Educational Brake Caliper

Version 1.0

Created By: Chris Halliday

The Educational Brake Caliper

Pull it apart and put it back together! See how it works from the inside out.Full documentation provided so you can fully understand how to orient your prints, post process, assemble and share your caliper.

Printed with PLA & ABS!

This documentation covers everything to do with your caliper. There is even a quiz attached if you are looking to share this with a class!

Contents

Introduction

ABOUT THE DESIGNER

Chris Halliday

When I am not working in Fusion 360 or trying to dial in my prints & printers for an optimal print I can be found out in the wilderness on Vancouver Island, British Columbia exploring the history and just plain interesting places that are around here.

I got started in 3d printing a couple years back when I took my passion for motorsports and let my thoughts go wild on how I could incorporate the two. It quickly lead to the purchase of my first printer and in late 2015 the addition of a 2nd printer.

The Educational Brake Caliper

Thank you for downloading and getting started on your own Brake Caliper! When you complete your project i'd like to hear back from you. Comment and Like the design on Pinshape!

Chris Halliday on Pinshape

Since the start of my obsession with 3D printing and computer aided design, motorsports has been on my mind. The Educational Brake Caliper is my first motorsports related design to be released to the public.

Instead of uploading a somewhat complicated design to Pinshape and letting you try to figure out what you have, i've opted to include some significant documentation so that this caliper can be shown and used as a hands-on educational piece. Along with it being based on an educational design, this caliper fits perfectly on a shelf or a desk as a display showing all of its intricacies.

My intent with the documentation provided will be to help you with printing, assembling, understand, teaching and testing with this caliper. If this document still leaves you with questions, I am always available and I can be contacted via the methods on the Contact page, page 25. Thank you

Sincerely,
Chris Halliday

Printing & Assembly

Here I will go over some tips on getting your prints setup correctly and assembled into working order. I will go over some of the tools used during my process of assembling the caliper. If at any time you aren't sure about which piece of the caliper is being discussed. Please reference the information on pages 20-22.

Necessary & Suggested Hardware

Magnets:
(Necessary)
The first and main component needed for this build aside from your printer and filament will be Neodymium Disc Magnets. No need to stress though as these magnets are small and cheap! These N52 magnets measure in at ¼" diameter and 1/16" thick.

Similar magnets can be found here - K&J Magnets

They can be found all over ebay as well or your favorite magnet store, you'll want to look for N52 ¼"(dia)x1/16"(thick) Disc Magnets. Each magnet has about 1.5 pounds of pulling force. You should stick to magnets giving you at least ~1.47 pound pulling force or greater.

An additional way to mount the two caliper halves together is with the use of bolts through the existing caliper mount holes. You will need M8x50mm hex head bolts (2) and two nuts to fit. This method will require a bit more work during dis-assembly but will provide a better means to fix the caliper halves together.

Super Glue/Epoxy:
(Necessary)
Some super glue is necessary to attach the bleed screws, magnets and the brake fluid inlet fitting. I have been using Gorilla Super Glue. While it has worked good so far with the bleed screws and inlet fitting I have run into issues with the magnets staying in place after repeated use. My magnets and the bed they sit in were not prepped before glueing. With proper prep and any super glue or even epoxy, you should not have any issues. You can find more information on pages 12-15.

Sand Paper:
(Necessary)
A bit of sandpaper will be necessary when fitting the piston seal and the piston into the piston bore. I typically used 160 grit and 320 grit.

Jewelers File Set:
(Suggested)
While these aren't needed they are a huge help. This caliper was designed with a reasonably tight tolerance to ensure everything sticks together and doesn't fall apart on the floor. The jeweler's files have the necessary files to get into the holes to help expand them to fit the next components. My biggest needs for the files were to enlarge the pad retainer clip where it passes through each caliper half, the wear plates, brake fluid inlet fitting and the brake pads where the retainer clip passes through.

These are a great addition to anyone's 3d printing arsenal as well. Here is a link to the set I have purchased
Princess Auto

Print Quantities
This section is a quick overview of how many prints you will need to make of each STL file. Below is the name of each STL file as well as the quantity needed on the right hand side.

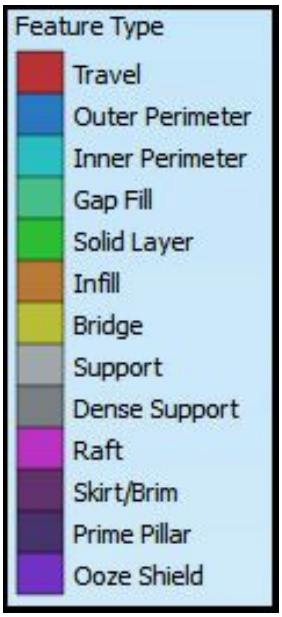
Caliper Side - No Mount - **(1)**
Caliper Side - Mount - **(1)**
Retainer Clip - **(1)**
Brake Line Feeder - **(1)**
Piston - **(2)**
Piston Seal - **(2)**
Brake Pad - **(2)**
Wear Strips - **(4)**
Brake Bleeder - **(4)**

Total = 18 printed parts

Print Orientation & Settings

In this section I am going to include a screenshot from each STL file when it was loaded into Simplify3D so you can see the orientation used when I printed the parts. You will also find some of the key settings used during the prints. PLA was used for most parts of the caliper with minimal ABS parts that will see distortion during use.

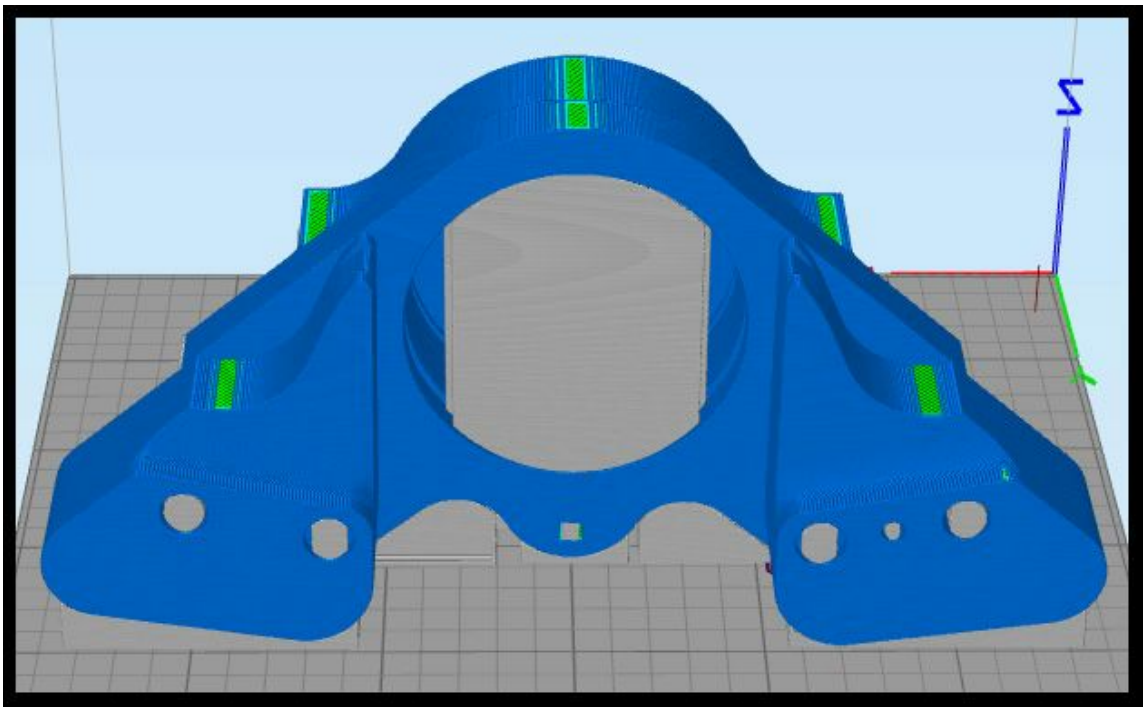
Here is the Simplify3D legend so you can see what each color represents when looking at the graphics below.



I have also included a Final Thoughts area to give you an idea of some possible changes and things to watch for when you are printing.

The checkered grey base of each image is the build platform of my printer. Most photos are showing a partial top down view of each file loaded on the print bed.

Caliper Non-Mount Side



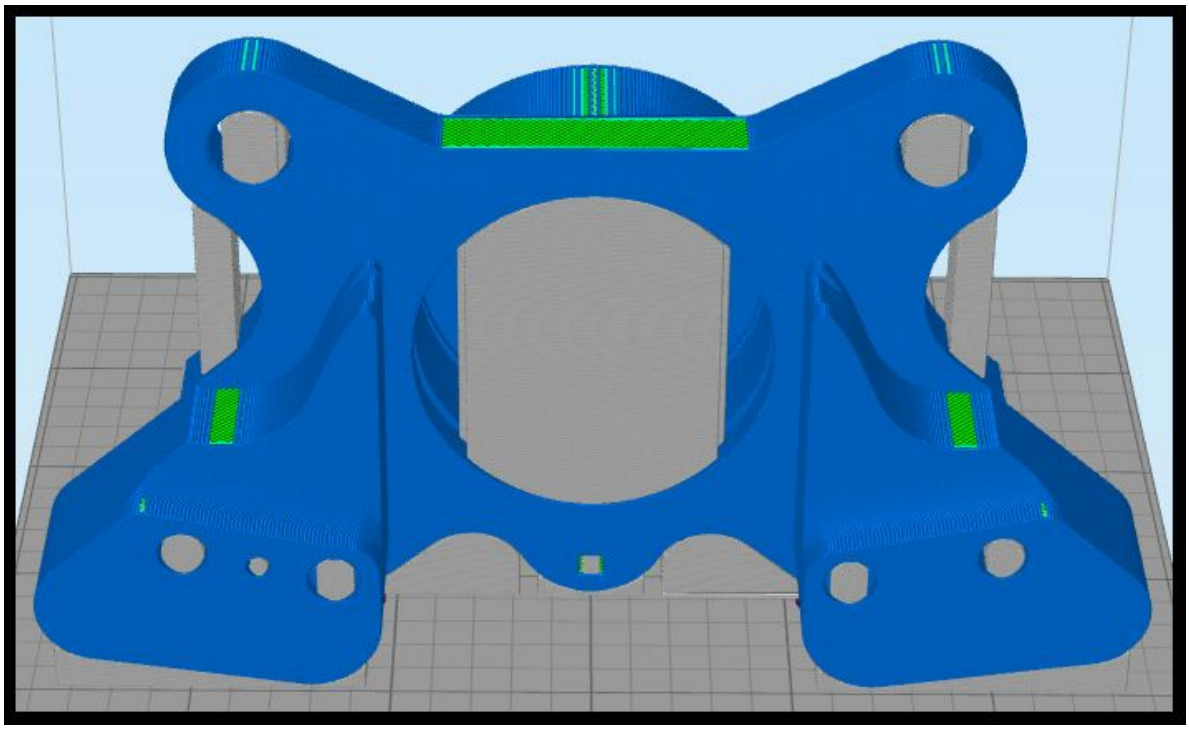
Print Settings:

- Supports at max overhang 45 degrees
- .2mm layer
- 2 outlines/perimeters
- 30% infill
- Printed in PLA (Yellow)

Final Thoughts:

Infill percentage could be dropped to decrease print time. Depending on your printer's capabilities, supports can be removed from some of the easier to print holes etc. Increasing the max overhang angle from 45 will reduce the amount of support needed. You'll need to manually remove supports you don't want.

Caliper Side - Mount



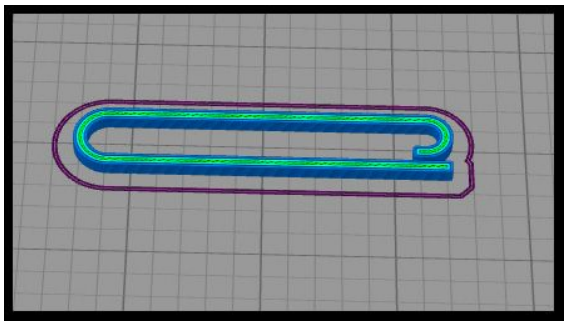
Print Settings:

- Supports at max overhang 45 degrees
- .2mm layer
- 2 outlines/perimeters
- 30% infill
- Printed in PLA (Yellow)

Final Thoughts:

Infill percentage could be dropped to decrease print time. Depending on your printer's capabilities, supports can be removed from some of the easier to print holes etc. Increasing the max overhang angle from 45 will reduce the amount of support needed. You'll need to manually remove supports you don't want.

Pad Retainer



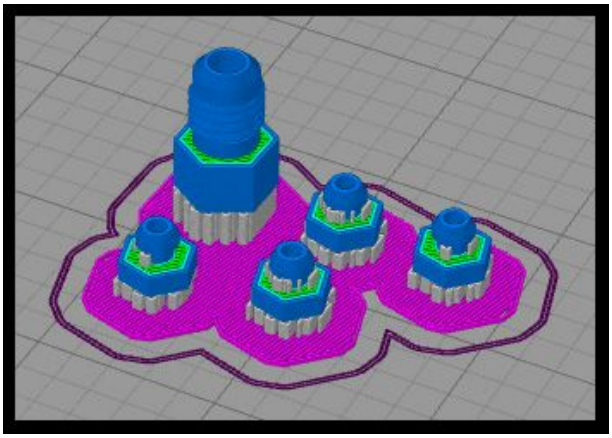
Print Settings:

- .1-.2mm layer height
- 1 outline/perimeter
- 30% infill
- Printed in ABS (Green)

Final Thoughts:

It is best to print this item in ABS or a semi-flexible material. During caliper disassembly, this Pad Retainer clip will see frequent bending.

Bleed Screw & Brake Fluid Inlet Feed



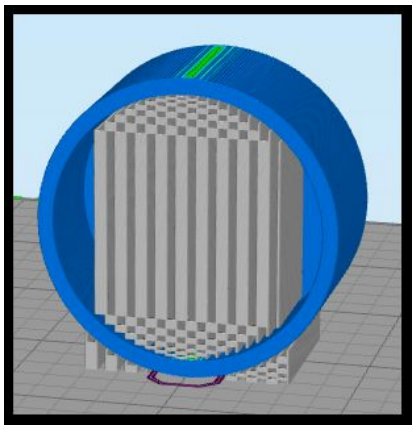
Print Settings:

- .1mm layer height
- Supports
- 1 outline/perimeter
- Raft - Offset 2mm from part
- 30% infill
- Printed in PLA (Light Blue)

Final Thoughts:

In order to ensure bed adhesion i've opted to use a raft. I have also added a bit of support as the bleed screws and inlet fitting have some overhangs at the nut portion and nipple portion.

Piston



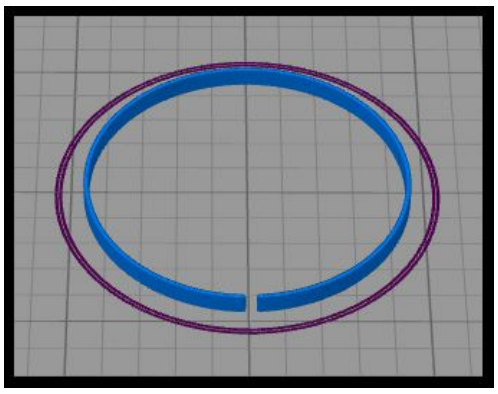
Print Settings:

- .2mm Layer Height
- Support at max overhang angle of 45 degrees
- Supports from built platform only - Max overhang angle 45 degrees
- 2 outline/perimeter
- 30% infill
- Printed in PLA (Grey)

Final Thoughts:

For best finish I printed the piston on its side. It seemed to hold its shape well at the end.

Piston Seal



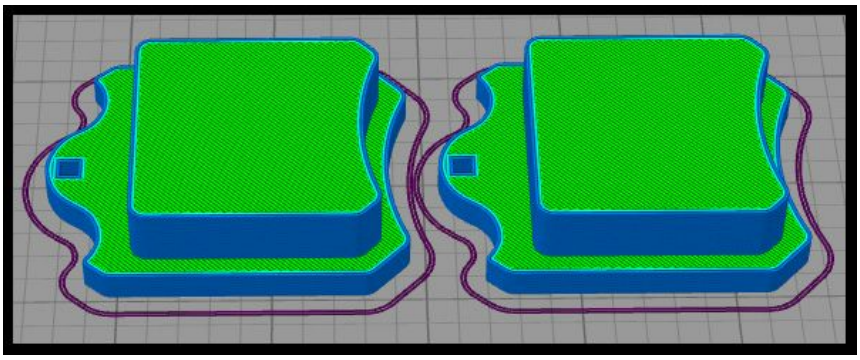
Print Settings:

- .1mm - .2mm Layer Height
- 1 outline/perimeter
- 100% infill
- Printed in PLA (Orange)

Final Thoughts:

I printed my seals in PLA. ABS should work as well as these will see flexing during installation and removal. PLA will work as long as they are not over bent. It is possible to print these seals with a .5mm nozzle using the settings above. The seal measures a thickness of 1mm.

Brake Pad



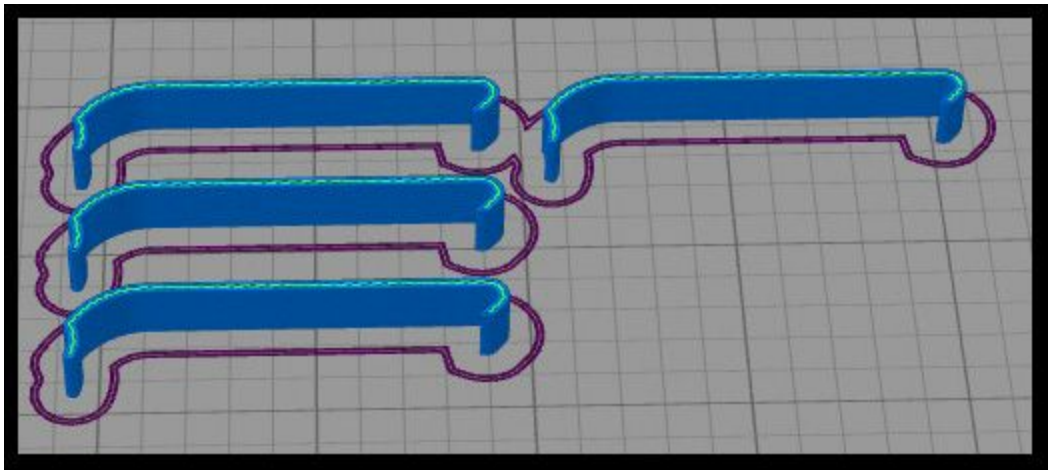
Print Settings:

- .2mm Layer Height
- 2 outlines/perimeters
- 20% infill
- Printed in ABS (Red)

Final Thoughts:

The brake pads print pretty easy. You can always reduce infill percent with these.

Wear Plate



Print Settings:

- .1mm - .2mm Layer Height
- 1 outline/perimeter
- 30% infill
- Printed in PLA (Black)

Final Thoughts:

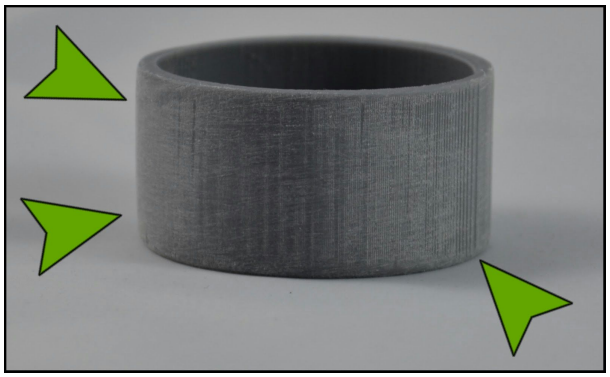
Due to the thin nature of the Wear Plates it is best to stick with a single perimeter. I ran 30% infill but this can be increased if you so choose. These do not see much stress or flexing on the caliper

Post Processing

With the post processing section I will go over areas to focus on with each printed part before assembly. Some massaging is needed to get the parts to fit snugly so they are not falling out of the caliper.

You'll find below each image, a write up on the areas of focus indicated by the green arrows. Printed items are listed here in order of which you should deal with first to the last.

Piston



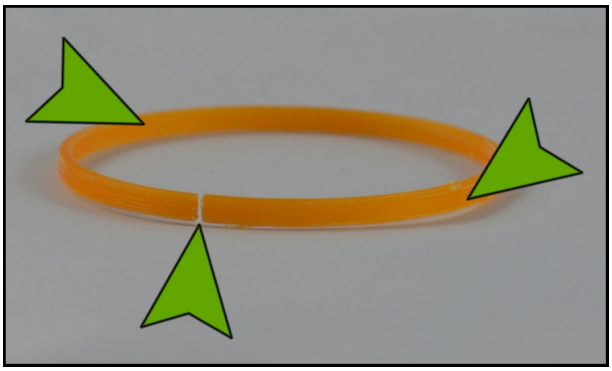
Focus Points:

The main areas to focus on with the piston will be the outside diameter as well as the bottom fillet indicated by the bottom right arrow.

I made sure to install the piston in the same direction each time I would take it out and re-install it after sanding. After a round of sanding, try putting the piston back into the bore, if you feel resistance you can pull the piston out again and look at the side of it. The darker grey areas will be the areas needing more sanding.

When fitting the piston, ensure the seal has already been put in place as it will add resistance when inserting the piston and allow you to properly fit the piston.

Piston Seal



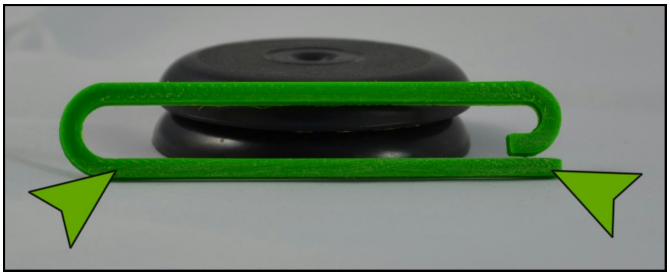
Focus Points:
As seen in the above image, the piston seal is split to allow it to be properly inserted as a 3d printed part. A typical caliper would have a 1 piece seal.

The piston seal is pretty easy to post process, keep in mind though that it can be fragile due to its thin wall construction.

The bottom center arrow is indicating the piston seal gap, this may need to be opened slightly with sandpaper so that when the seal is put into the piston bore it fits tight into the groove and both side of the seal should touch each other to appear as a solid seal ring.

The other 2 arrows are showing area's which may need post processing (Inner and Outer diameters) if you feel protrusions or a lip from the print bed. The seal needs to be smooth to fit well into the groove in the piston bore.

Pad Retainer



Focus Points:
The pad retainer shouldn't need much post processing depending on your printer. If you feel a lip from your print bed on the bottom part of this retainer, as indicated by the green arrows, you'll want to sand it down.

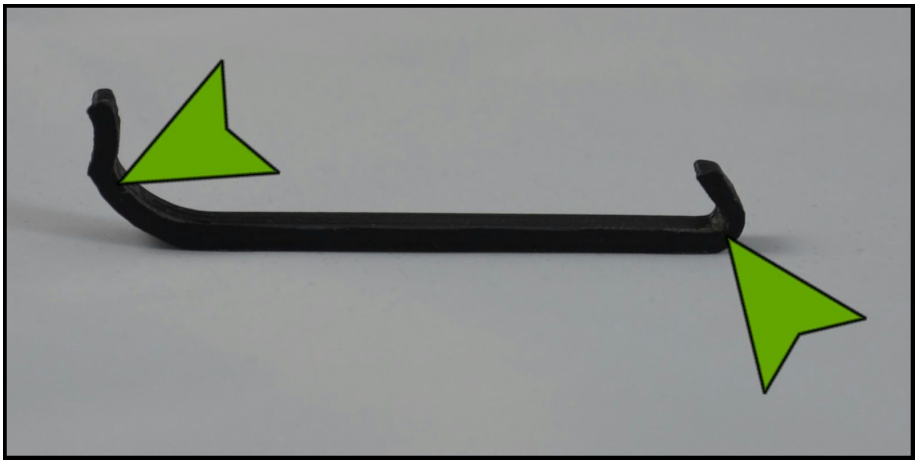
The top portion of the pad retainer won't need any work as it does not fit into any holes. With this retainer, you will want to make sure it slides into the caliper halves and brake pads with ease. More on that in the Brake Pads and Piston Bore sections.

Brake Pads

Focus Points:

The Brake Pads are another easy post processing print. As indicated by the green arrow, the main area to focus on is the Pad Retainer opening. Be sure your Pad Retainer can slide easily through each of the holes on the Brake Pads. The retainer should not be extremely loose but slide easily through the holes.

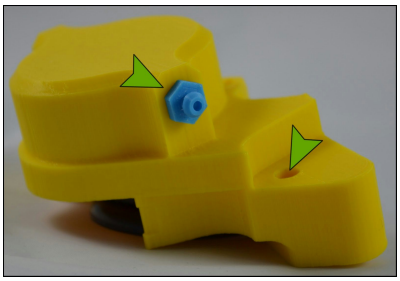
Wear Plates



Focus Points:

If your printer does not produce a lip on the print bed side of your Wear Plates then no post processing is needed. If you do feel a lip this will cause an issue fitting your Wear Plates. It is best to run an X-Acto blade to trip off the lip from the edges of the Wear Plates. These edges can be seen by the green arrows.

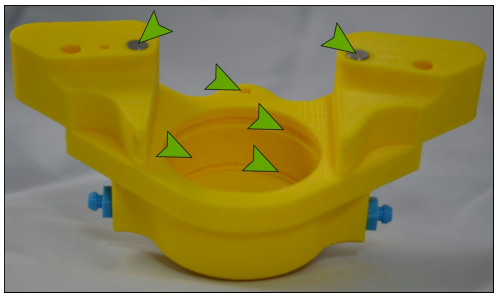
Bleed Screws & Inlet Fitting



Focus Points:
After you get your Bleed Screws and your Brake Fluid Inlet Fittings from your printer, you will want to make sure they slide into the appropriate holes in the caliper halves. Some resistance when putting the Bleed Screws and Inlet Fitting will be a good thing. You can go ahead and glue in the Bleed Screws and Inlet Fitting if you choose too. They were made to glue in so they would not be lost.

While you're at it, be sure all the holes around the Caliper halves have been sanded out properly especially if supports were used in the holes.

N52 Magnets & Piston Bore



Focus Points:
The magnet pockets should not need much work. Ensure your magnets fit snug into these pockets. You can go ahead and glue in the magnets.

Another area of focus on the caliper halves would be the Pad Retainer hole. It is shown above with the upper center most green arrow. Make sure the Pad Retainer fits easily through this hole on each half of the caliper.

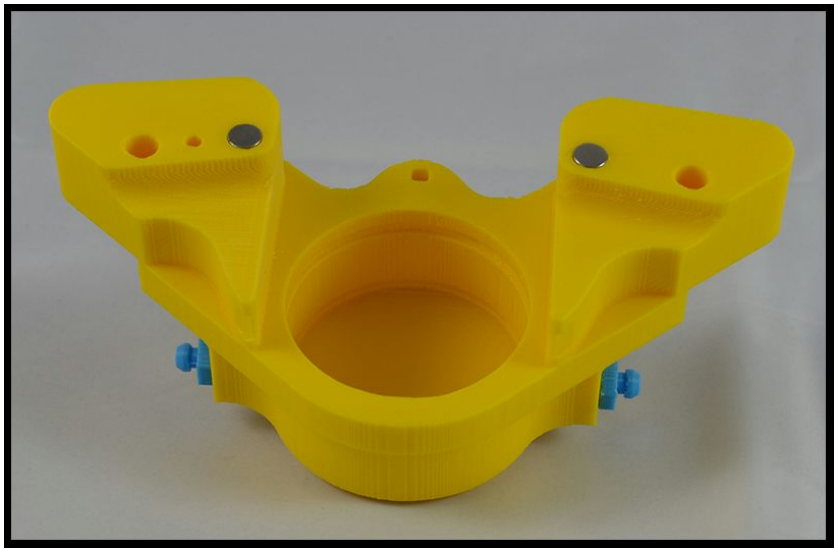
Finally, inspect your piston bores, piston seal grooves and the fluid grooves for any debris from printing. The uppermost groove (furthest from the bottom of the photo) is the piston seal groove and the one of importance. It needs to accept the piston seal in its entirety.

While inspecting the piston bore, ensure the bleed screw fluid passages are clear as well as the crossover port inlet which can also be found in the lower fluid groove. Three holes in total can be seen in the fluid groove and should be checked.

Assembly

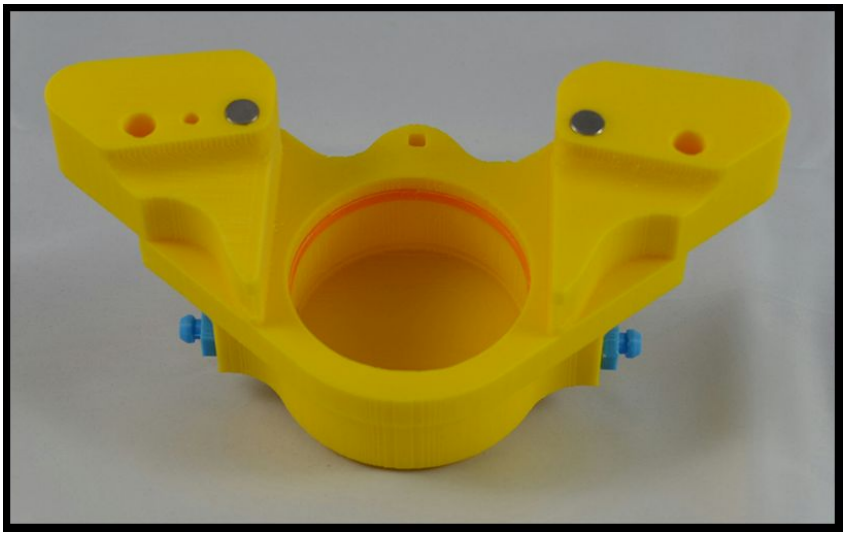
For the assembly, we will look at the process to putting the caliper together. At this point you've post processed your 3D printed parts and have probably nearly assembled your caliper already! Congratulations! I will just look at covering some points I used while assembling mine.

Step 1



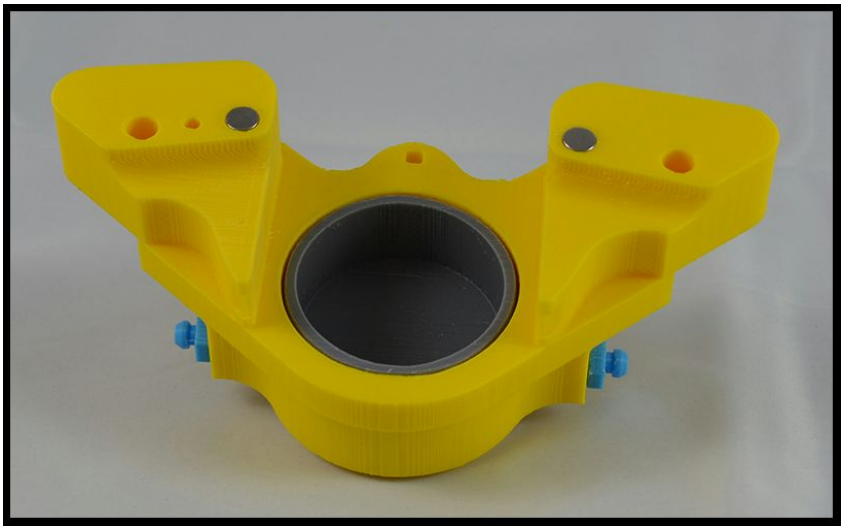
The first and most obvious of the steps would be to grab your caliper halves. For the graphical representation of the steps I will just be using one side until the final assembly steps. Start off your assembly making sure you have glued in your Magnets, Bleed Screws and the Brake Fluid Inlet Fitting.

Step 2



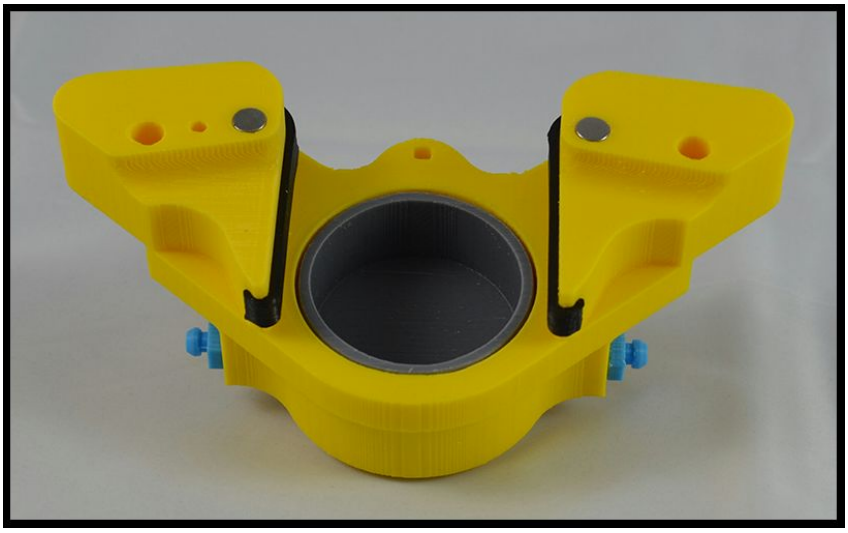
For Step 2 we will want to insert the Piston Seal into the uppermost groove in the Piston Bore. This is the Piston Seal groove. For consistency, I like to keep the gap/split in the Piston Seal to the top side of the caliper, closer to the Pad Retainer hole. This is optional but it ensures a consistent fit of the Piston in each half.

Step 3



Now we will look at inserting the Piston into the Piston Bore. For consistency like that with the Piston Seal, I have a spot in my Piston that I like to line up with the top of the caliper nearest to the Pad Retainer hole.

Step 4

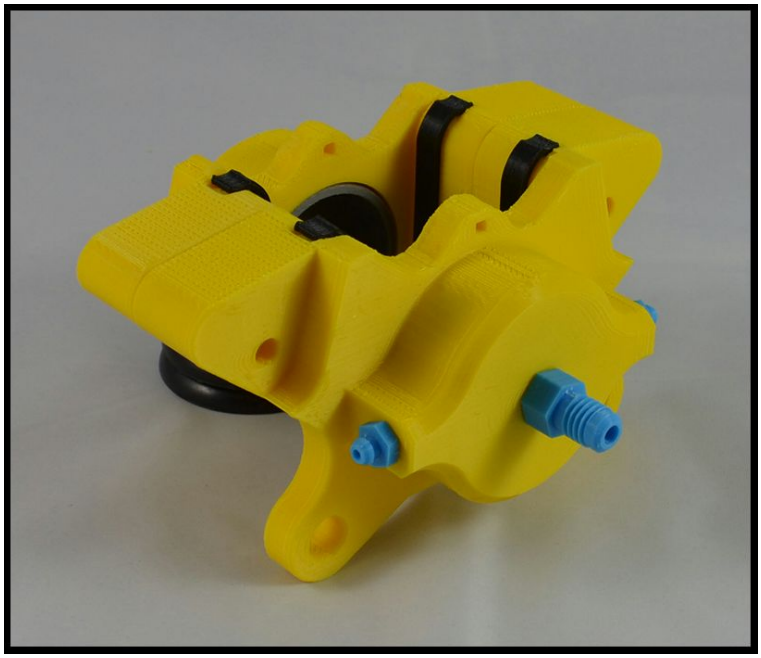


Next up we will fit 2 Wear Plates to each Caliper half. It is important to make sure each Wear Plate fits properly into the bottom groves as well as the top grooves. If they are not fitting on your model, make sure they are fitting into the groves. If you are still having issues you should refer back to the Post Processing section on pages 12-15.

Step 5

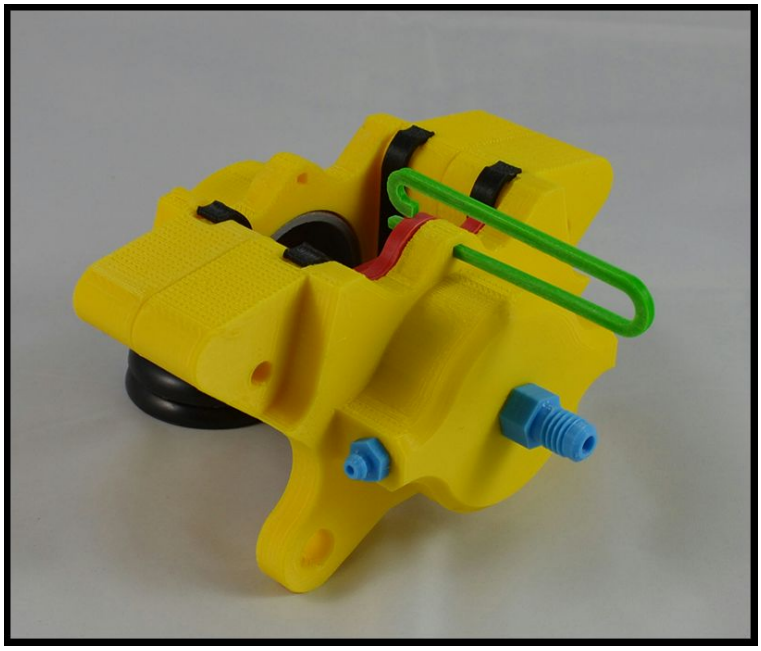
Step 5 is pretty simple :) Grab both halves of your caliper. They should look similar to the image above. Each half complete with the Piston Seal, Piston and Wear Plates. You will also notice the Magnets, Bleed Screws and the Brake Fluid Inlet Fitting are already glued in.

Step 6



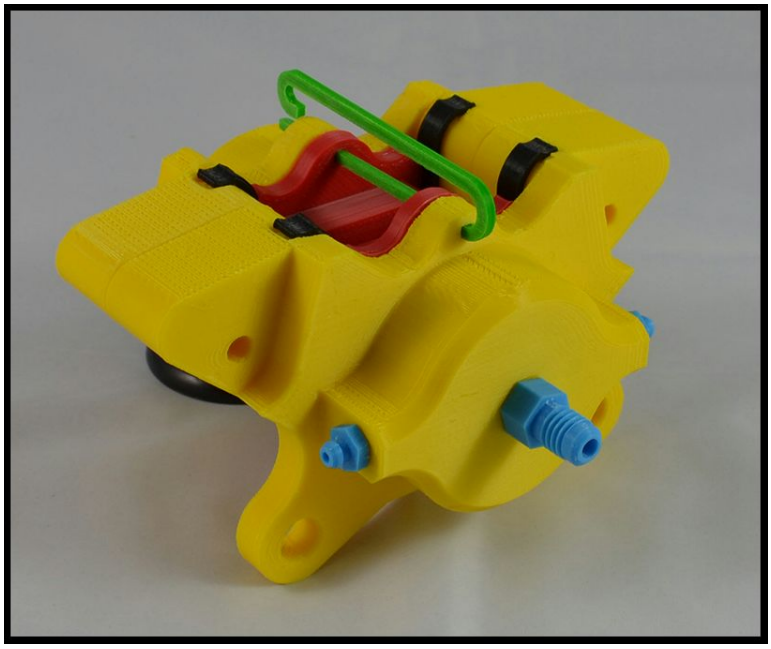
For Step 6, snap your Caliper halves together and start on Step 7.

Step 7



Start by inserting the Pad Retainer through 1 side of your Brake Caliper. Because this is a model there is no concern on which side you start the Pad Retainer from. You can then slide on 1 Brake pad. Make sure to slide the Brake Pad on in the correct direction as above.

Step 8



For Step 8 you'll want to continue to slide the Pad Retainer through the Caliper halves. Stop just before getting to the 2nd half of the Caliper and insert the last Brake Pad. After this, you can finish inserting the Pad Retainer the rest of the way through the Caliper. Yours should now look similar to the graphic above. Well done!

Learning About The Caliper

This is probably the most interested section of this document! We are going to have a look at the Caliper and how it typically works. Keep in mind this caliper is based on a Race Car application and if you are at all familiar with a typical OEM calipers you may notice some differences and/or parts missing.

Parts of the Caliper

Lets first take a look at all the physical parts of the Caliper

We will look at each piece of the caliper by the colors they were printed in above!

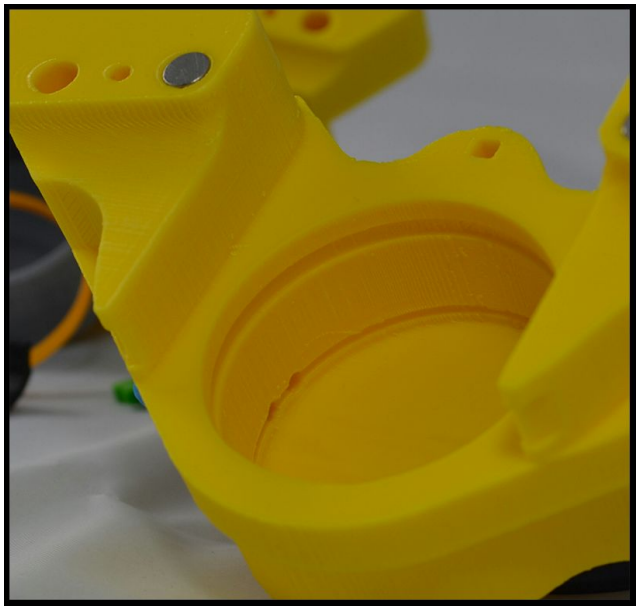
Caliper Body - Yellow

The caliper bodies are typically made via a cast or machined from a solid block of usually Steel or Aluminum. The bodies are the main structural piece of a caliper and need to withstand intense heat and stress from the braking force.

Crossover Ports:

Within the caliper bodies you will see the crossover ports used to take fluid from the Brake Fluid Inlet Fitting side of the caliper, in your model this is the side with the mount bolts on it. The crossover ports can be seen as the small holes between each magnet and the open mount holes.

Brake fluid, which is forced into and through the caliper from the act of the driver pushing the brake pedal gets to these cross over ports through a small fluid groove in the piston bore.



Piston Bore:

Here is a close up of the Piston Bore. As you can see deep in the bore, there is a small groove that runs the entire diameter of the piston bore. The crossover port can be seen as well up near the Magnet. As fluid passes from the main caliper half to the 2nd half fluid will enter this cross over port coming out in the uppermost hole of the fluid groove. From this groove, fluid will fill the void behind the piston until enough pressure is built to push the piston into the brake pad and finally the brake pad into the brake rotor. More on the Piston in the following section.

Piston - Grey

Pistons have a pretty easy job in the caliper. Once enough brake fluid pressure has built up in the void on the back side of the piston it starts its journey into the brake pad and pushes it into the caliper providing a braking force to the vehicle.

Have a look at the back side of each piston in your caliper and you will see the void where brake fluid acts on the piston.

Piston Seal - Orange

As pressure builds behind the piston and the piston moves the piston seal needs to do its job of keeping all the fluid in the piston bore. If there were no seal present sealing the piston to the piston bore fluid wouldn't be able to force the piston out, it would simply leak out of the caliper. The piston seal also keeps contaminates out of the brake fluid. Contaminates can be anything from water to dirt or brake pad material.

The piston seal has its own groove within the piston bore as seen above in the piston bore section.

Wear Plates - Black

As the pads move and wear against the brake rotor, the pistons start moving further and further out of the piston bore. The pads also see tremendous side forces as they start to grip the brake rotor. In order to keep the pads aligned properly to the rotor and to stop this side force from shifting the pads, wear plates are introduced to take care of this. The wear plates also help to protect the caliper body from wear and are typically replaced with routine servicing of the brake caliper.

Brake Pads - Red

Brake pads are the main factor in braking. They are the piece that physically grips the brake rotor and slows a vehicle down. There are many different compounds for brake pads. Compounds are basically the different combination of ingredients that go into making a brake pad. Sometimes more brake force is needed at lower brake temperatures or higher brake force is needed in a high heat environment. The needs for your brake system will make up what type of brake pad compound you use.

Pad Retainer - Green

With a race caliper, the need to quickly change brake pads between practice, qualifying and races can be needed. Team members need to be able to swap pads out easily without taking the brake caliper off of the car. For this, there is a Pad Retainer. This retainer lets team members easily remove and replace the brake pads. It basically allows the brake pads to hang within the caliper bodies.

Bleed Screws & Brake Fluid Inlet Fitting - Blue

Bleed Screws:

Over time brake fluid breaks down either from contamination or heat/duty cycles. When this happens you need to look at replacing the fluid with some fresh fluid. These bleed screws are used as a quick method to “bleed the brakes”. The typical method to bleeding brakes is to pump the brake pedal until pressure is built in the brake system, the bleed screws are then opened to allow fluid to exit the caliper. As this process goes on, new brake fluid can be added to the system improving brake performance once again.

Brake Fluid Inlet Fitting:

Found on the mount side of your caliper, the brake fluid inlet fitting is typically the last joint before fluid passes into the caliper. Your brake line will connect to this fitting allowing fluid to flow freely into the caliper.

Brake Fluid

Brake fluid is the component used to allow the force of the brake pedal being pushed to be converted into a force pushing the piston into the brake pads and ultimately slowing down the vehicle.

Brake Caliper Quiz

1. What are two of the typical materials brake calipers are made from?

    a. Brass b. Aluminum c. Wood d. Steel e. Lead

2. What does the crossover port allow?

    a. Allows fluid to cross from the brake fluid inlet fitting to the caliper

    b. Allows the fluid to pass from the main caliper half to the 2nd side of the caliper

3. Circle 3 features within the Piston Bore.

    a. Piston b. Brake Pad c. Brake Fluid d. Pad Retainer e. Piston seal groove

4. How does brake fluid get behind the Piston?

    a. It gets behind the piston through the fluid groove and the void behind the piston

    b. It finds ways around all the parts of the caliper and ends up behind the piston

5. True or False. The Piston seal is used to clean the piston as it moves in and out?

    a. True b. False

6. What is one of the purposes of the Wear Plates?

    a. They keep the caliper safe from being worn down by the brake rotor

    b. They keep the pads from wearing down the caliper bodies

7. What do the brake pads grip in order to slow a vehicle?

    a. Caliper body b. Pad Retainer c. Brake Pads d. Brake Rotor e. All of the above

8. True or False. Brake pads have multiple material compounds?

    a. True b. False

9. How is brake fluid released from the caliper when bleeding the brakes?

    a. Brake fluid is released by pushing the pistons back into the piston bore

    b. Brake fluid is released by the bleeder screws on the sides of the caliper

10. What fluid is typically used to allow forces to get from the brake pedal to the caliper?

    a. Water b. Brake Fluid

Quiz - Answer Sheet

1. B & D
2. B
3. A, C & E
4. A
5. B
6. B
7. D
8. A
9. B
10. B

13 Marks Total

Contact Information

Thanks for checking out my Educational Brake Caliper project!

I hope it has been a fun project for you as either an educational piece or simply as a display piece.

If you would like to get a hold of me for any questions, suggestions or anything along those lines I can be reached via my Pinshape Profile here, Chris Halliday

I also have a Facebook Page showcasing some of the work i've done for H2 Fabrications. The H2F page can be seen here, H2 Fabrications. I can be contacted from the H2F Facebook page as well.

I can also be contacted via email at, chris at 250explorer dot com
(Change at to @ and dot to .)

Look forward to speaking with you!

Education Brake Caliper Design Files:

All of the files for the Educational Brake Caliper can be found on my Pinshape profile at the link described above. Thank you

Glossary

Terms and their meanings can be found here.

Fluid Groove

This is the lowest most groove within the piston bore. It allows fluid to get into the piston bore and behind the piston

Cross-Over Port

This tiny port can be seen on the top right and left side of the caliper halves between the magnets and the open mount holes. The crossover port allows fluid to get from the main caliper half to the 2nd side of the caliper

Bleed Fittings

These are the small blue fittings on the sides of the caliper. There are a total of 4 on the entire caliper. These are used to bleed out old brake fluid from the caliper.

Piston Seal

The seal is used to seal in the fluid to keep it in the caliper which will allow brake pressure to build.

Piston Bore

The piston bore is the opening on each half of the caliper. The piston bore is where the piston is inserted as well as the piston seal.

Brake Pads

The brake pads are used to grip to the brake rotor and slow the vehicle.

Brake Fluid

Brake fluid is used to transfer the force of pushing the brake pedal to the brake caliper and ultimately the brake rotor.

Pad Retainer

This is the retainer used to keep the brake pads suspended within the caliper bodies.

Inlet Fitting

This is the large blue fitting on the main said of the brake caliper. This is where the brake line would attach allowing brake fluid to enter the caliper.

Caliper Body

These are the large yellow bodies of the caliper.

Mount

The mount holes can be seen on the main side of the caliper body.

Wear Plate

The wear plates are the small black strips used to stop pad shift and wearing out the caliper bodies.

Brake Rotor

Not visible in this design, but the brake rotor is the physical item allowing the brake calipers to slow the rotation of each wheel on a vehicle.