RPieces - TableTopXYZ

User and Assembly Manual

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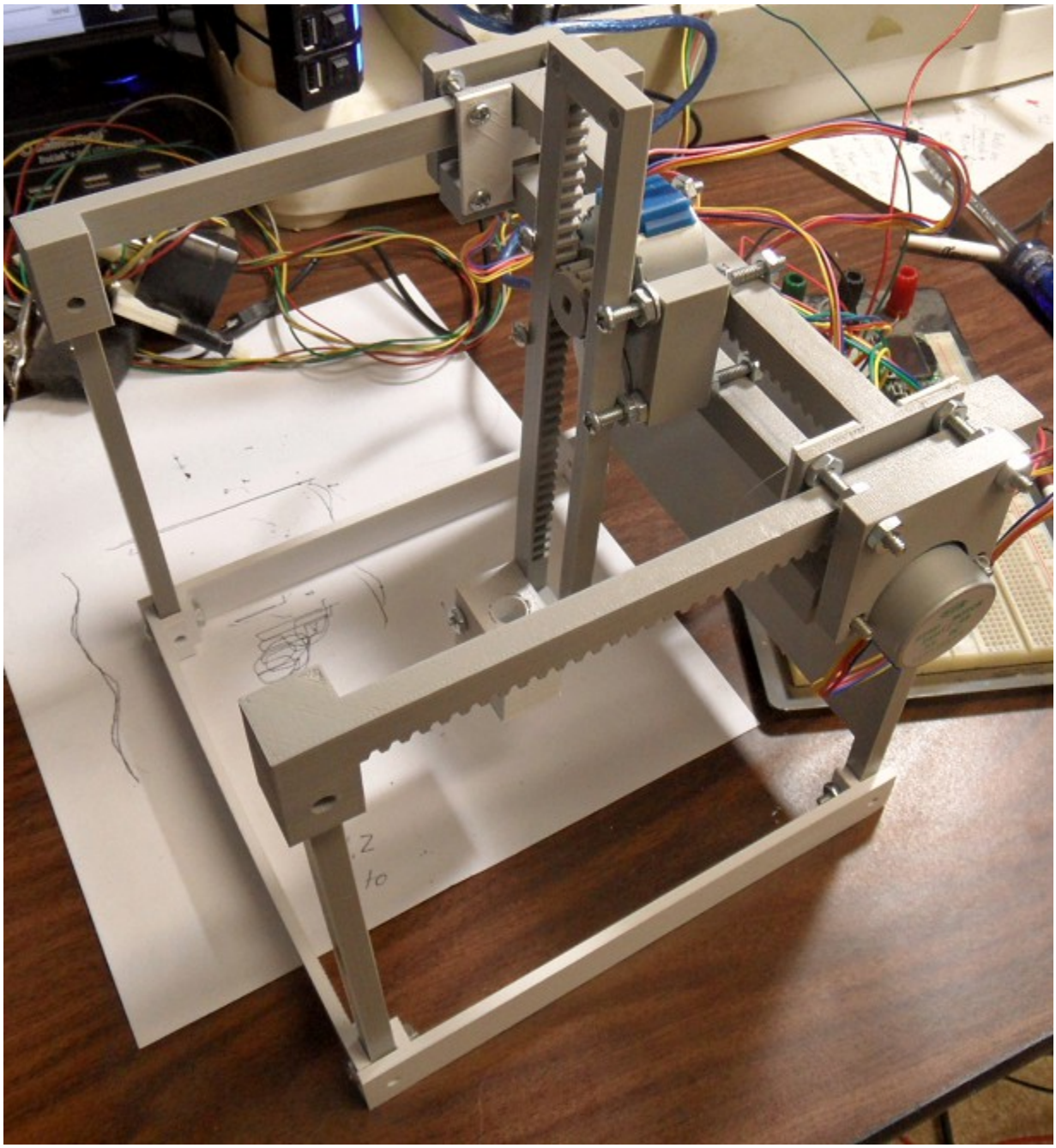
1. INTRODUCTION

The "***RPieces – TableTopXYZ"*** project's goal is to provide a simple and almost entirely printable motion frame for various usages. Including 3d printing, plotting and minor milling. The platform can also be used in testing software, firmware or just testing a model creation on a physical unit before sending it to a much larger commercial unit.

The project is Open Source and Resides at: https://github.com/tgit23/RPieces-TableTopXYZ
This documentation resides at: https://github.com/tgit23/RPieces-TableTopXYZ/docs



2. BILL OF MATERIALS - $28.07

2.1 Tools (N/A)

The following tools are required to build the project components

- ✔ 3D-Printer (With a 190mm x 190mm XY Build Envelope or Larger)
- ✔ Phillips head screw driver and nut driver

2.2 3D – Prints

- ✔ (1) BackSide.stl
- ✔ (1) Base-Front.stl
- ✔ (1) Base-Left.stl
- ✔ (1) Base-Right.stl
- ✔ (2) Leg.stl
- ✔ (4) MotorGear.stl
- ✔ (1) X-Guide.stl
- ✔ (1) X-Rack.stl
- ✔ (1) XZ-MotorTie.stl
- ✔ (2) Y-MotorMount.stl
- ✔ (1) Y-Rack-Left.stl
- ✔ (1) Y-Rack-Right.stl
- ✔ (1) Z-Rack.stl

2.3 Power Supply ($3.10)

Illustration 1: 5VDC Adapter

- ✔ (1) 5Vdc Adapter around 2A maybe less ($3.10)
  - www.banggood.com/3-Way-Port-Audio-Video-AV-RCA-Switch-Selector-Box-Splitter-p-964652.html

2.4 Electronic Control ($22.73)

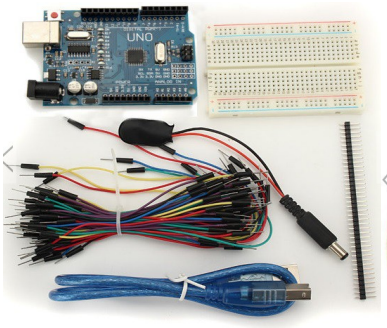


Illustration 2: (2) Arduino UNO R3

Illustration 3: LCD Keypad Shield

Illustration 4: M-F 20cm Dupont

- ✔ (1) UNO R3 Atmega328P Module, Mini Breadboard & Jumpers ($10.19/ea)
  - http://www.banggood.com/UNO-R3-Module-Mini-Breadboard-Jumper-Starter-Kit-For-Basic-Arduino-p-1065051.html
- ✔ (4) 28BYJ-48 5V DC Step Motor with ULN2003 Driver Board ($10.34/per5)
  - http://www.banggood.com/5Pcs-DC-5V-4-Phase-5-Wire-Stepper-Motor-With-ULN2003-Driver-Board-p-951162.html
  - Resources

- 28BYJ Data-sheet http://www.sensors.co.nz/datasheet/28BYJ-48%20Stepper%20Motor.pdf
- ULN2003 Data-sheet http://www.ti.com/lit/ds/symlink/uln2003a.pdf

✔ (~40) 20 to 30cm Male to Female DuPont Jumpers ($2.20)
- http://www.banggood.com/40-x-30cm-Male-To-Female-DuPont-Breadboard-Jumper-Wire-Cable-p-89708.html

2.5 Machine Screws ($2.24)

✔ **Complete List**

- (4) #6-32 x 2" Machine Screws ($0.06/ea = $0.24)
- (8) #6-32 x 1-1/4" Machine Screws ($0.05/ea = $0.40)
- (4) #6-32 x 3/4" Machine Screws ($0.05/ea = $0.20)

- (2) #6 Flat Washers ($0.05/ea = $0.10)
- (26) #6-32 Hex Nuts ($0.05/ea = $1.30)

✔ **Itemized List**
- X Gantry
  - (4) #6-32 x 2" Machine Screws
  - (12) #6-32 Hex Nuts
  - (2) #6 Flat Washers

- Y – Gantry
  - (8) #6-32 x 1-1/4" Machine Screws
  - (10) #6-32 Hex Nuts

- Frame
  - (4) #6-32 x 3/4" Machine Screws
  - (4) #6-32 Hex Nuts

✔ Online Price Reference
- Machine Screws @ https://www.boltdepot.com/Machine_screws_Phillips_pan_head_Zinc_plated_steel_6-32.aspx
- Washers @ https://www.boltdepot.com/Product-Details.aspx?Units=US&Category=Washers&Subcategory=SAE_flat_washers&Material=Steel&Plating=Zinc
- Hex Nuts @ https://www.boltdepot.com/Product-Details.aspx?Units=US&Category=Nuts&Subcategory=Hex_machine_screw_nuts&Dimensional_standard=&Material=Steel&Plating=Zinc

Minor variances in size shouldn't be a problem; but the (4) 2" Long machine screws are required. Other screws must be the listed length or longer. All except for the Frame screws need to fit inside the metal bolt holes of the 28BYJ Stepper Motor.

3. HARDWARE ASSEMBLY

Below is the list of the Parts that needed to be printed by a 3D-Printer along with any significant notes about the print. They can be printed with ABS or PLA but PLA is highly suggested over ABS for it's non-curling and non-flexible (brittle) attributes.

✔ Models that require precision (Slower Printing - Printed at a 0.1 Layer Height)
- (4) MotorGear.stl
- (1) X-Rack.stl
- (1) Y-Rack-Left.stl
- (1) Y-Rack-Right.stl
- (1) Z-Rack.stl

✔ Models that can be a little sloppy (Fast Printing – Can be Printed at a 0.3 Layer Height)
- (1) BackSide.stl - (175mm x 170mm x 7.5mm)
- (1) Base-Front.stl
- (1) Base-Left.stl
- (1) Base-Right.stl
- (2) Leg.stl
- (1) X-Guide.stl - (190mm x 45mm x 13mm)
- (1) XZ-MotorTie.stl
- (2) Y-MotorMount.stl
- (2) Y-MotorMount-Inner.stl

Items can be printed at any resolution desired; The sloppier the print the looser the screws will need to be for motion and the looser the completed unit will function (Low Prints = Low Precision).

3.1 Backside & Electronics

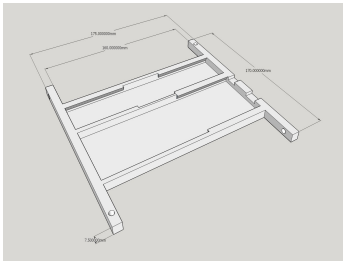


Illustration 5: Backside

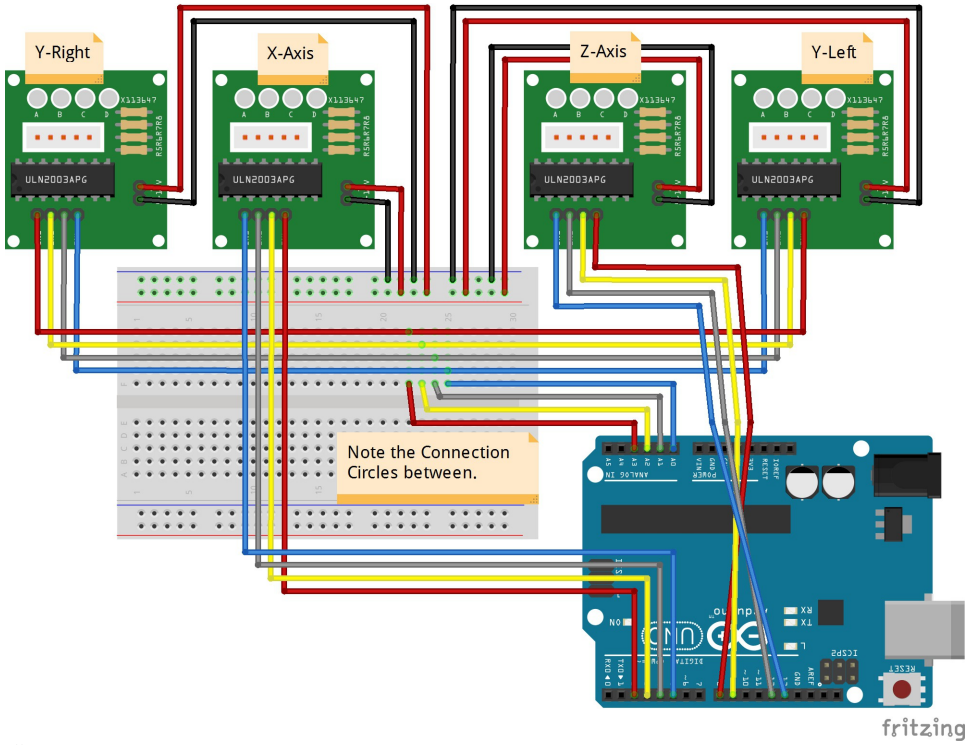


Illustration 6: Wiring Diagram

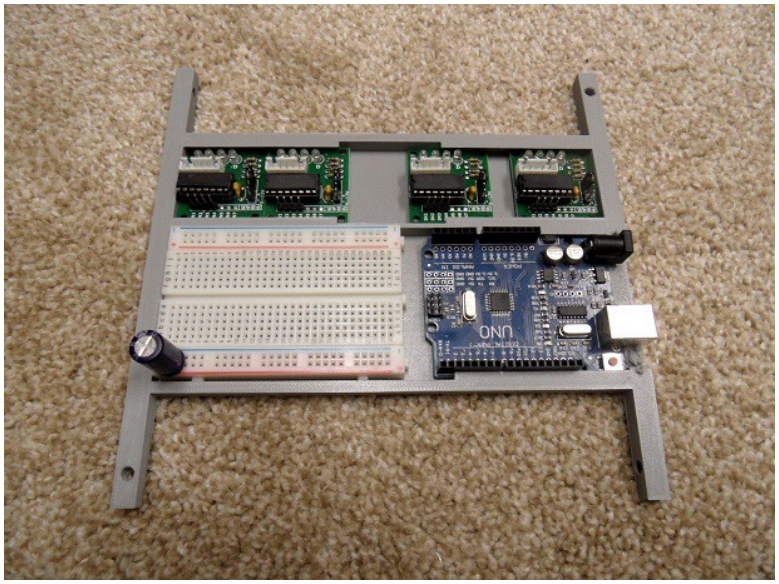
3.1.1 Print Backside

1. Print BACKSIDE.STL file on 3d printer.

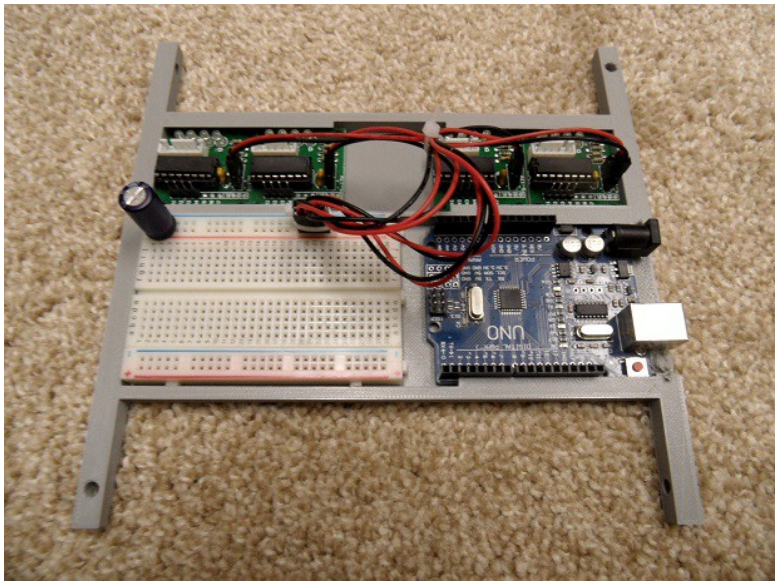
2. Once finished continue printing models (Used in Section 4.2)
   a) Y-RACK-LEFT.STL
   b) Y-RACK-RIGHT.STL
   c) (2) LEGS.STL
   d) BASE-FRONT.STL
   e) BASE-LEFT.STL
   f) BASE-RIGHT.STL

3.1.2 Electronics Assembly

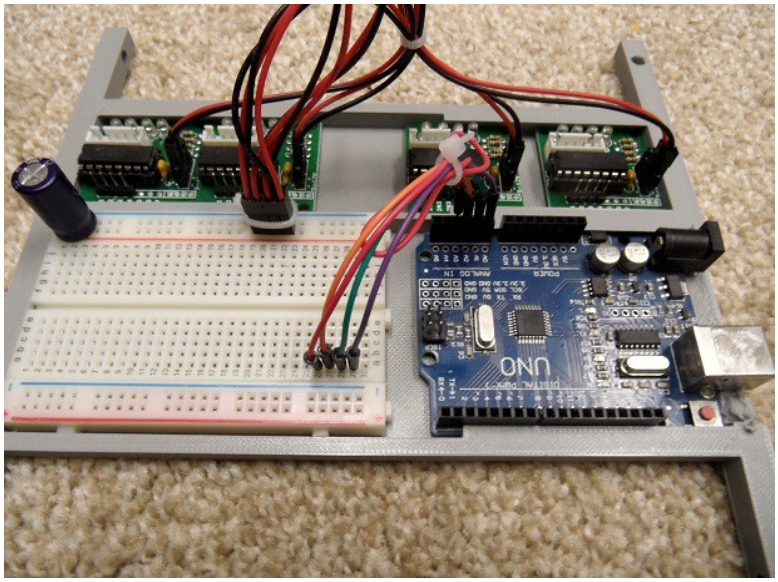
1. Place electronic assemblies inside the Backside Panel
    a) Place (4) ULN2003 driver boards - inserting them into the center and slidding them to the edge
    b) Place (1) Arduino UNO - inserting on the left and sliding to the right
    c) *OPTIONALLY* Place a half-size bread board on the left.



2. Wire power to the ULN2003 driver boards
    a) Use Dupont Male to Female jumpers to wire the Positive (+) and Negative (-) pins on ALL the ULN2003 boards together on the BB power rail



3. Wire the Y-Axis Motor Control pins for splitting to BOTH Y-Axis motors (A0 → A3)
    a) Use breadboard jumper wires to route from the Arduino UNO → Breadboard or common point
    b) Diagram coloring order is:
        - A0 = Blue/Purple
        - A1 = Grey/Green
        - A2 = Yellow
        - A3 = Red



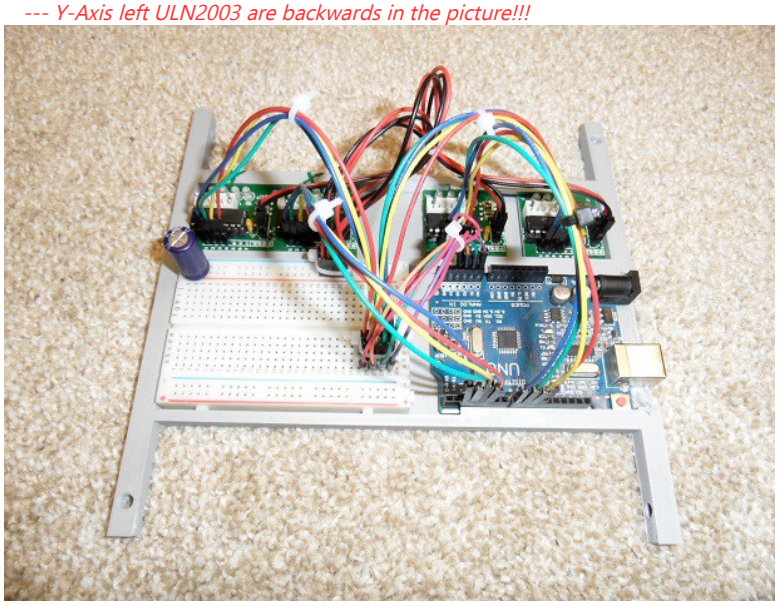
4. Connect control wires for the X, Y, and Z ULN2003 Control Boards

a) Right Side Y-Axis ULN2003
- A0 (Blue) → Breadboard → IN1
- A1 (Grey) → Breadboard → IN2
- A2 (Yellow) → Breadboard → IN3
- A3 (Red) → Breadboard → IN4

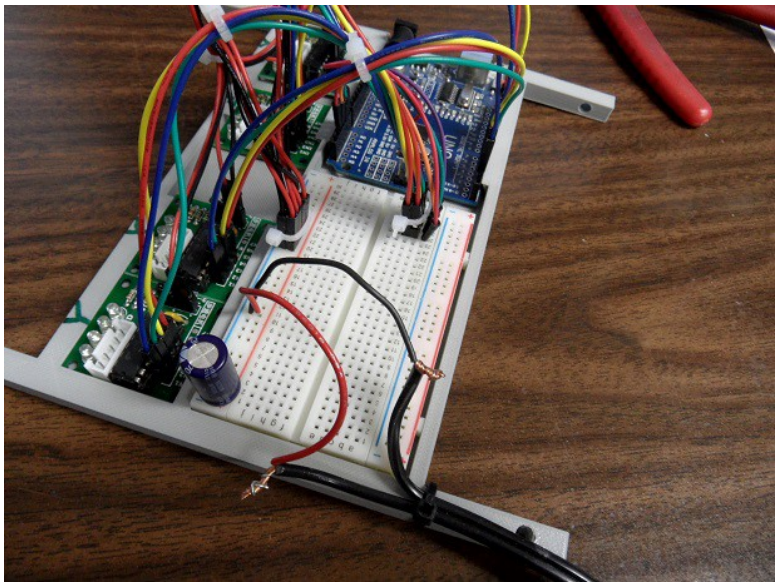
b) Left Side Y-Axis ULN2003 (**REVERSED WIRING**)
- A0 (Blue) → Breadboard → IN4
- A1 (Grey) → Breadboard → IN3
- A2 (Yellow) → Breadboard → IN2
- A3 (Red) → Breadboard → IN1

c) X-Axis ULN2003
- D5 (Blue) → IN1
- D4 (Grey) → IN2
- D3 (Yellow) → IN3
- D2 (Red) → IN4

Picture Has Errors!!! Following the Wiring Diagram or Text above.
--- D2...D5 are backwards on the Arduino in the picture!!!
--- Y-Axis left ULN2003 are backwards in the picture!!!



5. Wire Power Supply Adapter
    a) Cut and strip the ends of the 5Vdc Wall Power Adapter
    b) Wire-tie the end to the Backside leg
    c) Check the polarity of the power (+ / -)
    d) Attach power to the power rail wired in step #2 above
    e) OPTIONALLY an appropriate capacitor can be placed on this power rail.



3.2 Y-Rail / Frame

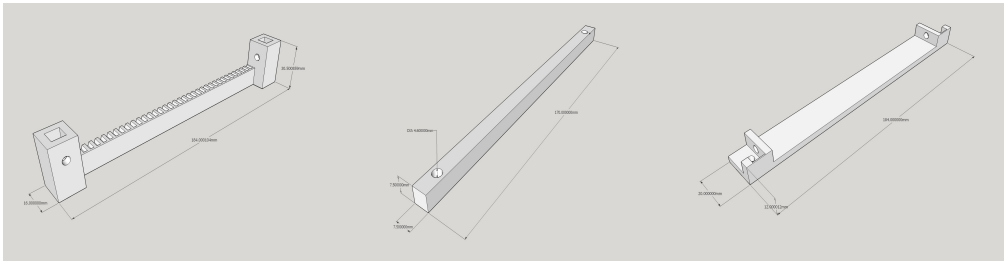


Illustration 7: Y-Rack (Left & Right) *Illustration 8: Front Legs* *Illustration 9: Bases (Front, Left & Right)*

1. Insert a Leg into the front side of Y-Rail-left (The rack/gear will always be at the farthest from center)
2. Insert a Leg into the front side of Y-Rail-Right
3. Insert the Back of both Y-Rail-Left & Y-Rail-Right into the Top Legs of the Backside Panel.
4. The Model should be standing now; Bolt the Bases (Front, Left & Right) onto the bottom of the legs.

3.3 X-Rail / Gantry Frame

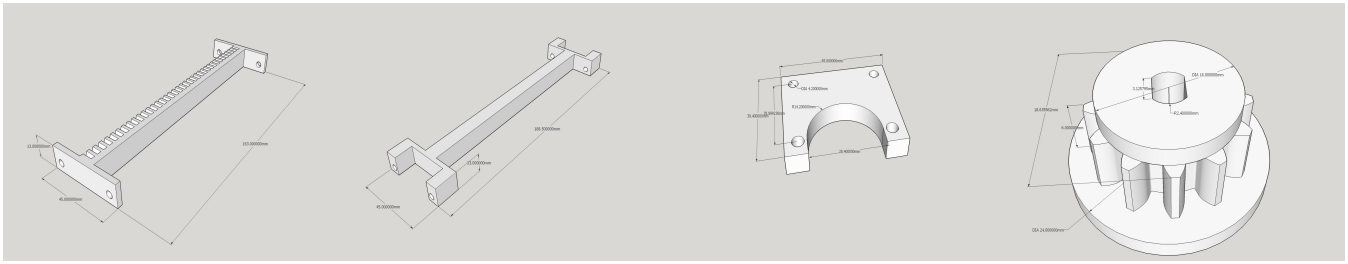
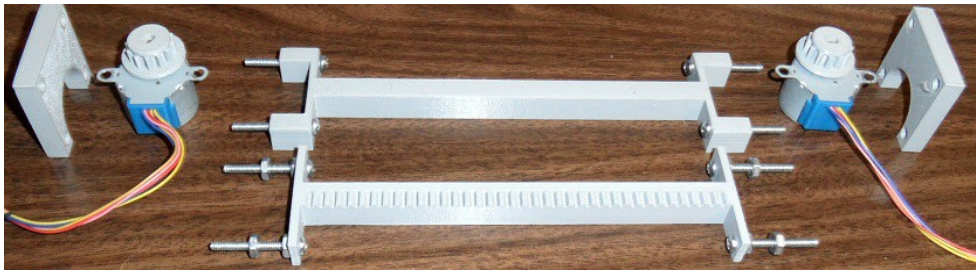


Illustration 10: X-Rack *Illustration 11: X-Guide* *Illustration 12: Y-Motor Mounts* *Illustration 13: Motor Gear*

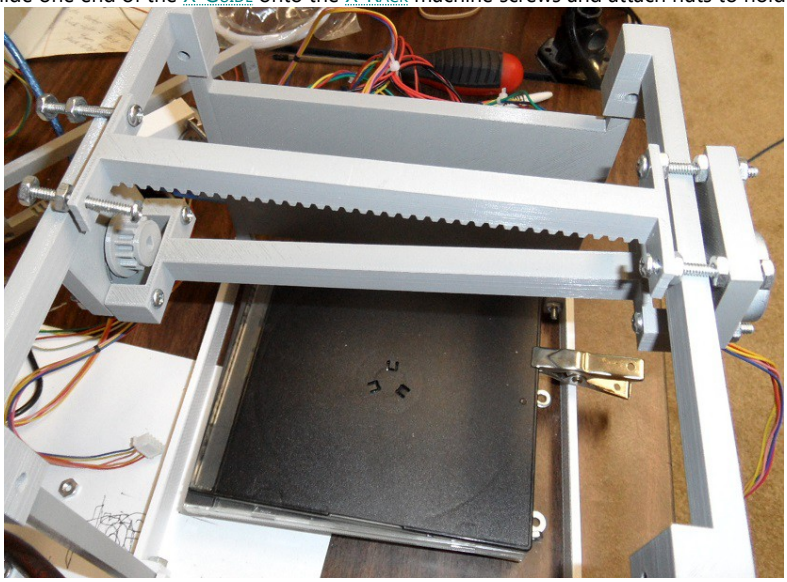
1. 3D Print the following files
   a) X-RACK.STL
   b) X-GUIDE.STL
   c) (2) Y-MOTORMOUNT.STL
   d) (2) MOTORGEAR.STL

2. Prepare the X-RACK and X-GUIDE
   a) Attach a MOTOR-GEAR to each of (2) 28BYJ-48 Stepper Motors (*Tap lightly with small hammer if needed*)
   b) Place (4) 1-1/4" long Machine screws through the four holes in the X-RACK; threaded ends pointing outward.
   c) Place (4) 1-1/4" long Machine screws through the four holes in the X-GUIDE; threaded ends pointing outward.
   d) Put on (8) Machine screws nuts on the X-RACK machine screws – but no need to tighten them just yet.
   e) Roll on (4) more Machine screws to the X-RACK screws leaving them ~ 7 to 8mm from the tightened nuts

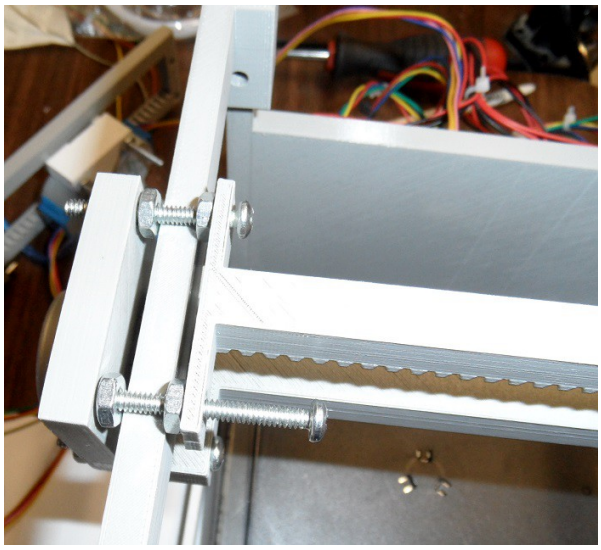


3. Bolt motors to the X-GUIDE using Y-MOTOR-MOUNTS.
   a) Position the X-GUIDE; Fat Side of Bolt hole with Wire side of Stepper Motors
   b) Run machine screw through the metal casings motor bolt holes
   c) Then slide the Y-MOTOR-MOUNTS onto both ends of the machine screws
   d) Attach nuts and tighten fairly snug (*Will need to adjust them later on*)

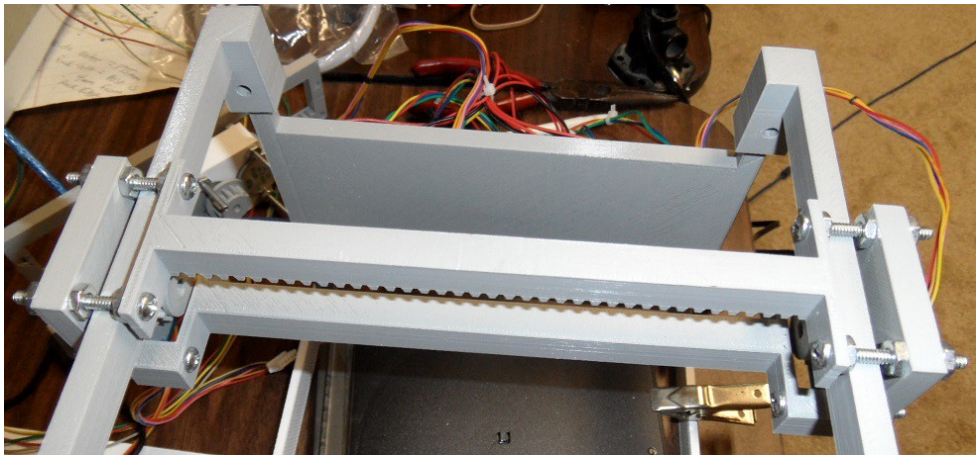
4. Place the X-RACK on top of the Y-RACKS and attach the X-GUIDE with attached Motors
   a) Position the X-RACK so the Gearing end faces forward and down.
   b) Slide one end of the X-GUIDE onto the X-RACK machine screws and attach nuts to hold it.



5. Lift the X-GUIDE and Thread the X-RACK machine Screws through the Y-MOTOR-MOUNT on the other end.



6. Attach nuts – Final assembly should look like the picture.



3.4 X & Z-Rail / Tool-head

Note: The Z-Rail has been changed to fit on the other side of the machine XZ Motor Mount screws (It'll be apparent when assembling) so pictures of the Z-Rail won't be quit correct.

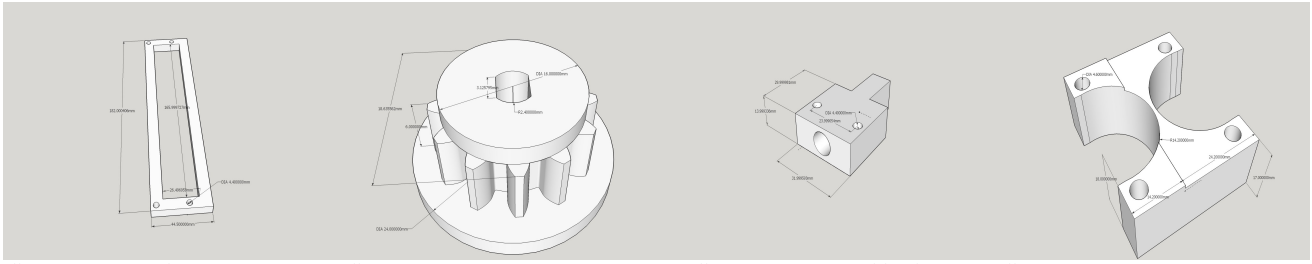
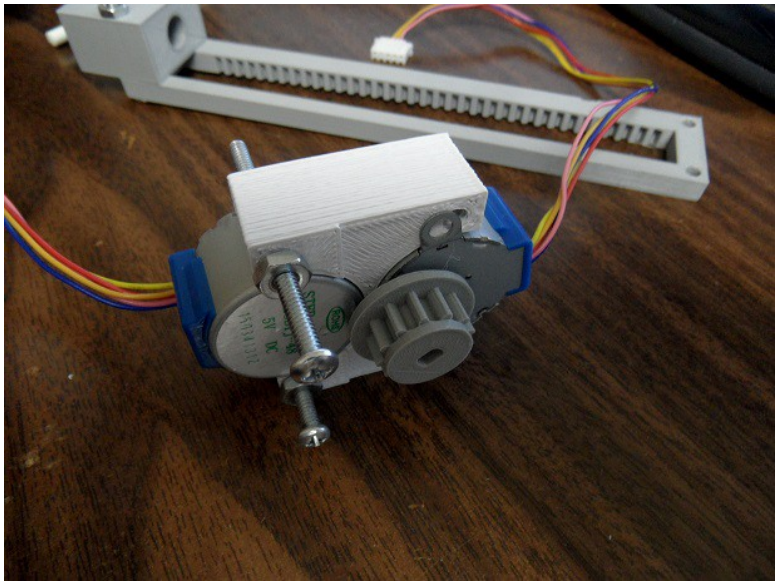
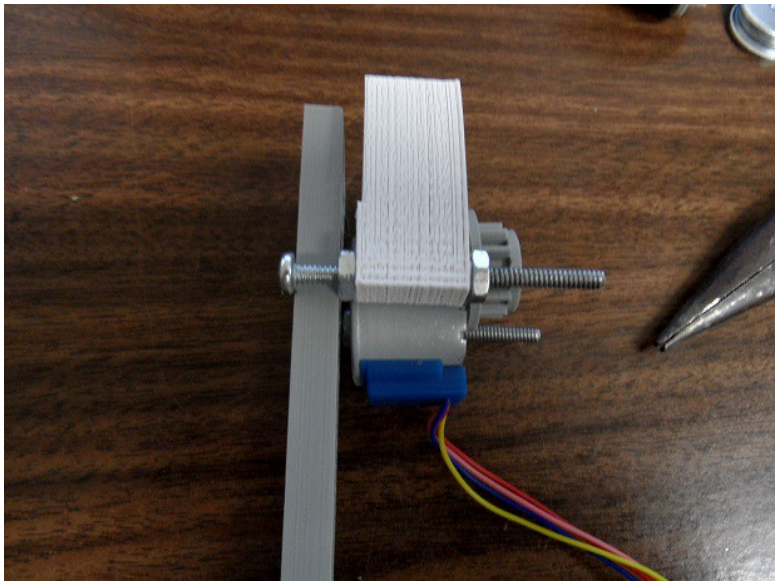


Illustration 14: Z-Rail *Illustration 15: Motor Gear* *Illustration 16: Pen Tool-head* *Illustration 17: X & Z Motor Mounts*

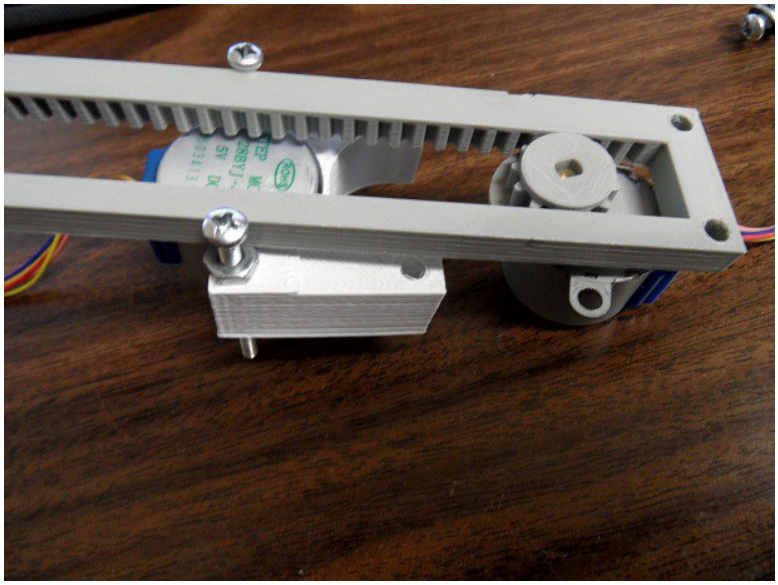
1. Install Motors into XZ-Motor-Tie
   a) Attach a Motor-Gear to each of (2) 28BYJ-48 Stepper Motors (*Tap lightly with small hammer if needed*)
   b) Place the two motors inside XZ-Motor-Tie Block and insert a 2" long machine screw with nut through the holes as shown.



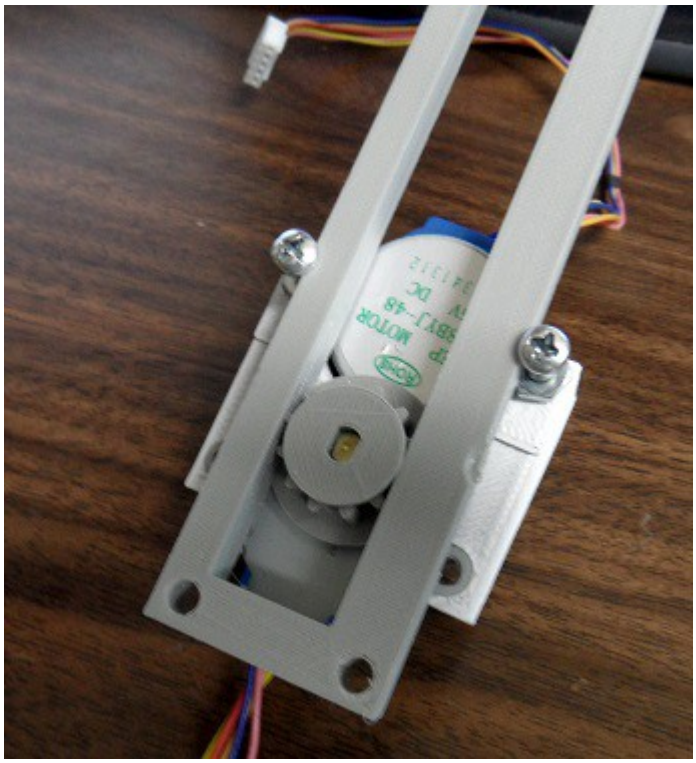
2. Using the Z-Rack for spacing – Tighten the two Machine Screws to the XZ-Motor-Tie Block as shown



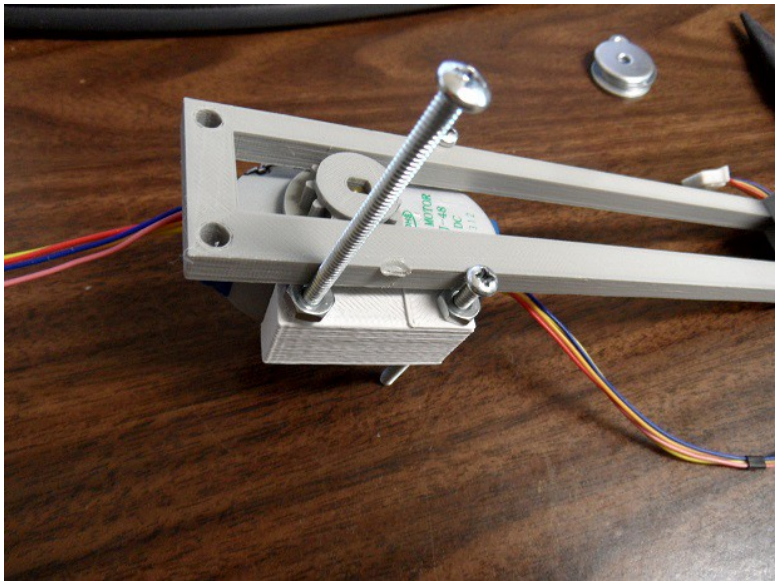
3. Slide the Z-RACK forward and insert the second 28BYJ stepper motor into the Z-RACK gearing as shown.



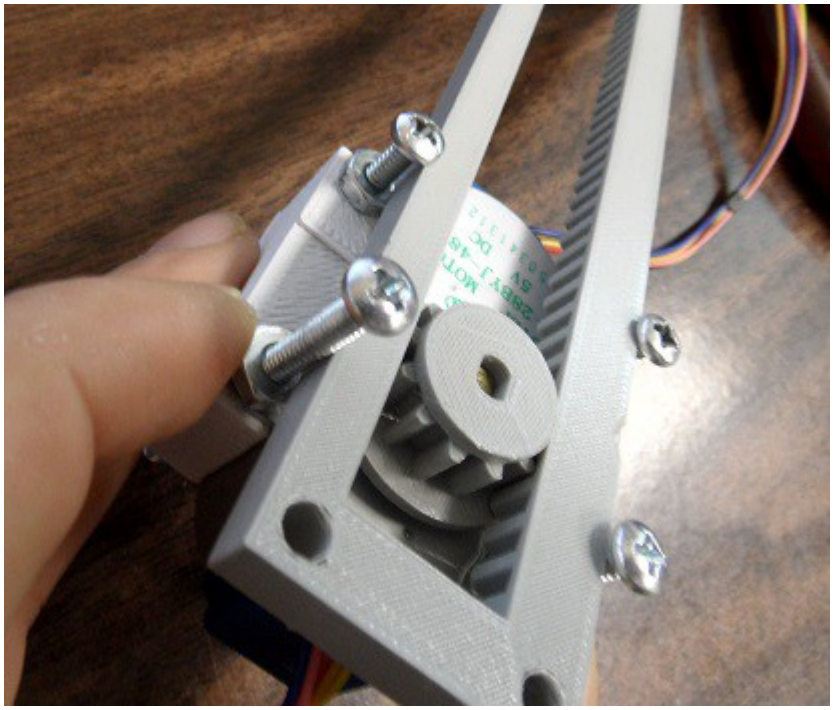
4. Slide the Z-RACK down until the inserted motor slides into place with its motor mount holes



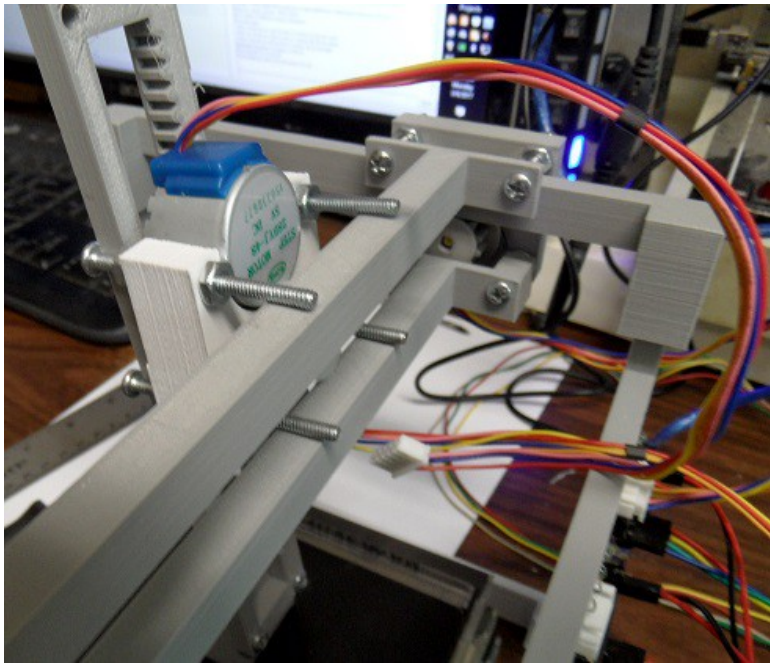
5. Obtain (2) more 2" machine screws. Start a nut on the very end of each.



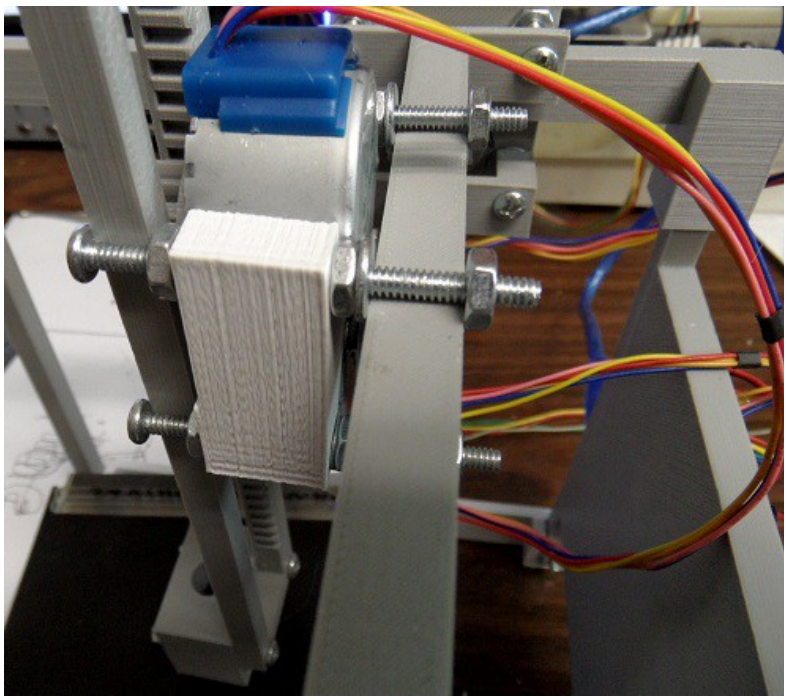
6. Using a finger to hold the end-nut from turning; twist the screw down into the XZ-MotorTie Hole. Once set into proper alignment with the Z-Rack put (2) more nuts on the back side and tighten these (2) machine screws to the XZ-MotorTie block.



7. The XZ-MotorTie assembly (i.e. center carriage) is now ready to be mounted to the X-Rack as shown.



8. Use (2) flat washer on the top bolts to keep the carriage aligned with the X-Rack/Guide. Then use nuts to lock the carriage to the X-Rack. Keep the screws fairly loose to allow motor to move across the X-Rail.
   a) Now adjust the X-Guide bolts on both ends to make a snug fit against the lower machine screws.



4. SOFTWARE / FIRMWARE

4.1 Firmware Upload

1. Install Arduino Sketch IDE https://www.arduino.cc/en/Main/Software

2. Install the modified GRB-28BYJ-48 Firmware
   a) In a web-browser; go to https://github.com/tgit23/GRBL-28byj-48
   b) Click on the file GRBL.ZIP
   c) Click on the DOWNLOAD button on the lower-right next to "History" and Save to a place you'll remember – like Documents or Desktop
   d) Run the Arduino Sketch IDE
   e) Choose Menu Item SKETCH → INCLUDE LIBRARY → ADD .ZIP LIBRARY
   f) Select the GRBL.ZIP Library file saved in step 'c' above

3. Upload the Firmware
   a) Inside any running Arduino Sketch IDE
   b) Choose FILE → EXAMPLES → GRBL → GRBLUPLOAD
   c) Select the Port the Arduino UNO is connected to; in Sketch menu TOOLS → PORT
   d) Select the Board; Sketch menu TOOLS → BOARD → ARDUINO/GENUINO UNO
   e) Press the Up-Arrow in the Top-Left Corner to upload the firmware onto the Arduino UNO board

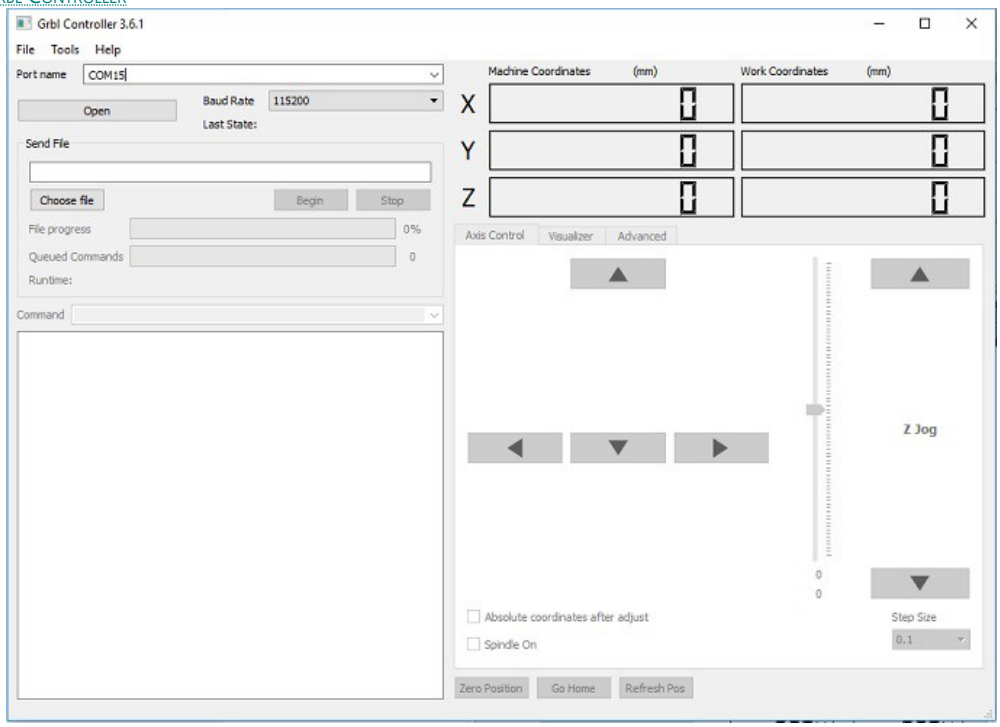
4. Now the unit is ready for operation.

- ✔ More Information
  - GRBL Wiki @ https://github.com/gnea/grbl/wiki
  -

4.2 Controller Install / Initial Settings

1. Download and install GRBL CONTROLLER located @ http://zapmaker.org/projects/grbl-controller-3-0/

2. Run GRBL CONTROLLER



3. Pick the Port on which the Arduino UNO is connected and click 'Open'

4. Enter GRBL Settings for the Machine (**First Time Only**)

a) $0=3 ; Step pulse, microseconds
b) $1=1 ; Step idle delay, microseconds (shuts off motors)

c) $100=100 ; X steps/mm
d) $101=100 ; Y steps/mm
e) $102=100 ; Z steps/mm

f) $110=550 ; Max rate X, mm/min
g) $111=550 ; Max rate Y, mm/min
h) $112=550 ; Max rate Z, mm/min

i) $120=100 ; X Acceleration, mm/sec^2
j) $121=100 ; Y Acceleration, mm/sec^2
k) $122=100 ; Z Acceleration, mm/sec^2

GRBL will store these values in the Arduino UNO EEPROM thus retain them during during power off and uploads.

5.
6. On the right pick 'Step Size' 10 and then 'Up-Arrow' on Z-Jog. The Z-Axis on the machine should move up.
7. Pick a file from https://github.com/tgit23/RPieces-TableTopXYZ/tree/master/nc-examples and download it.
8. Click on 'Choose File' select the (nc) file and click begin to run the design on the machine.

✔ In 3d printer terms the GUI Controller example would be 'pronterface'.

4.3 Running a design file

1. Run GRBL CONTROLLER

2. Pick the Port on which the Arduino UNO (Machine) is connected and click 'Open'

3. On Tab 'Axis Control' select 'Step Size' 10 and then click the up-arrow on Z-Jog.

4. Using the 'Axis Control' to operate the machine motion; position the 'head' at a point that will be represented as coordinate 0,0

5. Click 'Zero Position'

6. Under 'Send File' click 'Choose File' and select the design file (.nc) to run
   a) Example files can be gotten @ https://github.com/tgit23/RPieces-TableTopXYZ/tree/master/nc-examples

7. Click 'Begin' to start executing.

4.4 Design Software

Design Software for GRBL often includes the G-Code generator (In 3d printer terms – slic3r).

- ✔ Common free GRBL design software (the signifying difference being CAM or CAD)
  - FreeMill w/ VisualCAM (also free)
  - SketchUCam plug-in for Google Sketchup
  - pyCam
- ✔ Milling or drilling PCB
  - KiCad
  - FlatCAM

5. TOOL-HEADS

5.1 Pilot-Razor-Point-Pen

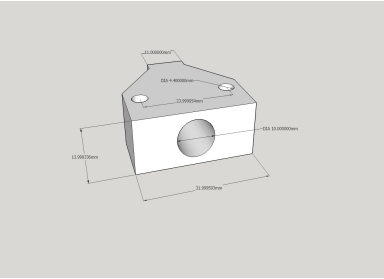


Illustration 18: ToolHead-PilotRazorPointPen.STL

- ✔ Example of the Pen @ http://www.staples.com/Pilot-Razor-Point-Pens/product_SS110064
- ✔ Mounting Hardware Required
  - (2) #6-32 x 1-1/4" (or Longer) Machine Screws
  - (2) Hex Nuts

5.2 Mini-Drill

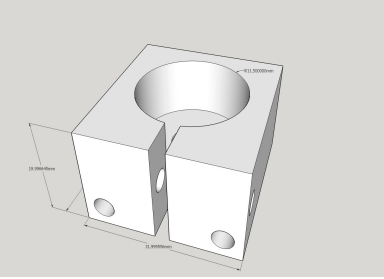


Illustration 19: ToolHead-PilotRazorPointPen.STL

- ✔ Example of Mini-Drill @ https://www.amazon.com/Lemonbest-Micro-Electric-Drill-1-5mm/dp/B01301L2L6/ref=pd_sim_60_3
  - Full Description Line — Mini DIY Micro Electric Hand Drill for PCB 0.7 to 1.5mm Craft Drill Chuck Tools with US Plug
  - Item Weight — 2.7 ounces
  - Product Dimensions — 5.1 x 1 x 1 inches
  - Wattage — 18 watts

- ✔ Mounting Hardware Required
  - ○ (3) #6-32 x 1-1/2" (or Longer) Machine Screws
  - ○ (3) #6 Hex Nuts