
6. Strip a small amount of the outer sheathing off of the thermocouple. Then strip $3/8$ " from each of the wires in the thermocouple. Fold each in half without overlapping the insulation.



Note

The fiberglass insulation of the thermocouple can be hard to strip. Use sharp strippers. The 20ga (0.5 - 0.75mm²) size is usually appropriate.

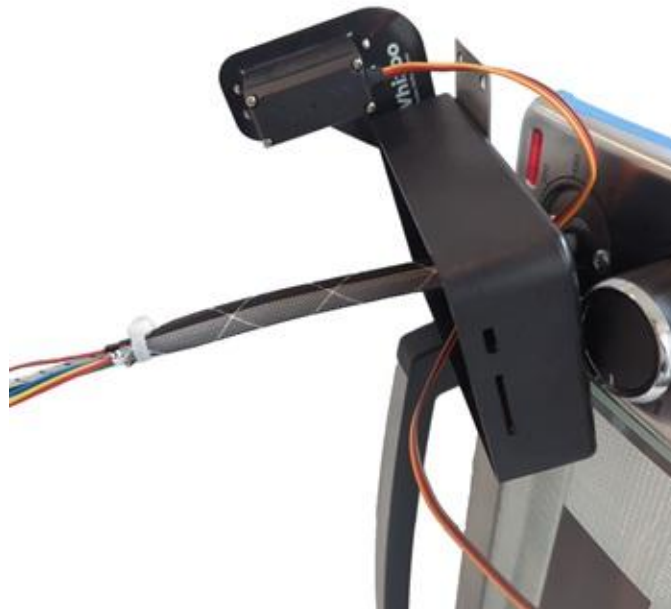


Respiratory Hazard

Stripping the thermocouple's fiberglass insulation will make fiberglass dust, so wear respiratory protection and gloves when doing so. We recommend an N95 mask or a respirator with a particulate filter.



7. Slide the controller enclosure you made earlier over the low voltage wire bundle. The servo wire should be routed into the controller enclosure.
8. Stretch the braided sleeving so that there are no bulges or slack. Secure the end of the braided sleeving in place with a large cable tie and pull it tight. This will prevent the wires from being pulled out of the oven.



9. Loosen the screw terminals and secure the wires into the controller as shown.

Cable Type	Conductor Color	Description
White Multi-conductor	Red	Output +
White Multi-conductor	Black	Output 1
White Multi-conductor	Blue	Output 2
White Multi-conductor	Yellow	Output 3
White Multi-conductor	White	Output 4 (optional)
White Multi-conductor	Brown	Output 5 (optional)
White Multi-conductor	Orange	Not used
White Multi-conductor	Green	Chassis Gnd
White Multi-conductor	Bare copper	Not used
Thermocouple	Striped Red	TC+
Thermocouple	Striped Green	TC-
5V power supply	Red	5V DC Power +
5V power supply	Black	5V DC Power -

Servo	Orange	Servo Ora
Servo	Red	Servo Red
Servo	Brown	Servo Bro



Note

If you want six outputs, then you'll have to connect to output 6. This is a bare solder pad labeled "6" near the middle of the board. It's a direct connection to a microcontroller pin, so it can be used as an input or an output.



Note

Controleo3 has reverse polarity protection to protect against accidental miswiring. Wiring the thermocouple backwards won't fry anything either; the readings will just go down when the temperature goes up!



Attention

Take care to make sure that all of the wire strands make their way into a screw terminal. Loose strands can cause a short circuit!



Attention

If you're colorblind, then you might not be able to tell the difference between the red and green wires. There's mobile apps you can download to show the difference.



10. Remove the plastic film from the LCD display.
11. Install the Controleo3 into the enclosure by inserting the USB port into its milled slot and gently levering the rest of the board in. Install the lid using the four enclosure screws.

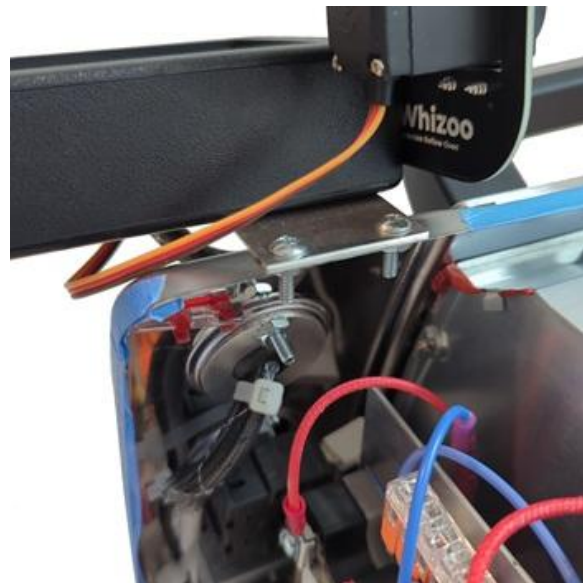


Attention

Don't overtighten the enclosure screws! They should be gently tightened until they barely secure the lid in place. Overtightening will cause phantom presses on the touch screen.



12. Mount the enclosure to the oven using two bolts.



Step 20: Testing the Wiring



Time

5 - 10 minutes



Electrical Hazard

We are testing mains voltage electrical wiring. If wired incorrectly, your oven can trip a breaker, cause a fire, or electrocute you. If you don't know what you're doing or think your oven is unsafe, then don't plug it in!

Congratulations! You've finished all the wiring. Let's test it out to see if it works!

1. Verify that the power cable's ground wire is connected to the chassis before plugging in the oven. Otherwise, incorrect wiring may electrify the oven chassis and electrocute you.
2. Check to ensure there's nothing flammable inside of the oven (e.g. paper backings from insulation). In case of fire, have a fire extinguisher on hand. If your oven catches fire, immediately cut power and extinguish it.
3. Plug the oven into a power outlet. Ideally this will be a switched outlet or a surge protector with a switch. If you have a Kill-A-Watt meter (or similar meter), then you should connect the oven to it and set it to read power.



Electrical Hazard

Keep away from all live electrical wires while the oven is plugged in.



Attention

If you're using a surge protector, then make sure that it's rated for the oven's power draw! For the oven in the guide, this is 15A @ 120VAC.

4. If you haven't already, turn on power to the oven. You should hear Controleo3 play a brief tune and see the screen power on. The controllers ship pre-flashed, so a menu should appear.



Note

Sometimes this can take as long as 10 - 20 seconds on the first power up. Be patient.



Note

If the controller shows a white screen but no menus, then please contact support.



5. On the screen, navigate to **Settings** → **Setup**. Here you'll configure which output on your Controleo3 corresponds to which heater(s) in your oven.

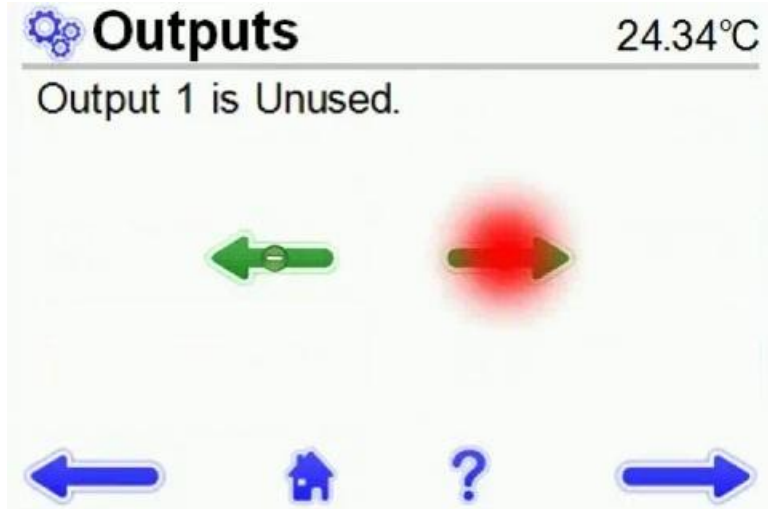


Note

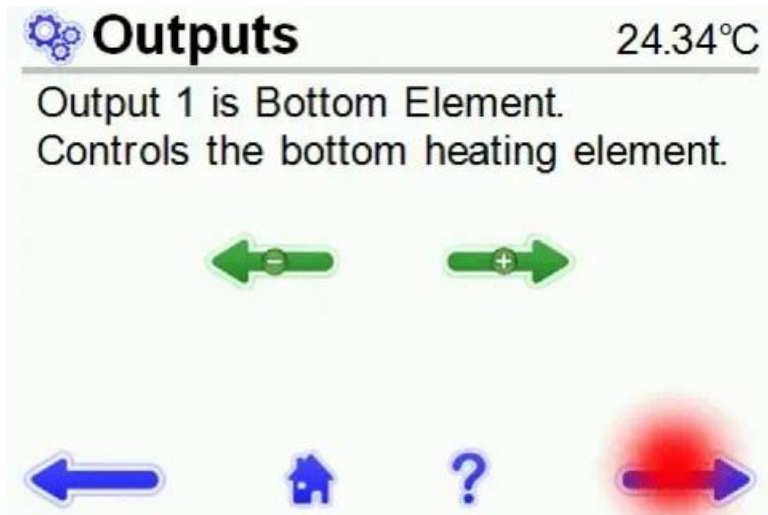
If you over-tightened the enclosure lid, then your screen might register “phantom” presses or not respond to touches. Loosen the enclosure screws a little.



6. Tap the green arrows until it shows the “Bottom” heater.



7. Tap the right blue arrow to switch to editing Output 2.



8. Repeat this process, ensuring that the outputs are set as follows.

Output 1 → Bottom

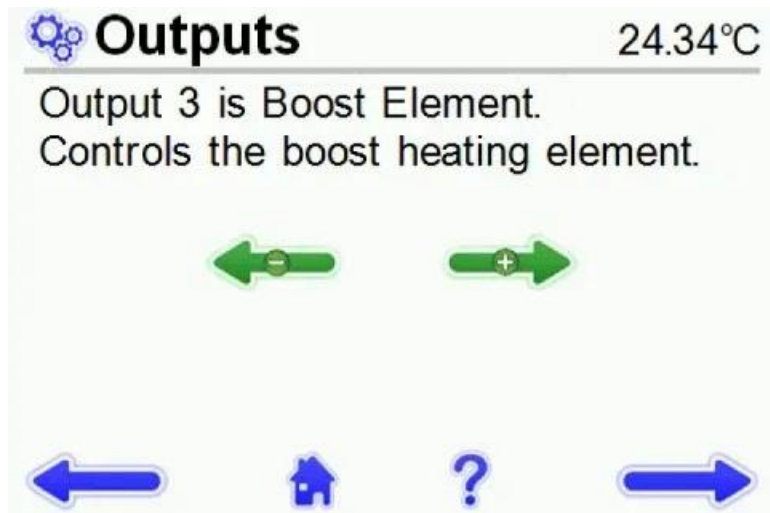
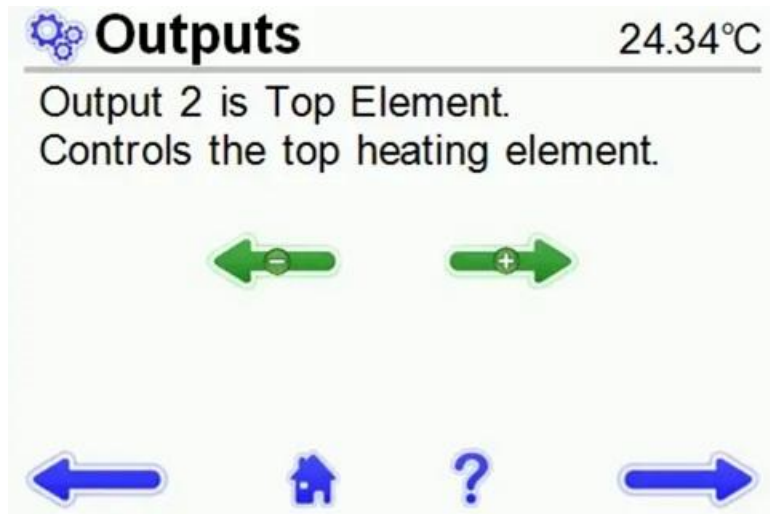
Output 2 → Top

Output 3 → Boost



Note

If you have convection or cooling fans, now is the time to configure them. Set output 4 to “Convection Fan” and/or output 5 to “Cooling Fan.”



9. Tap the Home icon at the bottom of the screen, then navigate to **Settings** → **Test**. This is where you'll test the heaters. The blue arrows will change which heater you're going to turn on/off. Tapping **Turn on** will turn on the specified heater. To turn it off again, just tap **Turn off** or leave the screen.

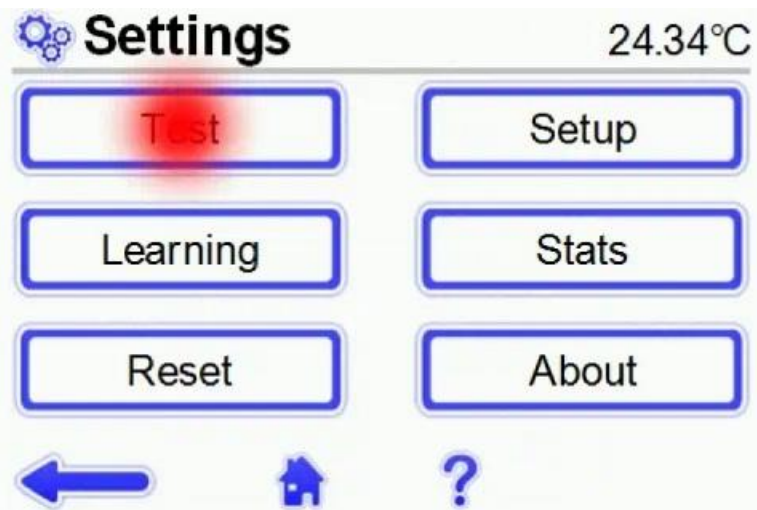
Turn on each heater for a few seconds, then turn it off. If you have a Kill-A-Watt meter, then you should see the wattage of the oven spike when the heater is on. Most ovens of this size have quartz heaters measuring between 400 and 600W each. The boost heater should measure between 400 and 500W.

If you don't have a Kill-A-Watt meter, then you can still test the heaters individually. Turn on each heater for a few seconds, then turn it off. Feel the air around the heater for warmth.



Heat Hazard

The heaters get very hot very fast! Don't touch them directly or you will burn yourself!



Test Outputs

24.42°C

Output 1 is On.

Turn Off



10. Check the thermocouple's temperature reading shown in the top right corner of the screen. By now, the temperature in the oven should have climbed well above ambient. It may still be climbing.

If the temperature reading shown is rapidly decreasing or is below ambient temperature, then you've probably wired the thermocouple backwards.



Note

If you are in a country where the mains power frequency is 50Hz instead of 60Hz, then you'll need to adjust the thermocouple IC's built in line frequency filtering. Navigate to **Settings** → **Setup** then tap the blue arrows until you reach **Power line frequency**. Change the setting to 50Hz.

11. If your heaters or thermocouple aren't working as expected, then fix the wiring mistakes now. You'll close the oven in the next steps.

Step 21: Adding Superwool Plus



Time

10 - 15 minutes



Respiratory Hazard

Superwool Plus can cause mild mechanical irritation of the eyes, skin, nose, and throat. It can also aggravate some pre-existing skin and respiratory conditions. It's essential to follow the safety precautions outlined below.



Attention

Don't unwrap the Superwool Plus until you've read the safety information and have prepared your workspace!



Note

It's not as scary as it sounds! Superwool Plus is considered **non-hazardous and non-carcinogenic**. It's just really itchy and probably not good to breathe in.

For more information about handling Superwool Plus and its potential health hazards, check out its [material safety data sheet \(MSDS\)](#).

Now we're going to install the Superwool Plus insulation. The blanket has amazing insulating properties, so the top of your oven will only be slightly warm during a

reflow. However, before handling it you need to understand the appropriate safety procedures.

Superwool Plus fibers are very fine. We'll do what we can to prevent them from getting airborne, and take precautions for when they do.

1. First, you're going to prepare your workspace.

- Find a workspace where it's okay to spill some Superwool Plus fibers. You'll wipe down the surfaces at the end, but you don't want to work over carpet or in the kitchen.
- Make sure that your workspace is draft-free. You don't want the fibers getting airborne. No fans and no wind.
- Make sure the workspace is free of food and drinks.
- Make sure the workspace will stay free of family, friends, and pets for the duration of the step.



Note

Outside on a folding table is usually a good choice if it isn't windy or rainy.

2. Next, prepare yourself for handling the material.

- Use the bathroom before starting.
- Change into clothes that you're okay with getting Superwool Plus fibers on. The fibers come out in the washer fairly easily, but you'll have to change and take a shower once the oven is closed.
- Wear shoes that you can easily wash afterwards. Flip flops are a good choice.

- Wear safety glasses. We don't want any airborne dust getting in our eyes.
 - Wear a mask. We recommend an N95 mask or a respirator with a particulate filter.
 - Wear gloves.
3. Make sure that you have all necessary tools on hand. We'll need scissors to cut the material and a ruler to push it behind the relay plate. We'll also need a screwdriver to reinstall the lid on the oven.



Note

Any blades you use to cut this material **will** get dull. Use scissors you don't care about (or can sharpen).

4. Remove all of the masking tape from the oven. Don't forget the piece securing the thermocouple!



Attention

The masking tape **must** be removed before closing the oven otherwise it will burn!



5. Shake out the oven to make sure that there's no more metal filings or loose bits of wire left in the oven.

6. Unwrap the Superwool Plus. Keep a few tips in mind for the next few steps.
 - Moving slowly will help to reduce airborne dust.
 - Don't touch your face while working! You don't want dust in your eyes, mouth, ears, or hair.

7. Unscrew the wire to the top heater from the relay. Set the screw and washer aside.



10. Cut a rectangle from the top-front of the material so that the Superwool Plus fits fully inside the chassis and you can put the lid back on later.



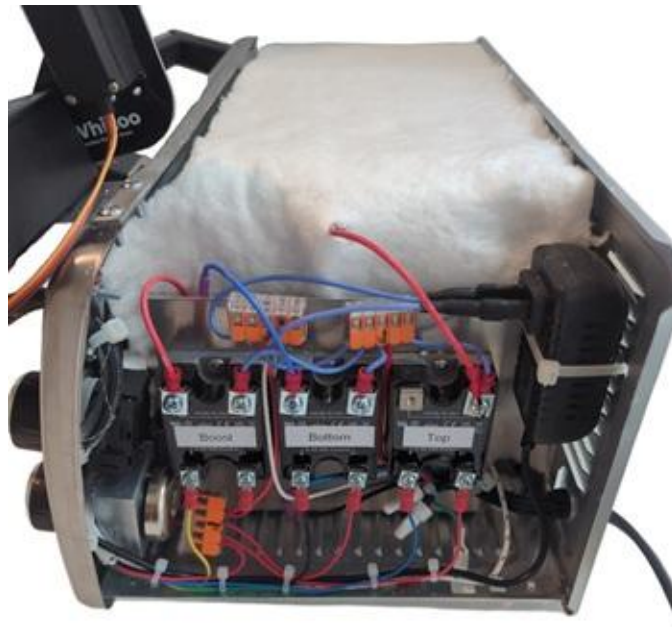
11. Using the scissors, pierce a hole in the Superwool Plus for the top heater wire to route through. You're going to tuck the Superwool Plus behind the relay plate.

- Using the ruler, tuck the remaining Superwool Plus behind the relay plate. Make sure that the top heater wire is routed through the hole you made.



Note

Make sure that any Silicone wires, Wago connectors, butt connectors, and crimps are kept away from the oven chamber walls.



- Resecure the top heater wire to its relay.

Congratulations! You're done with the Superwool Plus! Don't clean up until you're done closing the oven.

Step 22: Close the Oven



Time

5 - 15 minutes



Attention

Double-check that all tape has been removed from the oven. Don't forget the piece securing the thermocouple! It will burn at high temperatures!

It's time to get the cover back on the oven. This can be a struggle. The lids for these ovens fit very tight, so it isn't easy getting them back together again. Fortunately, you know it's possible because you took it apart!

1. Tuck the front-top of the lid under the sheet metal on the front of the oven.



Note

Depending on where you mounted the controller and chassis wire, you may need to trim a small amount of metal from the lid to make clearance. This can be done with tin snips or a grinder.



2. Lever the rest of the lid into place.
3. Reinstall all of the chassis screws, oven feet, and their rubber inserts.



Attention

Make sure the chassis and feet screws don't pierce any of the wiring you've just done!



4. Clean up from the Superwool Plus. Below are a few tips for doing so.

- Don't take off your protective equipment until you're done cleaning up!
- Wipe down your workspace with damp paper towels. Don't use a vacuum or try to sweep because it will make airborne dust.
- Take a shower and wash your clothing immediately.

Step 23: Install the Nomex Door Seal



Time

5 minutes

To stop air loss through gaps around the oven door you will install a Nomex high-temperature gasket.

1. Make two cuts of Nomex.

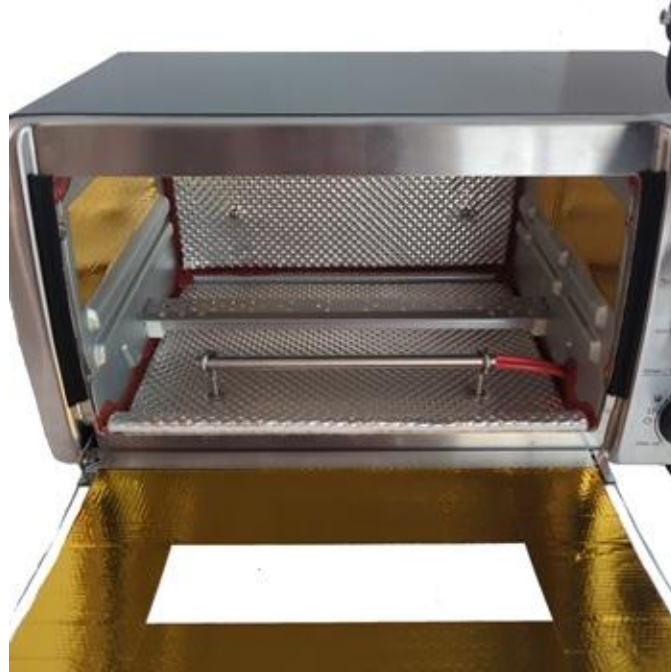
Cut Description	Qty	Length (in)	Length (mm)
Long cut	1	11"	280mm
Short cut	1	4"	101mm

2. Cut the short cut in half lengthwise.
3. Peel the backing off one of the short cuts and stick it onto the oven as shown.

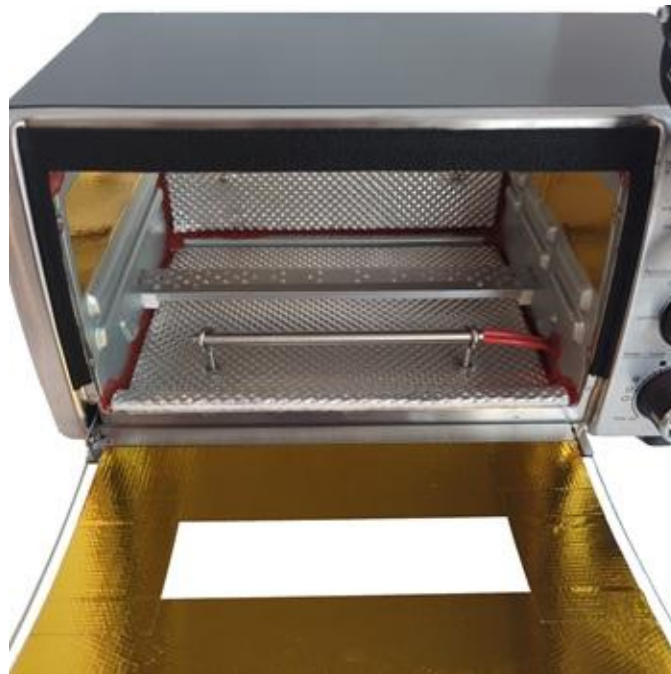


Note

Peeling the backing off the Nomex can be difficult. The easiest place to start is on a long edge towards one of the ends.



4. Repeat this for the other side of the door.
5. Peel the backing off the long cut and stick it onto the oven as shown. Try to butt it up against the short cuts to create a seamless appearance.



6. Ensure that the door can close without a gap between the Nomex and the door. If it can't, then you may need to trim some off the bottom of the left and right pieces of Nomex.



Step 24: Door Servo Setup



Time

5 - 10 minutes

It's time to finish setting up the door servo. You'll need to assemble the servo arm, mount it to the servo, and calibrate its "door open" and "door closed" positions.

The servo has two calibration values. The "door open" position is where the servo will move to when the controller runs the "**open door**" profile command. The "door closed" position is where the servo will move to when the controller runs the "**close**

door” command. It’s possible to open the door somewhere between these two positions using the **“door percentage”** command.

The door servo is always moved to the closed position when the oven powers up. For most profiles, the door will be set to open when the solder has reflowed and closed again when the oven cools to 50°C. However, you can change the behavior in the reflow profile.

1. Plug the oven in. This should move the servo to the 90° position. If it doesn’t move, then it might be in the correct position already.



Note

Because the MG996R 180° servos only have a 180° range of motion, it’s important that you move to the 90° position before installing the arm. Otherwise you might install the arm at an angle that can never fully open the door.

2. Assemble the servo arm as shown.



Note

Pay attention to which side you mount the aluminum servo disc on. Only one side is correct.



3. On the oven screen, navigate to **Settings** → **Setup** and tap on the right blue arrow until you reach “Door open position.” It should show 90°.



4. Secure the door bracket as shown using masking tape.



5. Mount the servo arm as shown. This will be the middle of the servo's arc. Try not to rotate the servo shaft too much while installing it or you'll lose track of the position.

The servo discs are sometimes a very tight fit. If you're struggling to get your servo disc to fit the motor shaft, then there's a few things you can try.

- Rotate it slightly to see if the teeth aren't engaging properly.
- Tighten the arm into place with the center screw.
- If all else fails, it may be necessary to thermally expand the servo disc using a heat gun. Wear gloves!



6. Tap the green arrows to move the servo to a suitable “door open” position. The oven door should open around 1”.



7. Tap the right blue arrow again until you reach “Door closed position.”



8. Tap the green arrows to move the servo to a suitable “door closed” position.



Note

Make sure that the “door closed” position isn’t in direct contact with the door bracket. Otherwise, any change in the position of the controller enclosure can cause the door to be stuck open.



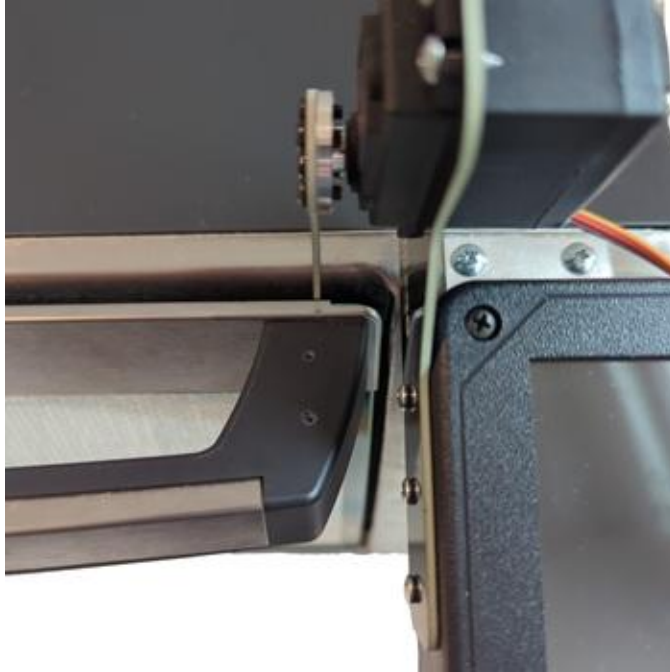
9. Using the blue arrows, move left and right between the “door open” position and “door closed” position. Ideally the tip of the servo arm will make contact with the door bracket first. If it doesn’t, then you may need to move the door bracket further forwards. Make sure that you’re happy with its movement before proceeding.
10. Using a 1/8" (3mm) drill bit or 1/8" (3mm) transfer punch, make marks on the door handle where the holes in the door bracket are.



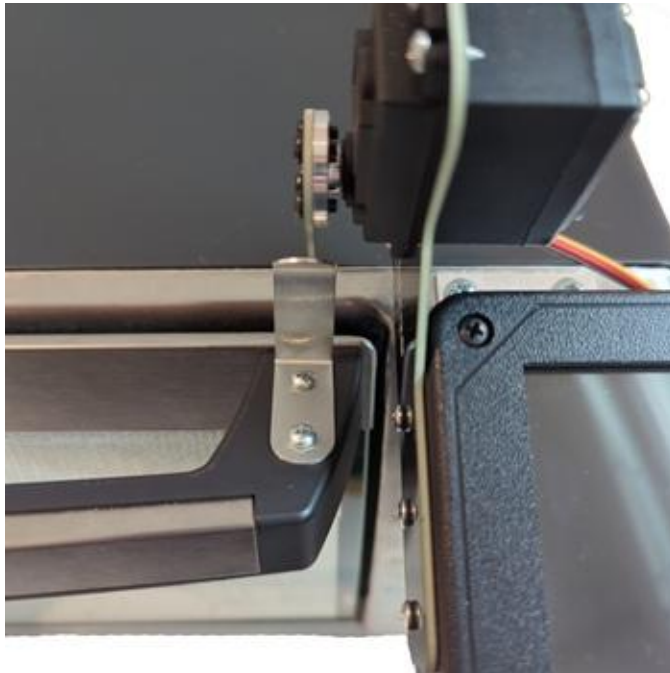
Attention

You’re just making marks so we know where to drill! Don’t drill all the way through yet!

11. On the marks we made, drill two 1/16" (1.5mm) pilot holes using a drill bit. It’s a good idea to remove the door bracket before doing this. The door handle is usually hollow.



12. Install two #4 x 5/16" sheet metal screws that hold the door bracket in place.



Step 25: Install the PCB tray



Estimated Time

5 minutes

The PCB tray is critical to a successful reflow oven build. Good heat distribution is paramount and the tray is the biggest part of the equation. The trays that typically come with toaster ovens are made from steel. As previously mentioned, the thermal conductivity of steel is roughly 1/10th that of aluminum. That means it won't spread heat around the oven very well, so you'll get hot spots near the heaters.



Note

If a tray is magnetic, then it's probably steel!



Note

Your tray doesn't necessarily need to be made of aluminum. Any metal with a good thermal conductivity will work. Copper is even better!

Wire racks can be successful, but they usually suffer from a few issues.

- First, they are usually made of steel and don't have a large cross section. That means that they won't distribute the heat very well.
- Second, they often have a high thermal mass that causes ovens to struggle to ramp fast enough. This can be solved by removing some of the cross members.
- Third, using a wire rack casts shadows on certain places while letting heat reach others. This can cause inconsistent thermocouple readings if your rack shades the thermocouple for one reflow but not for another. It can also result in cold spots where the rack makes contact with the PCB.

For this oven we're using a custom cut 8 x 10-5/8" sheet of 1/32" thick 5052-H32 aluminum sized for our oven. It has a 1/4" flange to prevent the tray from sagging, and it's slightly narrower than the width of the oven to allow room for thermal expansion.



Note

It took a lot of experimentation to determine that 1/32" is the right thickness. Any thicker and we're just adding thermal mass. Any thinner and it will lose rigidity.



For larger ovens (especially forced convection ovens), it's a good idea to use the wire rack that came with the oven but remove most of the cross members to reduce thermal mass. A thin aluminum or copper sheet can be placed directly on top of this modified rack to improve heat distribution.

Make sure there is airflow around the tray - especially for forced convection ovens! Make holes in the tray if necessary. Otherwise, Controleo3 will be unaware of how much heat is coming from the bottom of the oven.

Step 26: Run the Learning Cycle



Estimated Time

30 - 35 minutes

While writing an oven control loop might sound simple, there's a lot more to it than checking if the oven is too cold and turning the heaters on until that changes. That approach causes oscillations between too hot and too cold. These temperature fluctuations can mean the difference between a perfectly reflowed board and a defective one.

To solve this, Controleo3 uses a PID algorithm to follow the reflow curve. This is where Controleo3's learning cycle comes in. Your controller will run some tests on your unique oven to determine how much power is needed to hit your temperature targets. It takes around 25 minutes to run this cycle.

At the end of the learning cycle, the controller will calculate a score reflecting your oven's performance. It also breaks the score down into three sub-scores: power, inertia, and insulation. You can read more about this [here](#). If your oven's performance is poor, you might be able to [improve it](#).

1. Take the oven to a well ventilated area (ideally outside).



Respiratory Hazard

Anytime the oven is used, it **must** be done in a well ventilated area to prevent inhalation of toxic fumes! The oven experiences off-gassing from the insulation's adhesives, the components, the PCBs, and the flux in the solder paste.

2. Install the reflow tray in the oven.



Attention

The learning cycle must be run with the oven with its typical load. That means that your reflow tray must be inside the oven during learning. You can add a PCB or two if you want.

3. To run the learning cycle, and navigate to **Settings → Learning**. Tap **Start Learning** to start the process.
4. Review your oven's scores. For the oven in this guide, typical scores range from 70% to 100%. If you're having problems with your oven's performance then you can find helpful information [here](#).

Step 27: Run Some Test Cycles

Now that you've finished the learning, it's time to test it out! You'll want to determine if it's too hot or too cold, and where the hot and cold spots are.

For this step, it's recommended to use scrap PCBs and components. Apply the solder paste and components to the boards, then place them in a 3 x 3 grid on the oven tray. This will help you determine if you have any hot or cold spots in your oven. The corners typically run a little cooler than the center. Do a reflow and examine each

board in turn. Was there sufficient heat for the solder reflow to happen, but not too much that the boards warped or components were burned?



Note

A simple test is the "yellow capacitor" test as documented in a Kickstarter [update](#). A much better method is to use [Temperature Test Labels](#), as shown [here](#).

If you're not using the door servo, then open the door an inch or two when instructed to do so. Be careful not to let the cool down rate exceed 6°C/s; the optimal rate is 2°C/s. Once the oven cools to 100°C the boards can be removed, but you can leave them in longer so you don't need gloves to handle them.

Step 28: Your First Reflow

Understanding the Reflow Process

There are a number of guides on how to do this, and a quick search of YouTube or the Internet will produce results. Click [here](#) for a pretty good one.

Sourcing Boards and Paste

[OSHPark](#) produces excellent quality boards and delivers them quickly. For most prototype boards, having a stencil reduces assembly time and improves soldering so much less rework is needed. We love stainless steel stencils, and have had success using [OSH Stencils](#). For larger quantities we often order boards and stencils from [PCBWay](#) (use coupon code CD16CBDE) in China.

We personally use Chip Quik SAC305 lead-free paste and we're happy with the results. From feedback we've received, any no-clean lead-free paste appears to be as good as any other. Paste freshness is important; the flux in the paste will degrade over time. Keep it refrigerated per the manufacturer's instructions. Fine-pitch components and especially BGA's will need the freshest and best quality paste. If you're doing a low-frequency design with large component pads you can probably use cheaper, older paste.

Create Your Own Profiles

Controleo3 comes preloaded with two default profiles. The lead-free profile is optimized for SAC305 no-clean pastes. The leaded profile is optimized for Sn63/Pb37 no-clean pastes.

If you're using a different paste or want to make changes to the default profiles, then you can create your own reflow profiles by following this [guide](#). It's recommended to use the default profiles as a template.

Optimizing for Your Solder Paste

Solder paste manufacturers want to sell paste to contract manufacturers with conveyor belt reflow ovens. For the contract manufacturers, time is money. That means that the reflow graphs on solder paste datasheets typically show the shortest reflow duration under ideal conditions.

All datasheets state something along the lines of "use this graph as a starting point for process optimization." Your oven won't get hot instantly, so it's best to zero-base the manufacturer's profile graphs to 50°C or 75°C. A longer pre-soak phase will improve your oven's heat distribution with almost no meaningful downside.

Improving your Oven's Performance

Your oven might do perfect reflows immediately, but it'll probably take a few tuning runs before that happens. You should take a closer look at your [oven's performance numbers](#). You might need to modify the [profile](#) to suit your paste and your oven.

Congratulations! You're done!

Enjoy your new reflow oven! If there is anything we can do to improve this guide, then please [let us know](#). Feel free to join our mailing list to stay up-to-date on Controleo!

Controleo3 Tips and Tricks

Now that you're done, here are some tips to help you get the most out of Controleo3.

Take a Screenshot

To take a screenshot, tap 3 times in the top left corner of the screen. If there is a SD card, a bitmap of the screen will be written to the card. Writing the bitmap takes around 10 seconds, and Controleo3 will freeze during this time (so avoid doing this during a reflow!). You'll hear a beep every second to let you know something is happening.

Touchscreen Calibration

The touchscreen is calibrated as part of the final test procedures. If you feel it isn't accurate enough, you can recalibrate it. Go to **Settings -> Stats -> Reset -> Touch Calibration**. You should use a stylus for better accuracy.

If the touchscreen isn't working at all, try loosening the enclosure lid screws or removing the lid completely. The pressure from the lid can push down on the touchscreen and cause phantom presses or make it unresponsive.

Tap-and-Hold

Controleo3 supports tap-and-hold. For example, when setting the bake temperature you can tap-and-hold the "+" arrow to quickly increase the temperature.

Celsius / Fahrenheit toggle

Reflow temperatures are always given in Celsius, but if you're ever curious what the oven temperature is in Fahrenheit then you can tap on the temperature in the top-right corner of the screen.

Removing the SD Card

Reading from or writing to the SD card is unbuffered, so the SD card can be removed without pressing an "eject" button!

Detailed Logging

There is a lot more going on behind the scene than what's displayed on the screen. Controleo3 continuously dumps information via the USB port. To see it, attach a USB cable to your PC and run Arduino's Serial Monitor (or PuTTY). The default serial baud rate is 115200.

Open Source Software

The source code for Controleo3 is [open-source](#), so feel free to modify it as you see fit!