Prototype Assembling Instruction of Button Simulator

This document is the assembling instruction of the button simulator, which is a part of the Button simulation via FDVV Models project. For more details, please refer to our project page at:
https://userinterfaces.aalto.fi/button-design

Our paper (Button Simulation and Design via FDVV Models, CHI'20) can be found at:
https://dx.doi.org/10.1145/3313831.3376262
https://arxiv.org/abs/2001.04352

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If you have any questions regarding assembling, installation, or running the system, please contact me via the above email.

1. Prepare all the required components (3D print parts, laser cutting layers, and screws)

a.
Before assembling, please download all the files in the "simulator_prototype/3D_print_models" and "simulator_prototype/laser_cutting_layers" folders. Print out all the 3D models by any 3D printer and make all the laser cutting layers by laser cutters with materials at least 3mm thick. All the files should print/cut for one item. However, you should print these files "layer_support_1", "layer_support_2", and "layer_support_3" four times each, and "contact_shield" should be printed twice.

b.
Also, one important component you have to prepare is 1.5 mm thick teflon laser cutting material, which is used for fixate the button stand among the layers. Teflon material is very slippery, so it can effectively reduce the friction between the sliding part and other parts of the simulator. Open the "teflon_parts.svg" file under the "simulator_prototype/laser_cutting_layers" folder, and cut the teflon layers with it.

c.
You also need to prepare various screws:
M4 (8 mm) screws X 58 (for the main part of the simulator)
M3 (12 mm) screws X 4 (for the travel range control)
M2 (12 mm) screws X 4 (for the travel range control and travel range limiter)
Plastic M3 (at least 4 mm) X 2 (for connecting the button stand and the force actuator. Note, it has to be plastic to avoid the electromagnetic effects caused by the coil.)

d.
Follow the instruction below to assemble the prototype. Then follow the other document to connect all the wires and circuit.

2. System Overview

The whole simulator has 4 parts and 4 laser-cutting layers as presented below.

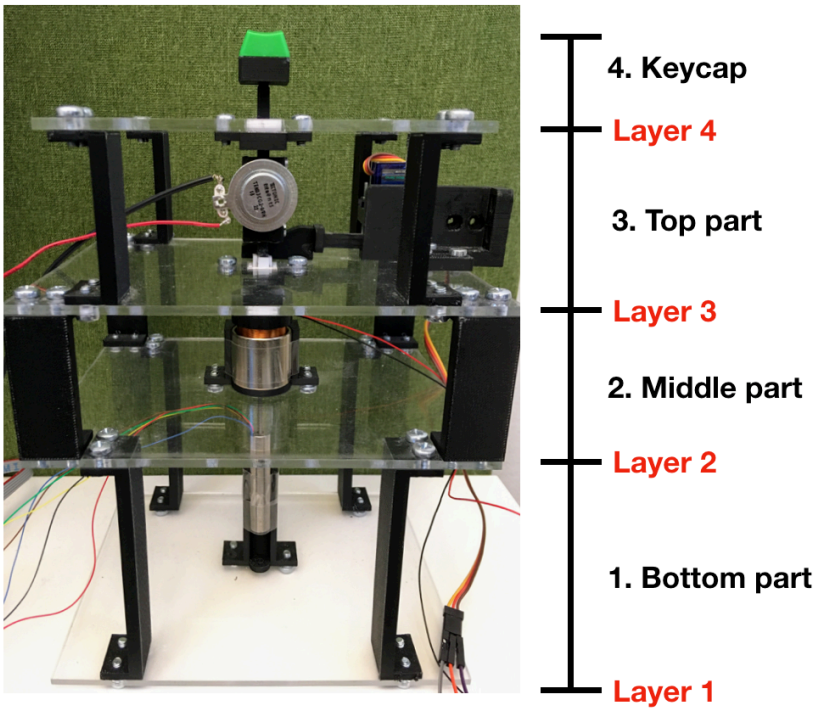

Figure 1. The overview of the system.

The bottom part contains the 1D position sensor. The middle part contains the force actuator and the slider contact. The top part is slightly more complicated, you have to assemble the travel range control and attach the vibration motor. Above these three layers is the keycap. There is a "key stand", connecting the keycap to the force actuator in the middle part, penetrate the top layer.

The assembling order should be: top part → insert the key stand and connect the keycap → connect the force actuator onto the bottom of the key stand → assemble the middle part → place the sensor in the bottom part → bottom part → assemble the travel range control and attach it on the simulator → attach vibration motor.

3. Step-by-step assembling

Step 1. Assembling the top part

Prepare the below components, you need to have 4 X layer support 3. Use only M4 (8 mm) screws to connect layer 4 and layer 3 through layer support 3. The travel range control and vibration motor can wait later. Also, don't insert the key stand; it needs to be inserted after the slider shield is done (next step).

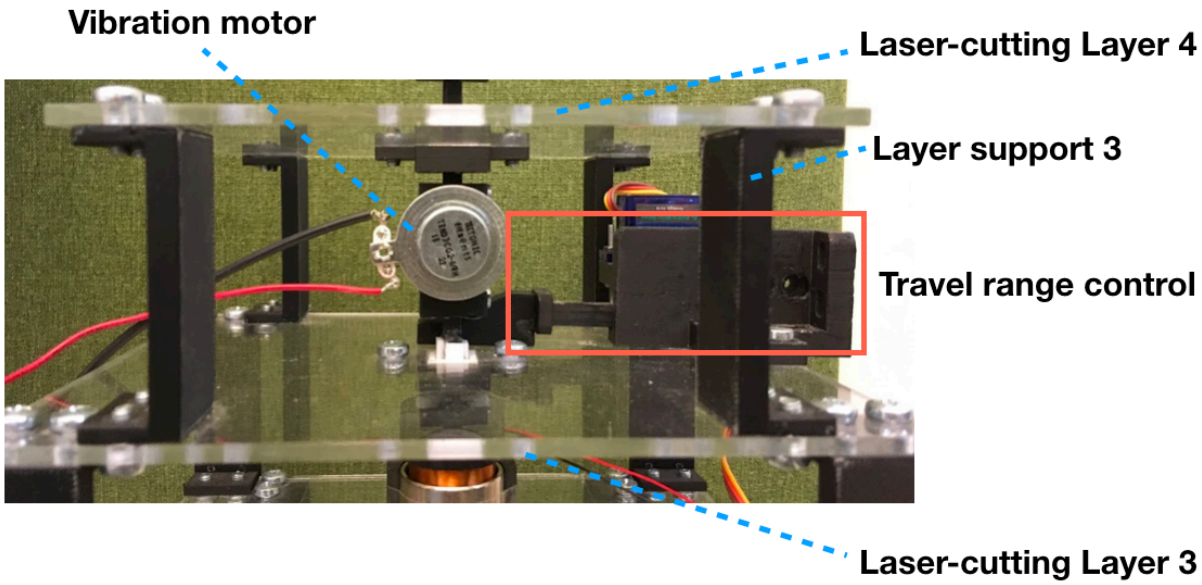

Figure 2. The top part of the simulator.

Step 2. Attaching slider shields on layer 3, layer 4 and attaching teflon layers

Print two slider shield components, one for layer 4 and one for layer 3. You also need to prepare the teflon segments which is can be done by laser cutter. For each slider shield, first, you attach the slider on two layers with 2 M4 screws. Then, use glue to stick the bigger teflon segments on the four sides of the slider shield. You can refer to the following figures, the outer teflon layer is attached on the slider shiled while the inner teflon layer is attached on the key stand.

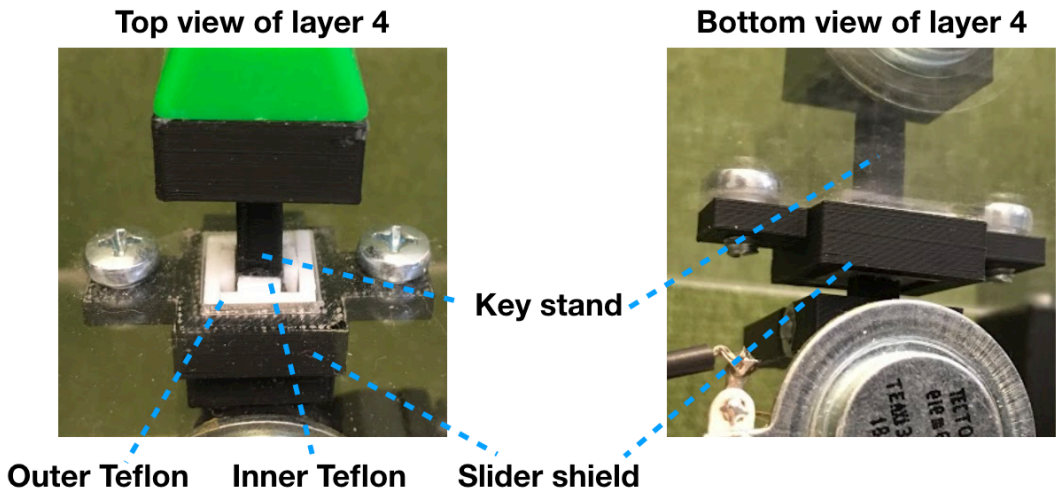

Figure 3. Attaching the slider shield on the layer 4.

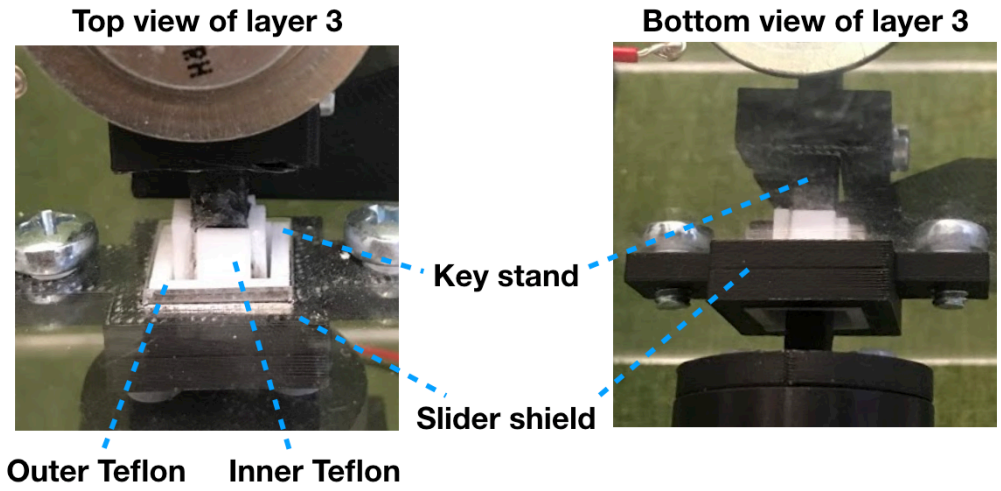

Figure 4. Attaching the slider shield on the layer 3.

Then take out the key stand 3D model. Be careful, observe the model, the side having a small hole is bottom side. The hole is for connecting the sensor probe. Take the smaller teflon pieces, and use glue to fixate the innter teflon layer on the 4 sides of the key stand at the following position: ~1.5 cm and ~6.5 cm away from the top of the key stand.

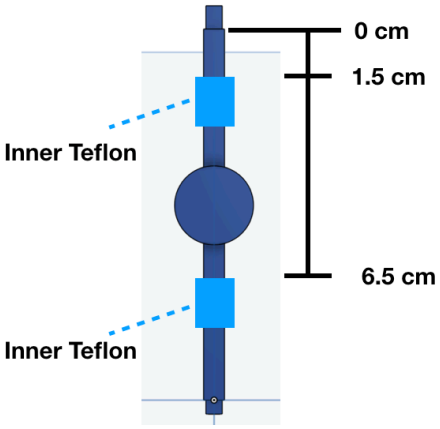

Figure 5. Attaching the inner teflon layer on all the 4 sides of the key stand.

Step 3. Insert the key stand into the top part and mount the keycap

Now, insert the key stand to the top part as you just assembled in previous two steps. If it goes smoothly, the inner and outer teflon will contact each other with nearly no empty space and it should be sliding without much friction. The side with no hole should be on top to connect the keycap. Several keycaps are provided with different tolerance. The most fit one will depend on the 3D filament and the printer settings.

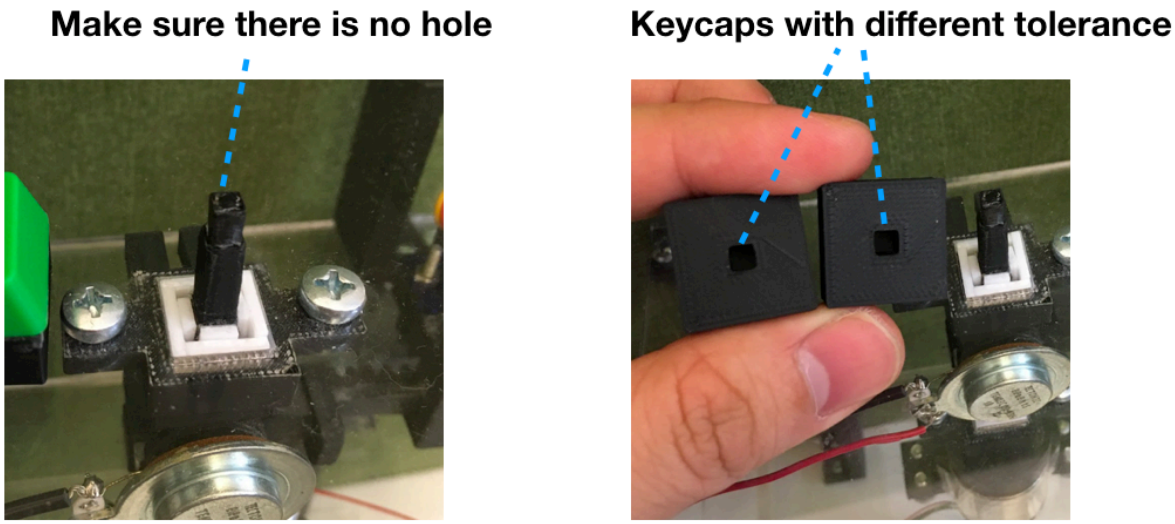

Figure 6. Connecting the keycap with the most suitable tolerance to the key stand.

Step 4. Connecting the key stand bottom and the force actuator

Before linking the key stand bottom to the key stand, connecting the key stand bottom and the force-actuator coil with plastic M3 screws. You have to cut the screws, making it ~ 4 mm.

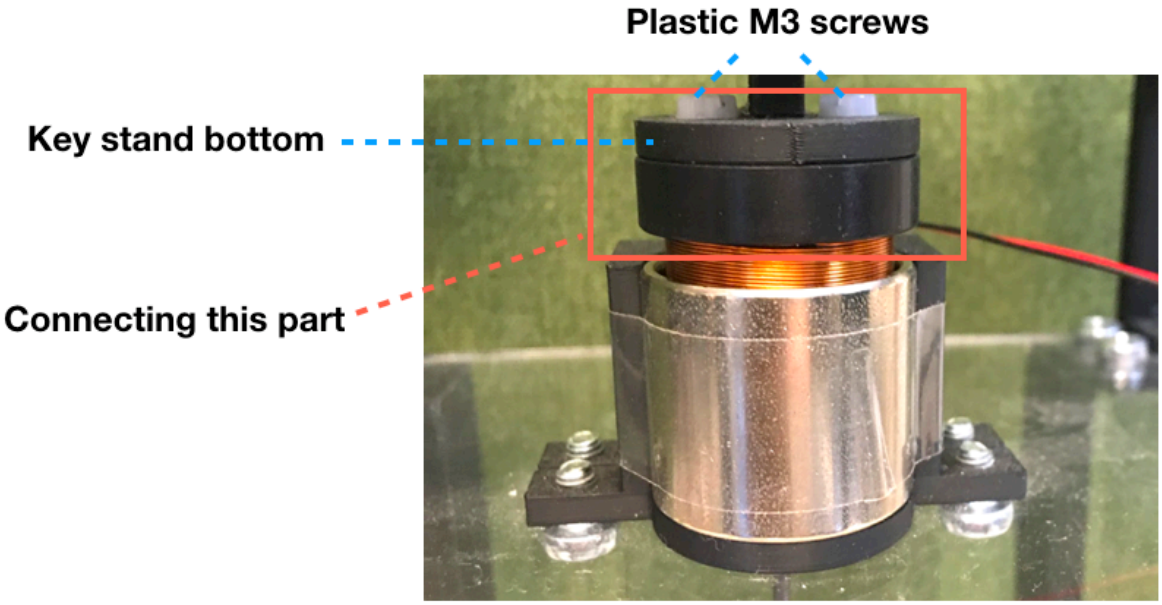

Figure 7. Use plastic M3 screws to combine the key stand bottom and the voice coil of the actuator.

Step 5. Connecting the key stand and the key stand bottom

Insert the key stand to the hole in the center of the key stand bottom.

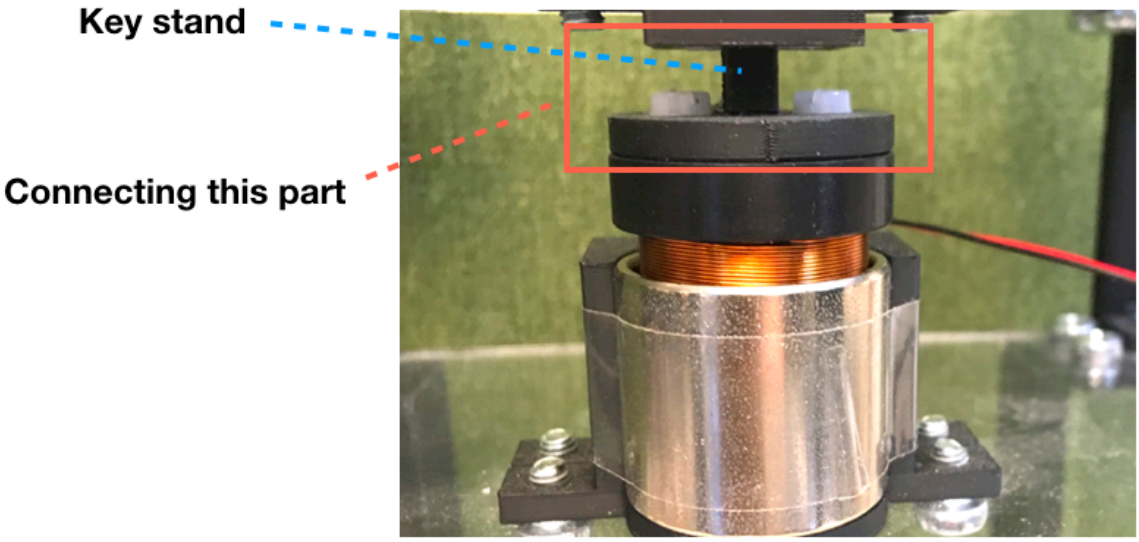

Figure 8. Insert the key stand to its bottom.

Step 6. Constructing the middle part of the simulator

Then use M4 screws to assemble the whole middle part. Note, the actuator has to be placed in the actuator holder now. Again, you will need 4 X layer support 2.

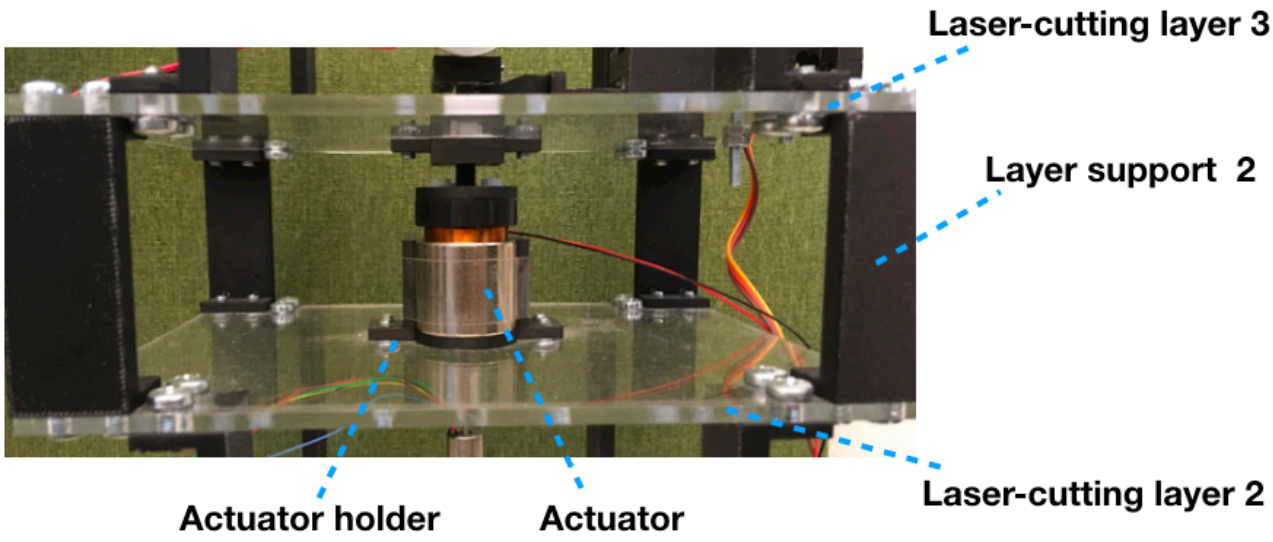

Figure 9. The middle part of the simulator.

Step 7. Insert the sensor axis through the actuator and connect to the key stand

Find the sensor axis from the sensor package and insert it through the hollowed force actuator. Then insert it into the hole left on the key stand. Screw it, and mount it.

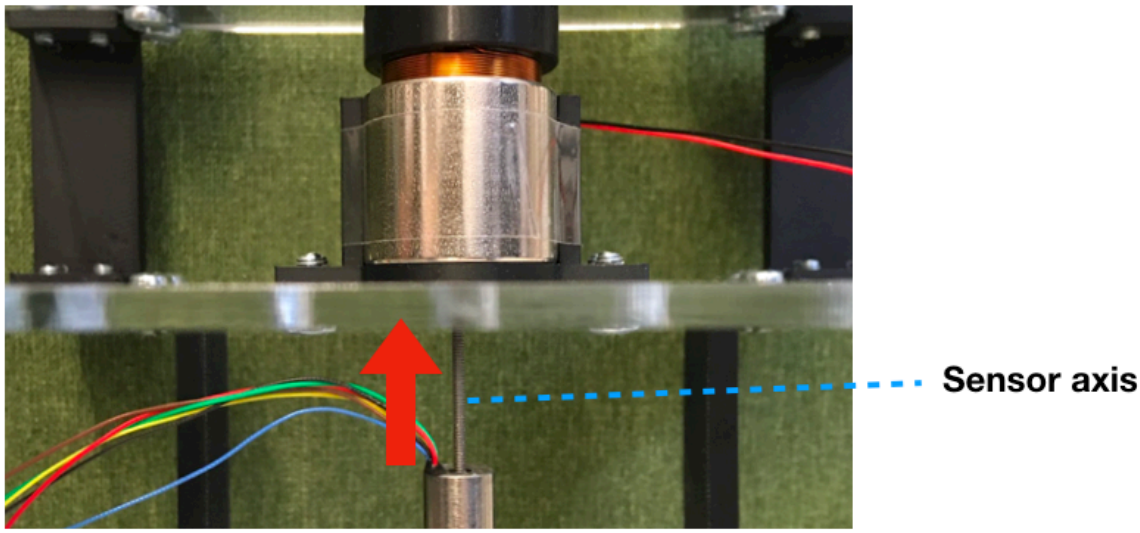

Figure 10. The sensor axis should go through the force actuator and connect to the bottom of the key stand.

Step 8. Assembling the bottom part

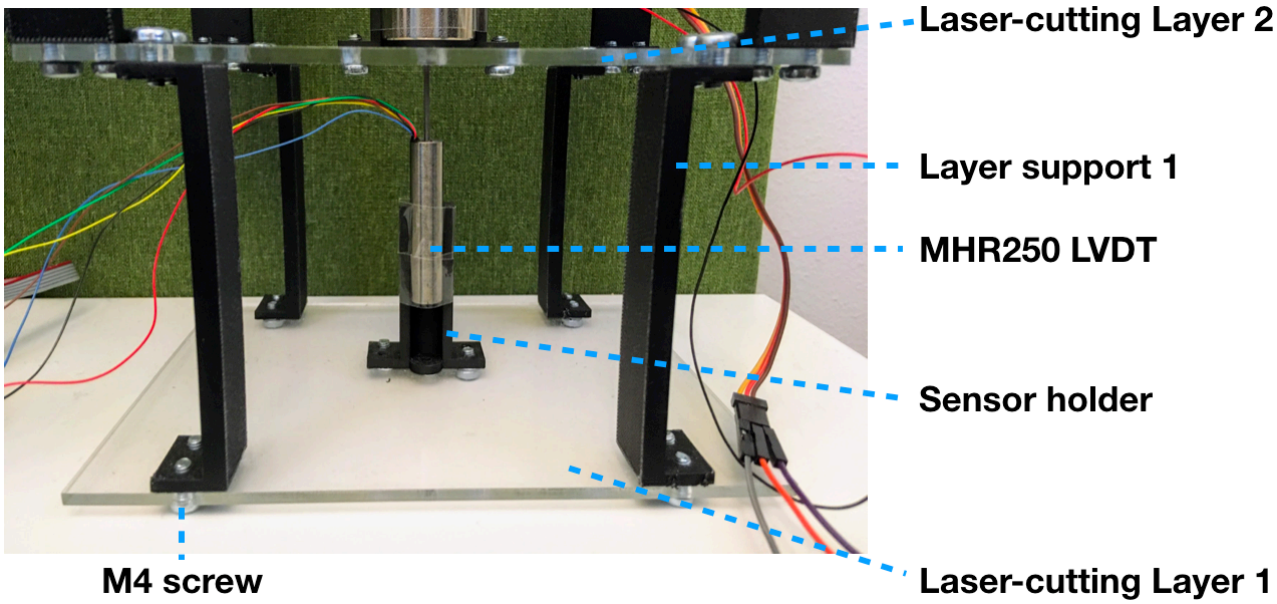

Figure 12. The bottom part of the simulator.

Take all the materials as shown in above figure. There should be 4 X layer support 1. This step is straight-forward, just use M4 screws to connect the layer supports and the 2 laser cutting layers. The other thing to keep in mind is that to attach the sensor holder on the laser-cutting layer 1, you just need one screw on the left side and another on the right side. There might not be enough space

for mounting 4 screws all together. Also, MHR250 LVDT (sensor) needs to be placed in the right place now.

Step 9. Making the travel range control (a linear servo actuator)

Follow the instructions here to make the linear servo actuator:
https://www.thingiverse.com/thing:3170748

The required 3D models are in the "simulator_models/3D_print_models" folder. You will also need a **tower pro sg90** servo motor for driving the linear actuator. This part will be the travel range control of the simulator.

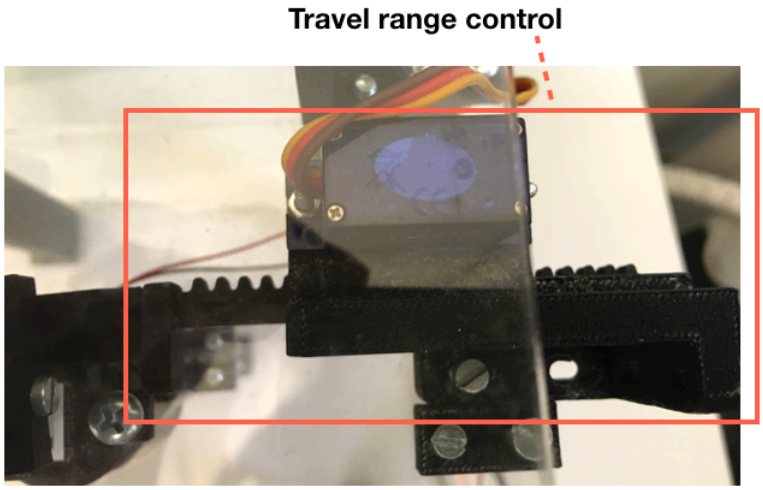

Figure 13. Make the travel range control (servo actuator).

Then, attaching the travel range control head in front of the travel range control with glue. Then mounting the whole travel range control on the layer 3 of the simulator.

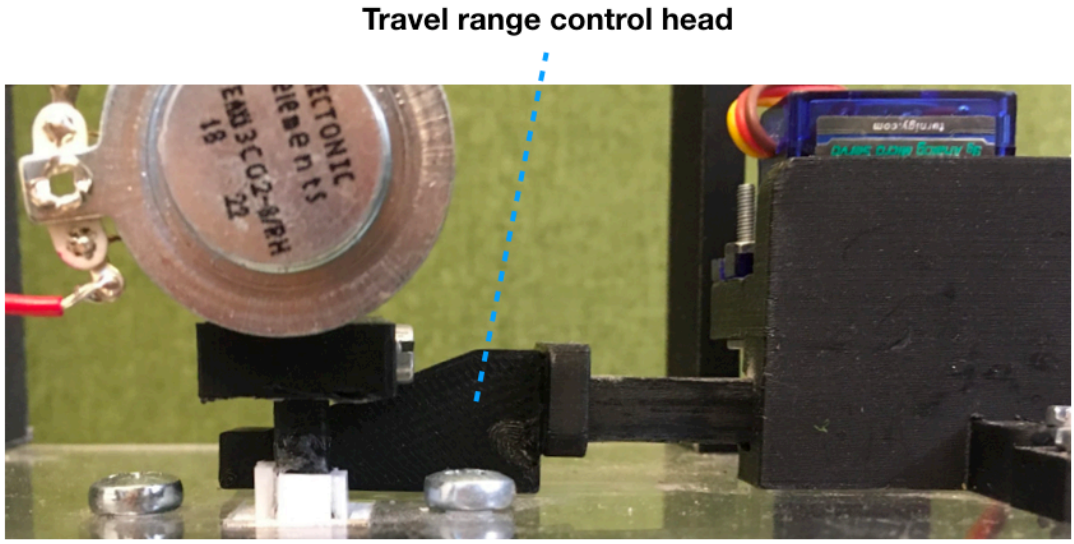

Figure 14. Use glue to connect the head of travel range control.

Step 10. Mount the travel range limiter

Mount the travel range limiter with M2 screws. One near the layer 2 and one near the layer 3. Which will determine the possible travel range of the simulator.

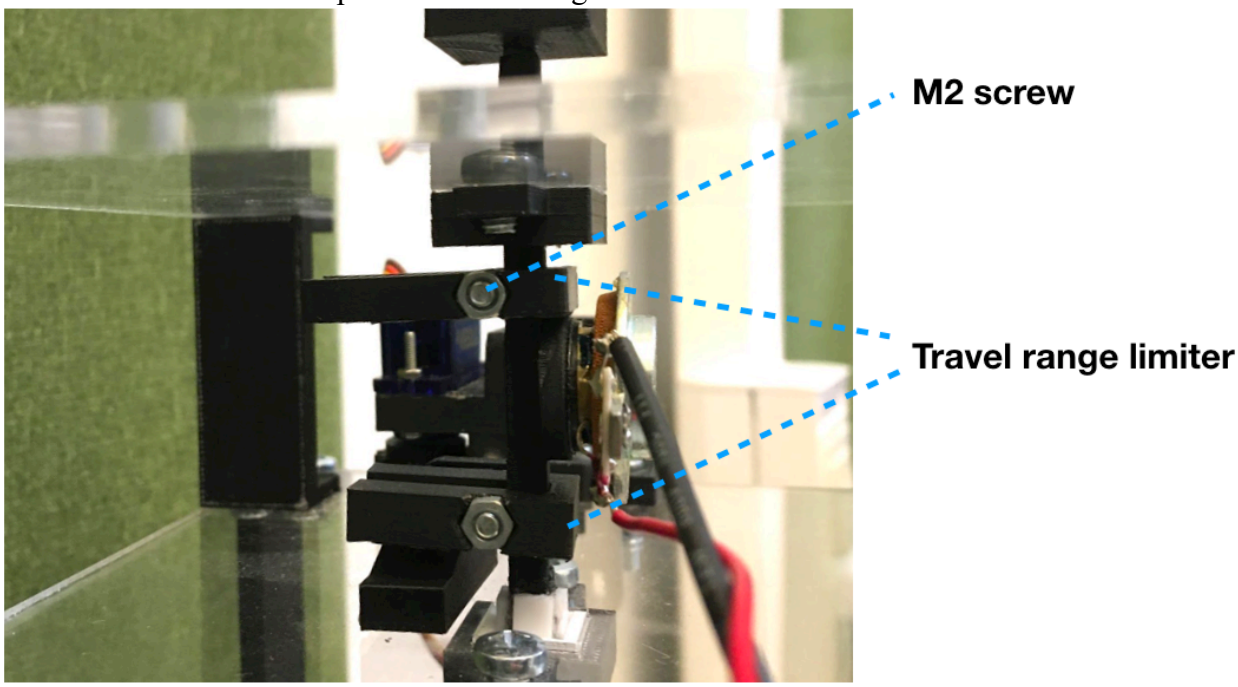

Figure 15. Mount the travel range limiter.

Step 11. Attach the vibration motor

Lastly, the vibration motor should be attach on the key stand.

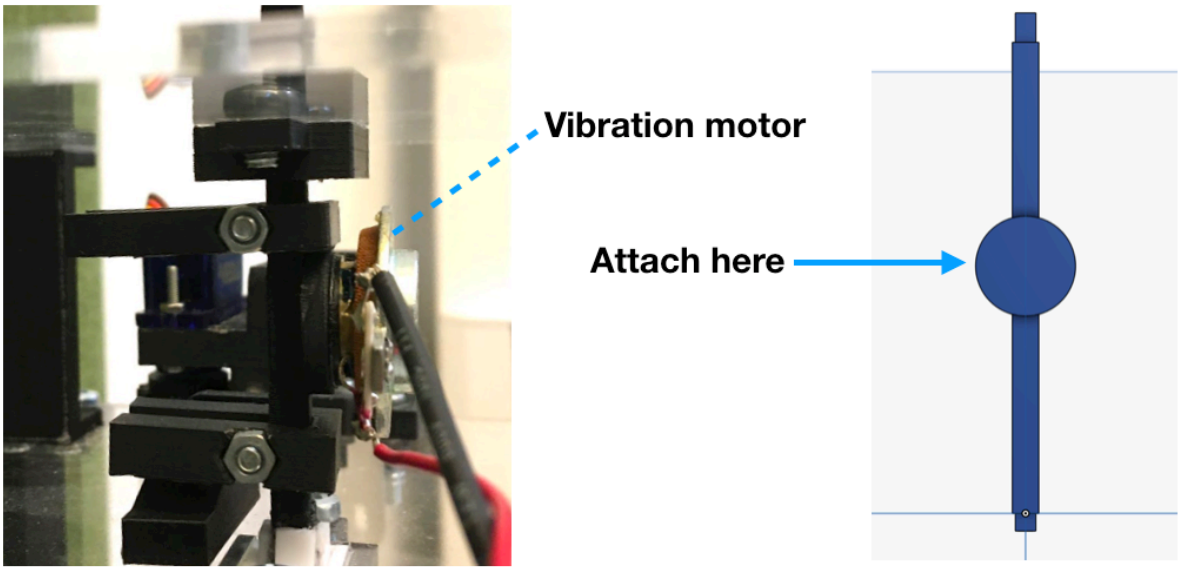

Figure 16. Attach the vibration motor on the key stand.