ShopBot Shop Stools for the Family

Everyone needs an extra stool for the shop or house. When made with ¾" plywood, these stools are sturdy and stable.

You can also make them in ½" ply, which makes them a bit lighter to tote around, but not quite as sturdy.

 The project includes 3 sizes: 28" tall, 15" tall, and, for the littlest tykes, 12" tall (not shown.)

28" tall Shop Stool has 4 parts:

- "legs" with the bottom slot and the ShopBot logo
- "legs" with the top slot
- a support piece/foot rest that slides over the assembled legs
- a seat with pockets in the underside for the legs to fit into and a handhold for moving the stool easily

The 15" inch and 12" small Shop Stools have three parts:

- "legs" with the bottom slot
- "legs" with top slot
- a seat with pockets in the underside for the legs to fit into and a handhold for easy transport

DISCLAIMER:
All CNC machines are potentially dangerous and because ShopBot Tools, Inc has no control over how the project described in this manual might be used, ShopBot Tools, Inc. cannot accept responsibility for any loss or damage to the work piece, machine or any individual, howsoever caused. Extreme care should always be taken and the output from the software thoroughly checked before sending it to a CNC machine. The information in this document may be subject to change without any prior notice.

What Zip file(s) should I download?

It depends: Do you want to put your material down on the table and start cutting, or do you want to play with the PartWorks CAD/CAM files themselves.

For those who just want to slap down their material and start cutting:

### Zip file for "Buddy Sized Material" that measures 24" x 48" or 24" x 32":

The "Load and Go" files have been generated for three quarter inch material only. In each folder, ShopBot Parts (.sbp) files have been generated for each file so you can run the .sbp files in the order suggested. The files have been written for a .25" bit, with a 60V bit for V-carving lettering.

When there is a bit change, the size and type of bit is included in the name of the .sbp file. If no bit is specified in the file name, then use the .25" bit. Zero the Z at the top of the material, the X and Y at the lower left corner of the material. Suggested spindle speed is 12000 RPM for the Move Speeds of 4 and 1 ips. Cut depth is set for .77 inches so that the material will be cut through and cut into the table surface a minimum amount. Check the true thickness of your material to avoid cutting too deeply into the surface. *(Note: you can use the ShopBot software to avoid cutting too deeply without rewriting the toolpaths in the PartWorks CAD/CAM file. Measure the material and add 0.02". Then divide that number by the depth of the toolpath. [Example: (0.678 + 0.02) / .77 = 0.88] For the part files that cut through the material, at the FP START page, change the proportion of the Z to reflect that number (.88). Do not change the Z proportion for files that do not cut all the way through, such as the pockets in the seat bottom or V-carving. See below for more suggestions on working with materials that vary in thickness)*

The PartWorks (.crv) file with tool paths is included in the folder so you can make changes as necessary or take a moment to see how the files were laid out and toolpathed. There are many ways to do things, so feel free to change files as you become more comfortable with the software and the ShopBot. There are other suggestions on how to compensate for different thicknesses of plywood below.
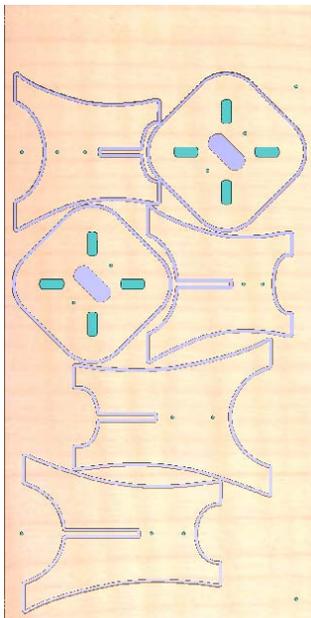
24" x 48" material
15" and 12" tall stools
.25" bit
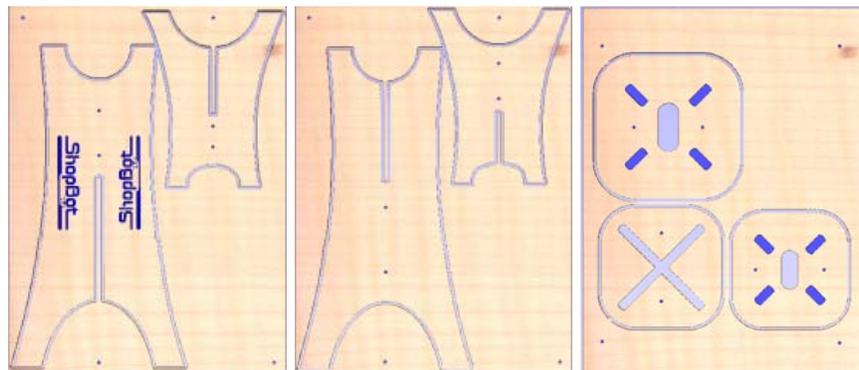
24" x 32" material
28" and 15" stool requires 3 sheets of stock
Cutting files and PartWorks file for .75" stock only
Requires .25 bit and 60 degree V bit for cutting logo
Remember to Zero the Z at the surface of the material
every time you change bits

Zip file for a full sheet of 96"x48":

Four stools (Two 28" tall stools and one each 12" and 15" stools) are laid out on a full sheet of plywood, with room to spare.

The "Load and Go" files have been generated for three quarter inch material only. In each folder, ShopBot Parts (.sbp) files have been generated for each file so you can run the .sbp files in the order suggested. The files have been written for a .25" bit. No V-carving has been included with these files. While it is not very efficient, the .sbp files each do a specific thing so that you can get used to starting and using .sbp files.

Zero the Z at the top of the material, the X and Y at the lower left corner of the material. Suggested spindle speed is 12000 RPM for the Move Speeds of 4 and 1 ips. For the toolpaths that cut throught the material, cut depth is set for .77 inches so that the material will be cut through and cut into the table surface a minimum amount. Check the true thickness of your material to avoid cutting too deeply into the surface. *(Note: you can use the ShopBot software to avoid cutting too deeply without rewriting the toolpaths in the PartWorks CAD/CAM file. Measure the material and add 0.02". Then divide that number by the depth of the toolpath. [Example: (0.678 + 0.02) / .77 = 0.88] For the part files that cut through the material, at the start page, change the proportion of the Z to reflect that number (.88). Do not change the Z proportion for files that do not cut all the way through the material, such as pocketing under the seat. See below for more suggestions on working with materials that vary in thickness)*

The PartWorks (.crv) file with tool paths is included in the folder so you can make changes as necessary or take a moment to see how the files were laid out and toolpathed. You can customize the Shop Stools by adding a name or logo, and V-carve it with whatever V-bit you have. Delete the smallest stool in the top row and copy and paste to add a third tall stool, or add some more small stools. Just remember that, if you change the layout, you must retoolpath and generate new ShopBot part (.sbp) files. You can put more that one toolpath into a single .sbp file as long as they use the same bit, it makes sense, and the toolpaths are listed in the correct order. There are many ways to do things, so change the files as you become more comfortable with the software and the ShopBot. And, if you get totally lost, you can always download the original file again.
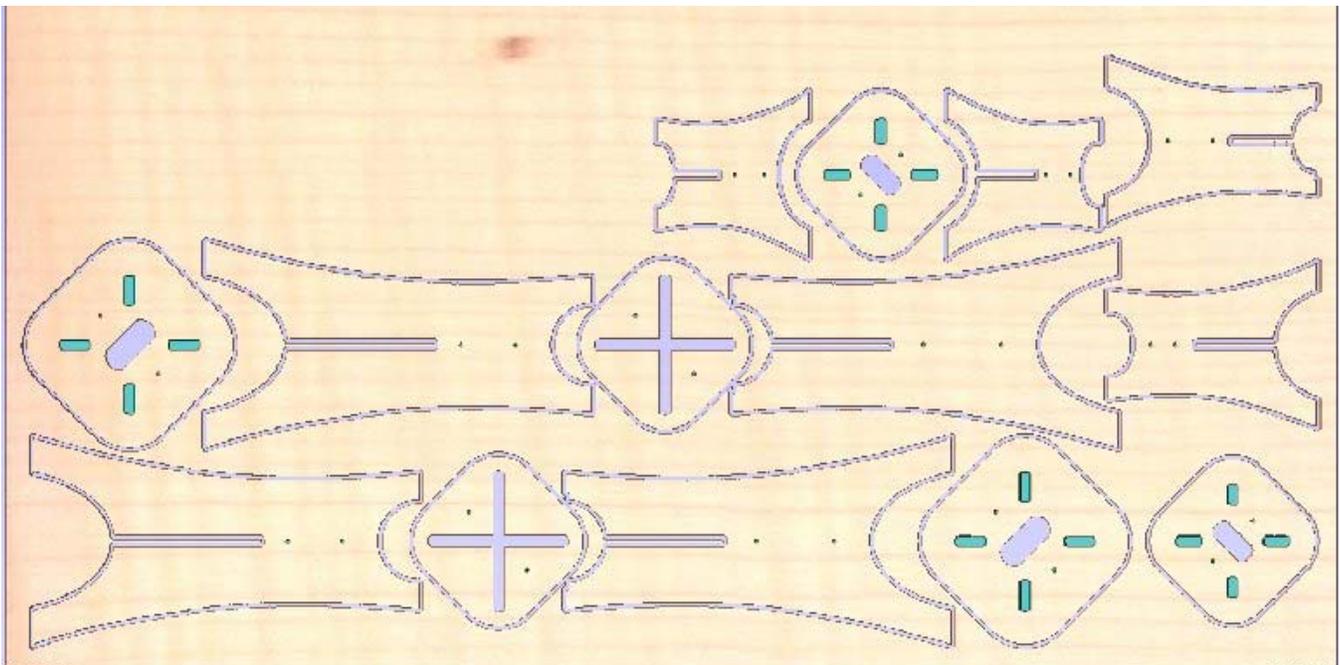
For those who want to play with the PartWorks CAD/CAM files:

Zip File: Master PartWorks files. All the parts for the stools are laid out on a sheet of 96" x 48" material. There is a Master file for .75" material (slots .78" wide), and one for .5" material (slots .53" wide). No tool paths are included the Master files.
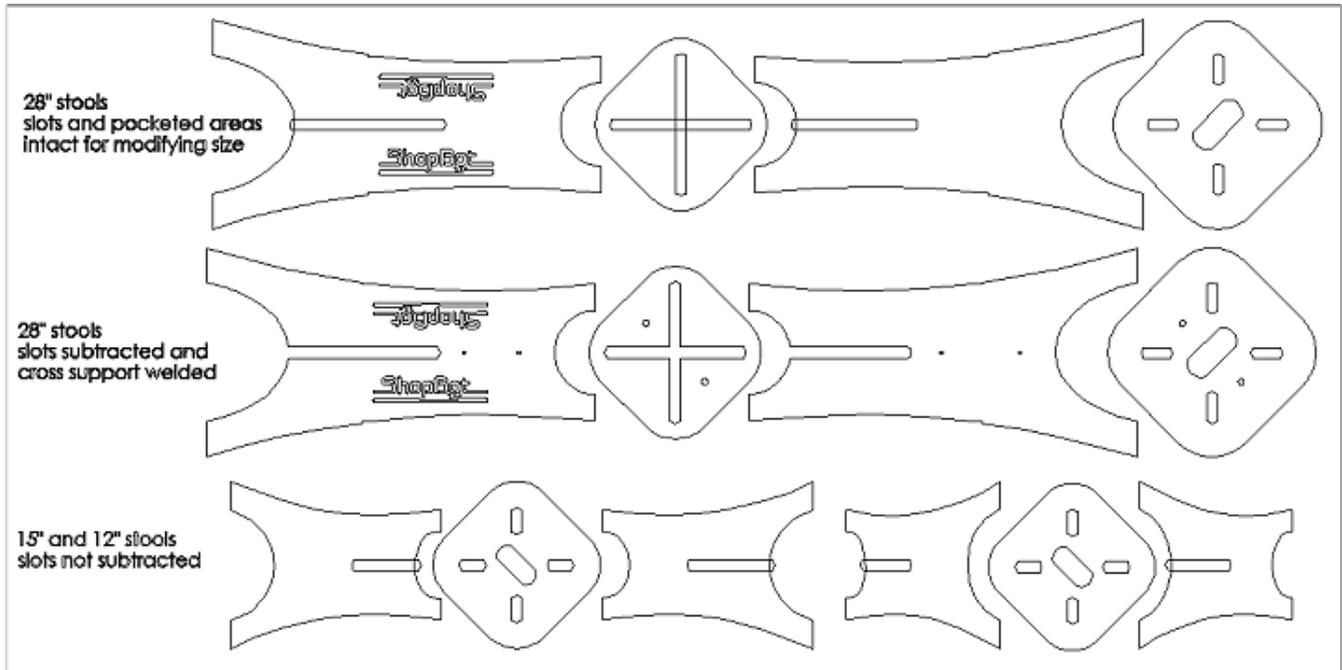
Explanation of the Master File:

28" tall stool:
     The top row has the slots lined up to make quick changes in the slot width so you can compensate for different material thicknesses. Suggestions on how to use the **Scale Selected Vectors** tool to change the slot size in the Techniques and Tips section below.

After the slot size was set up, the parts were copied into the middle row. Then, the **Subtract Vectors** and **Weld Vectors** tools (see Techniques and Tips) were used to create parts that are more efficient to cut out. Circles were added to the parts to indicate where it would be safe to put a hold down screw.

15" and 12" stools were left with the slots intact to make it easy to make changes

To use: Make a copy of the Master File (**Save As** with the name of your choice), and make any changes in the new version of the PartWorks file so that you always have the original Master file if you get lost in making your changes.

Possible Changes to the CAD drawings:
- Change the width of the slots to reflect differences in material thickness, or allow for painting the shop stools
- Change the height or width of the shop stools
- Customize the shop stools with a different name or logo
- Change the layout to reflect the material size and shape

After you have made the changes to the shop stool parts:

- **Copy** the altered parts
- Open a New PartWorks file and edit the **Job Size and Position** to reflect your material
- **Paste** the altered parts into the new PW file
- Lay out the parts the way you want
- Toolpath the parts. Suggestions for the types of toolpaths you can create are found below. Examples of toolpaths to create are found in the Zip files for those who just want to slap down their material and start cutting.
- Generate the ShopBot Parts (.sbp) files for the ShopBot Control software to cut out the parts (**Save Toolpaths**). Remember that any toolpath that uses the same bit can be put into a single .sbp file…just make sure it makes sense (example: the HD files need to be run first and separately) and the toolpaths are listed in the correct order (pocket slots before cutting out the part)
- Remember to **Save** the PartWorks (.crv) file in case you need to make changes to the .sbp

Notes on creating toolpaths:

1) While it is clearly necessary to **pocket** out the areas under the seat for the legs to fit into, one could choose to **profile along the inside** of the vectors for the slots for the supports and the handhold instead of pocketing them. It does take a bit longer to pocket out the waste material, but it also is safer. The "waste" is turned into sawdust (chips) and vacuumed up rather than becoming loose projectiles that can fly across the room or clunk into the dust collection system.

2) We spend some time making the slot in the legs part of the overall piece, but one could choose to keep the slot separate from the legs and create two toolpaths for each leg: one to the inside for the slot, and one as a profile to the outside for the legs. Since they use the same bit, one could put the slot toolpath and the cut out toolpath into the same .sbp file…just make sure you have listed the toolpaths in the correct order so that the slots get machined before the parts get cut out.

3) When it comes to the slots for the cross supports, one MUST weld them into a single piece in order to have them cut out properly. Try it on screen (or see below) to see what happens if you don't either weld the overlapping vectors or toolpath them separately.

4) Cut depths:

    a. Pockets under the seat for the legs to fit into : 0.25" -0.27"

    b. Toolpaths that cut through the material: add 0.02" to the real thickness of the material to get a clean cut through and not scar the table (You must create a new toolpath and a new .sbp file for each change in thickness of plywood.)

    c. *Advanced strategy for <u>cutting through</u> sheets of material without having to create a new toolpath for every change in thickness of material. (Put pockets to a specific depth into a separate .sbp file.)*

        i. *Make your cut depth for cutting through the material 1.0"*

        ii. *Go into the .sbp file and add two lines to the code somewhere near the beginning to remind yourself of your cleverness. Before the line* 'Turning router on *is a good place*

            1. 'Did you set the Z proportion to the correct depth?

            2. Pause

        iii. *Measure the thickness of the board on the table and add 0.02"*

        iv. *Zero the Z at the top of the material*

        v. *When running the ShopBot file, at the Start screen, change the proportion of **Z** to reflect the measurement in step iii*

        vi. *Smile when you see the reminder that you remembered to do step v. Otherwise, quit the file and restart*

General Information:

Where to Zero the Z: These files are created with the Z Zeroed at the TOP of the material. That way, the depths of all the pockets for the legs and the V-Carving will be correct. However, it may create an issue if your material is not really .5" or .75" inches thick. Thinner, and you will scar the ShopBot table and your slots may be a bit loose. Thicker, and you will not cut all the way through and you will have to do a bit of sanding to make your slots fit. Measure the true thickness of your material before you start. Ways to work around these issues and re-do toolpaths are discussed above.

Hold Down of the material and parts is critical for efficient and safe CNC work. Therefore, each file should include circles to indicate where it is safe to put a hold down screw into the material. If you do not have an effective vacuum hold down system, the first file that you should run is the HD or Hold Down file. The HD file will create dimples in the material where it is safe to place a screw. After you run the HD file, turn off the router/spindle, move it out of the way, and screw a brass or sheetrock screw through the material and into the sacrificial board. For the best results, back the screw out and screw back in to make sure the material is flat against the ShopBot table surface. Re-zero the Z after you have attached the material to the table. If you have a vacuum hold down system that you trust, you can skip the HD file. Don't forget to Zero the Z at the surface of the material AFTER you turn on the vacuum hold down.

To Tab, or Not to Tab: In the files generated for Buddy-sized material (24" x 32" or 24" x 48"), the hold downs were put in each part, so no tabs are necessary. There are a couple of extra hold downs points in the corner of the material so that the waste stays in place.

In the files for 96"x48" sheets with 4 step stools, putting two hold down screws in place for each part is a lot of screws. So, the hold downs were put in the waste area of the material, and the tabs were added to the parts to keep them attached to the substrate. Then, a final toolpath was added to go back and cut out the tabs.

Bits: The files were written for a ¼" bit and, where V-Carving, the 60 degree V-bit included in the ShopBot starter bit kit. While any ¼" bit will do, I suggest a down spiral bit (example: Onsrud 57-910) because it will help with hold down by pushing the material down as it cuts. An added benefit is that the top surface of the material will be clean (no ragged edges). A straight bit will leave both the top and bottom surfaces fairly clean, but a single-flute straight bit is most likely to leave ridges on the sides of the parts. An up spiral bit will pull up the material as it is cutting, and leave the top surface ragged (more sanding for you.) Of course, if that's the only bit you have, go with it. Just be sure that you have enough screws in place to hold down the material as you cut.

Material: Standard plywood. The nominal thickness for material is .75" or .5", but it is never really that thickness, even across the same piece of material. The actual thickness of the material is important for two reasons: the size of the slots AND whether you cut out the parts completely or scar your ShopBot table. That said, the files are set up for the nominal thickness of the material. You can have a bit of "slop" in the slots since you will be fastening the top to the legs with screws or glue.

   The PartWorks (.crv) files are set up for a standard 4' x 8' sheet of ply, either whole, or cut into 4 (24" x 48") or 6 pieces (24" x 32") pieces to fit on the smaller ShopBot Buddy. Where possible, the files are set up so that the grain of the plywood runs with the length of the legs of the step stools, but this is for visual effects, and is not relevant to the structure of the stools.

Other Tools:

- Calipers for measuring the true thickness of the material
- Drill for placing hold down screws
- Screws for holding down material/parts to ShopBot table
- Screws and/or glue for attaching shop stool seat to legs
- Sandpaper

Techniques and Tips

Using the **Scale Vectors** Tool

Use the Scale Vectors tool to change the width of the slots from the Master File
All the slots should be lined up in the Master File. It's always a good idea to check, though.
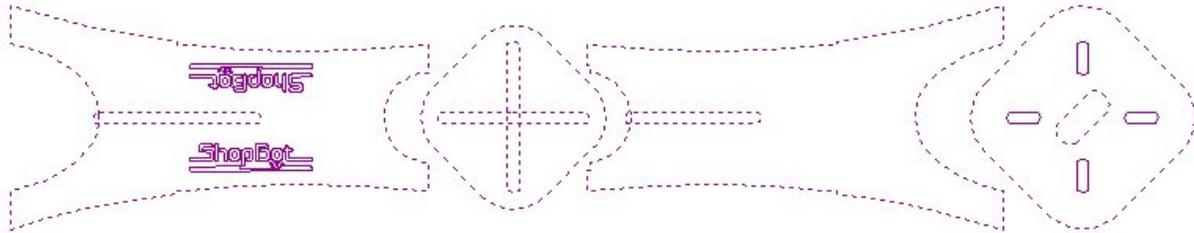
Select the slots and the horizontal slots for the support and the dadoes under the seat for the legs to fit into
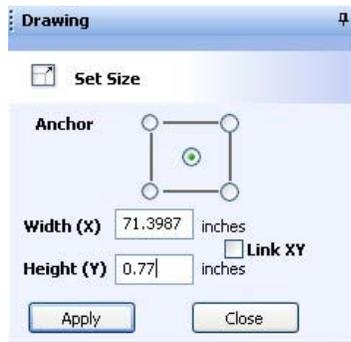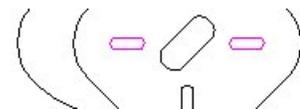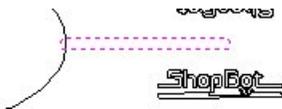
Open the Scale Vectors tool. Make sure that the **Anchor** point is set to the center of the object

Unlink the X and Y by unchecking the box. Change the height to the measurement you would like.

After you have hit **Apply,** select the vertical support slot and change its width before selecting the vertical dadoes and changing their width

Using the **Subtract Vectors** Tool

Use the Subtract Vectors tool to make the slots and the legs of the stool into one object

*Just as in arithmetic, the order of selection is important when subtracting vectors. Choose the legs (the larger object) first

*Hold down the Shift Key and select the slot (the smaller object) second. Click on the **Subtract Vectors** icon

*If you have selected the objects in the correct order, you should see the following results

*If this is what you see, **Undo** and reselect the objects in the correct order
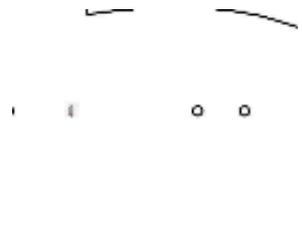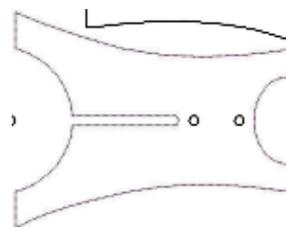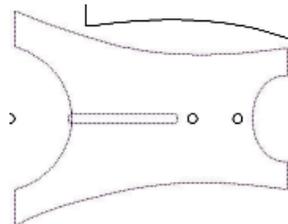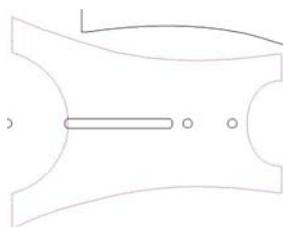
Using the **Weld Vectors** Tool

Use the Weld Vectors Tool to weld the slots for the support piece that slides over the legs
It is important to weld the two parts of the slots into a single piece so that it toolpaths correctly.
The order of selection is not important for the Weld Vectors Tool.

* Pocket toolpath before welding.	*Pocket toolpath after welding	*Select the two parts that you wish to weld together. Click on the **Weld** icon	*Objects welded successfully (only the outside vectors remain.)
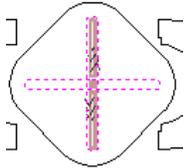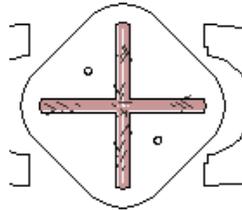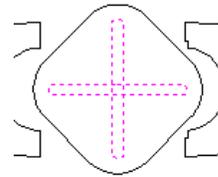
Two overlapping objects
selected, only one
toolpathed
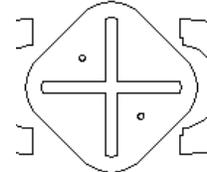
Some Design Nuances

Q. Why do all the slots have rounded ends?
A. Because a bit cannot get closer into the corner than its radius. So, one must either make
the slot longer by the diameter of the bit, or change the end shape to allow the bit to cut out an
area as long as is needed for the slot to fit.

Detail of Solid shows the actual amount of material removed. Notice that the
corners are not machined out.

| Techniques and Solutions	Toolpath	Simulation of machined part

Original drawing

No alteration
Corners not machined out
Slot functionally too short
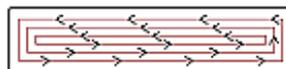
Add arcs to ends of slot
Bit fits sufficiently into corners
(In 'Node' Mode, put curser on end span
and press "A". Put cursor on center node
and use arrow keys to reduce size of arcs)
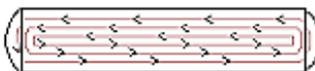
Use the Fillet Tool in PW
Regular fillets shorten the slot
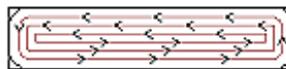
Use the Fillet Tool in PW
Dog-Bone fillets
Slot the correct length
"ears" at end

Use the Fillet Tool in PW
T-Bone fillets
Slot the correct length
"ears" on sides
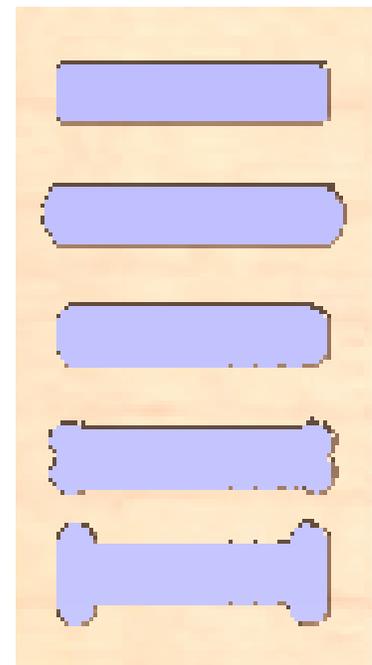
Assembling the ShopBot Shop Stool

Sand the parts of the stool. If you want to paint, stain or seal the parts of the stool, now is the time.

Lay out the parts for the stool. There are 4 parts for the Large Stool, and 3 parts for the Small Stools

Slide the two legs together

Slide the support/foot rest over the top of the legs
(Skip this step when assembling the smaller stools)

Fit the legs into the pocketed areas on the bottom side of the seat

Screw or glue the seat to the legs
If you only put two screws through the top of the seat into the legs, be sure to put the screws into the legs that come up from the bottom so that you don't pull the stool apart each time you lift it to move it.