

CNC Router Basics

Ace Makerspace Training for Certification



Introduction & Check-in

Ace Makerspace CNC Router Program Features and Etiquette

Ace Requirements to Operate CNC Router

- Ace membership or Guest Account
- Ace CNC Router certification
- Ace Shop Basics certification

- Personal Protective Gear

- Slack account
- Willingness to learn and share

Fees & Billing

- Ace members are expected to pay machine use fees. [See the Ace Store](#)
 - This is done on the honor system.
 - Folks go to the product on the Ace store to pay the fees.
- Ace membership and certifications are required to operate the CNC Router.
- Fees are:
 - 1 hour or less = \$6 (ie 2 hours would be \$12, and so on)
 - Half Day - 1-5 hours = \$25
 - Full day - 5 to 10 hours = \$50

**Excessive commercial use may result in a renegotiation of fees*

Slack and the CNC Program

Slack is a chat platform we use to:

- Call Dibs to reserve time on the CNC Router.
- Report Problems.
- Request Help and Contact the support team [@team-workshop](#).
- Share our projects.

The Slack channels for Ace CNC Router users are:

#workshop and #cnc-router.

Calling Dibs in Slack

Call Dibs in Slack channel **#workshop** to reserve time on the CNC Router.

Make sure to Pin Your Dibs!!!

Your post should:



- Start with the word “Dibs”
- Include the date, day of the week, and hours you will be using the router.
- State that use of CNC Router will claim 1 project space.

Check to make sure nobody has already called dibs on your time, and check the calendar to make sure there isn't a class then.

Transparency in action

- /Asset
- Down Signs
- Who to contact in an emergency

"Good records give us the data to have nice things... and prevents us driving tools into the ground like a 16 year old's first Honda."

AMT375 Status Logs (wiki)

Status

- Down. Bolts came in yesterday (11/7). We are waiting until @daveasharps back in town to work on it as he and @rob were the team who worked with FS to figure out the issue. [@crafty @ 11/08/2022 10:08 pm]
- down The spindle has been trammed to around 0.001" per inch of diameter, need to replace a couple bolts/nuts from the gantry though as they were stripped. Also x axis has some slop on it which needs to get fixed up, seems like it shouldnt be too crazy complicated to fix, but not easy to see [@daveasharps @ 11/03/2022 03:50 am]
- DOWN. Router is not square to the bed. Need to consult FS and get two dedicated people to correct. [@crafty @ 10/29/2022 02:23 am]
- up a couple quick parts for frank everything went super well Around

<https://wiki.acemakerspace.org/amt375/>

Certification

Certification is required without exception.

- You **must** be certified and a current member to use the CNC Router, or certified with a current member supervising.
- You **must** complete the entire Basics Certification Class in order to take the Knowledge Check.
- You **must** pass the Knowledge Check to qualify for certification.
 - You may take the test as many times as you need in order to pass.
 - The test will give you feedback even when you don't pass.
 - It is okay to use the notes, wiki, or the Slack #workshop community when taking the test. It is “open book” style.

Materials: What CAN be cut on our router?

- Wood, mdf, ply>cut all day!
- Plastics>turn off dust collection
- Foams>totally fine, but lots of cleanup
- Aluminum>need more training

NOT ALLOWED: Carbon fiber, anything glass filled

NOT ALLOWED: Steel (*While Ace CNC is capable of cutting steel, as a shared community tool, we want to protect the machine from mishap so we can all continue to use it.*)

Everything else, ask Team Workshop first
so we can make sure you and the machine are safe

How Materials Storage Works

Ace Storage Policy

Ace does not provide long term storage.

Everything must be tagged and tags get you **only 2 weeks of storage**. Learn more about the complete storage policy and exceptions on the wiki: wiki.acemakerspace.org/storage-at-ace/



How to not close the Shop with your trash

- Never leave your drops and off cuts. Your waste board must be packed out.
- If you want to donate your material you must get approval from Team Workshop.
- If too much trash builds up, the shop will be closed until Members clean it up.

Staff, Team Workshop, and Janitors will not clean this up for members.

Do NOT stash things under the CNC Router.

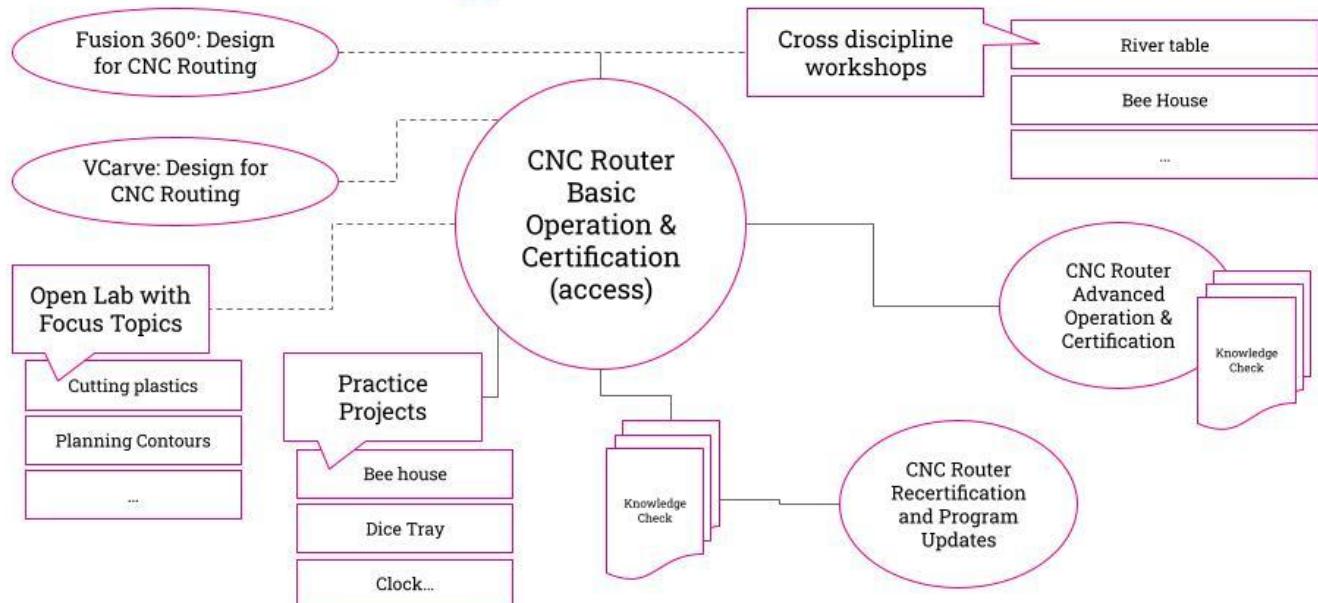
How certification class fits in Ace Program

This class is one of the steps towards gaining **access** to Ace's CNC Router.

This class provides a **basic overview** and an **introduction**.

For more in-depth education, Ace will have additional classes and projects and open labs.

CNC Router Program - Education Overview



Get to know Team Workshop!

Team Workshop is the team of Ace member volunteers who support the Ace Workshop, which includes Ace's CNC Router. [[@team-workshop](#) on Slack]

Get Involved!

- Engage with your fellow CNC Router enthusiasts on Slack channels: [#workshop](#) or [#cnc-router](#)
 - Post your project successes
 - Share any project fails
 - Ask Questions & Share Lessons Learned
- Write an article for Ace Wiki or post on the Ace Blog
- Sign up to be an Ace Buddy
- Volunteer to join Team Workshop

CNC Router Concepts

What is a Router?



Routing is a **Subtractive Process**, which means material is being carved away.

Routers use **spinning blades** to cut wood.

A router is essentially a motor that rotates spinning blades at a very high speed to perform cuts.

What is a CNC Router?

What is CNC? Computerized Numerical Control means automated control of machining tools.



You could think of a
CNC Router as a

**Robot-controlled
cutting tool**

What is possible on a CNC Router?

- 2D Cut Outs like signs
- Carving and inlays
- Prototyping
- Art, tools, furniture,
3D and more



(Source: IndustrialCNC)



(Source : Ace Maker @DampRabbit on Slack)



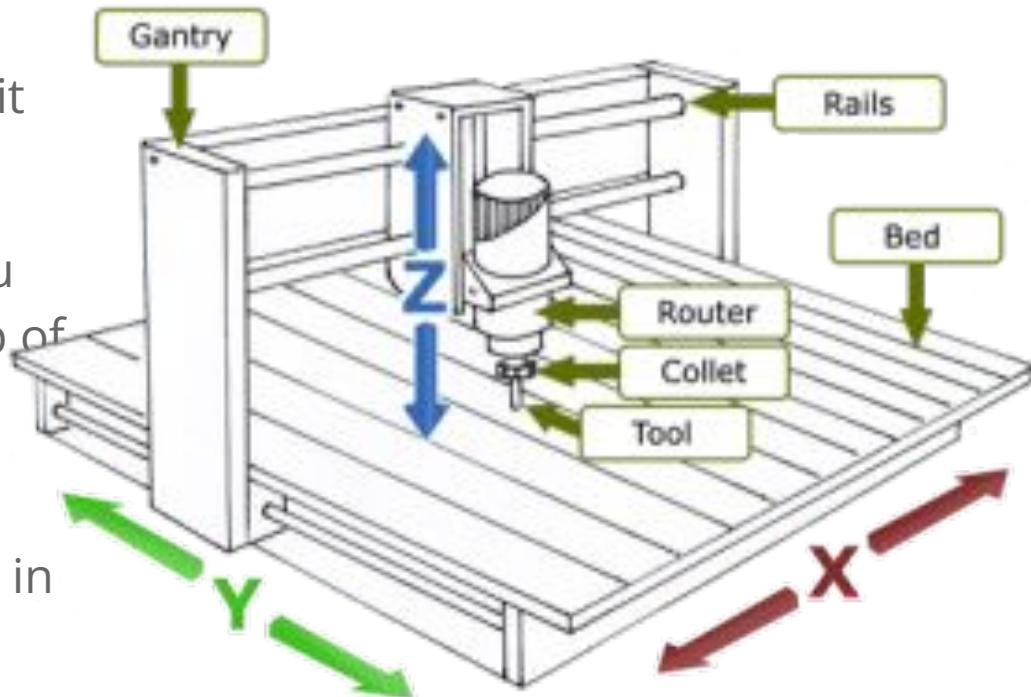
(Source: [LTDWoodworks via Instructables](#))

Get to Know the 3-axis CNC Router

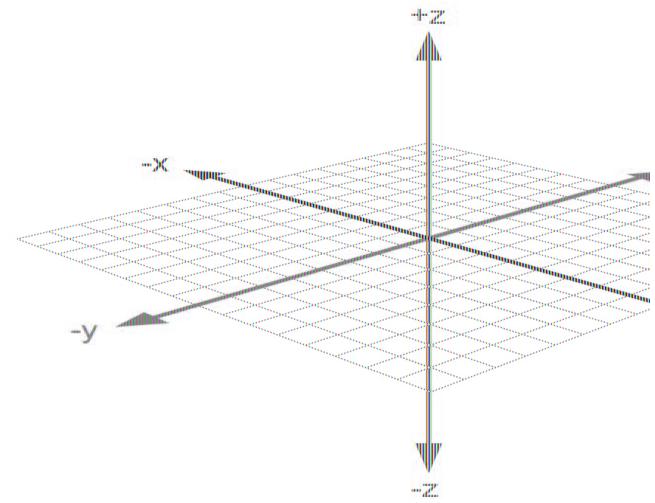
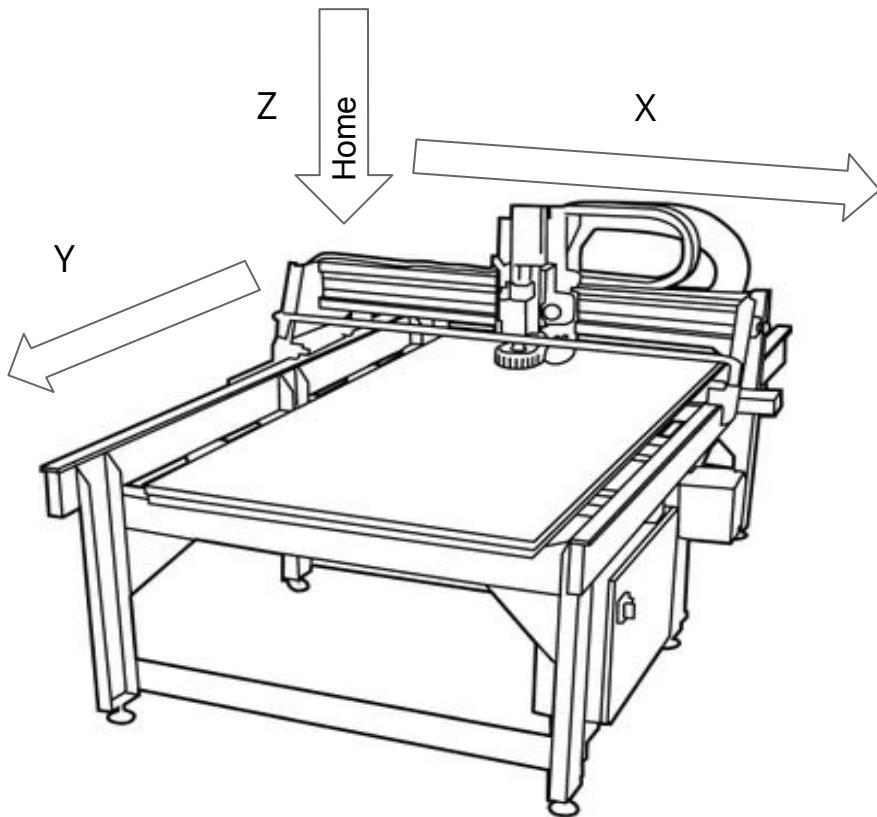
The **router** is mounted on the **gantry** so that motors can move it in a controlled manner.

The **bed** of the table is where you will clamp your **workpiece** on top of a **spoil board**.

The gantry motors in the CNC router will move the router head in 3 dimensions to cut your **workpiece** with its spinning blades.



How does Router Move? Axis Overview XYZ



- The Center Rail moves on the Y Axis
- The Router Head moves on the X Axis
- The Router moves up and down on the Z-Axis

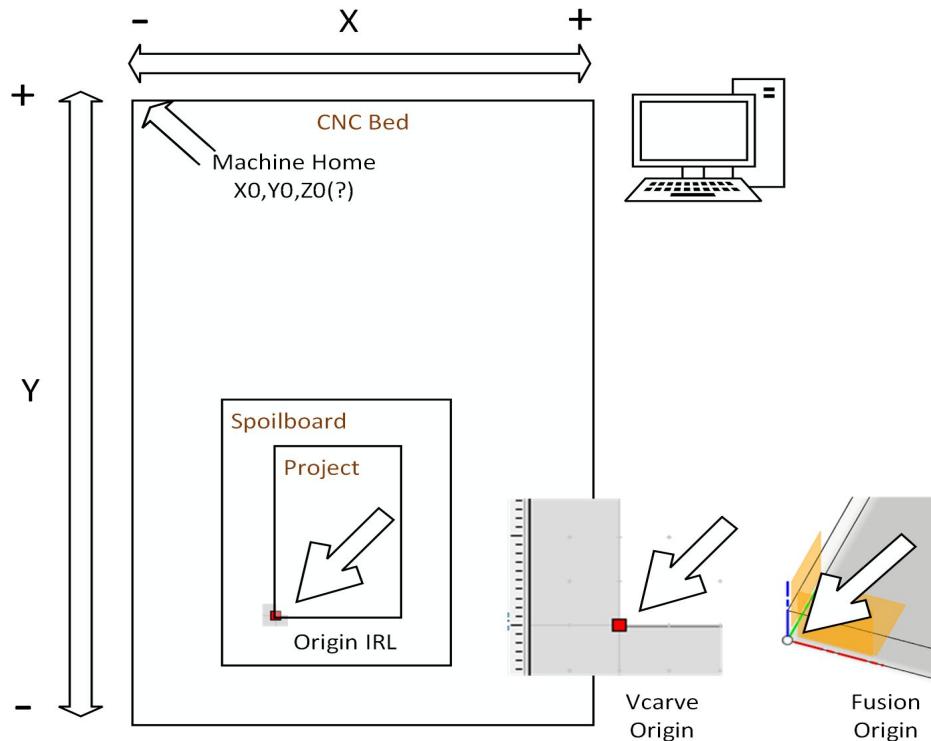
How does Router Move? Origins & Your File

Origins and how they relate to your file art

Machine coordinates are the X,Y,Z extents of the machine

Note: 3d model including work coordinate system on part, part on bed of
machine)

Design Origin X, Y,



What is **relative positioning**?

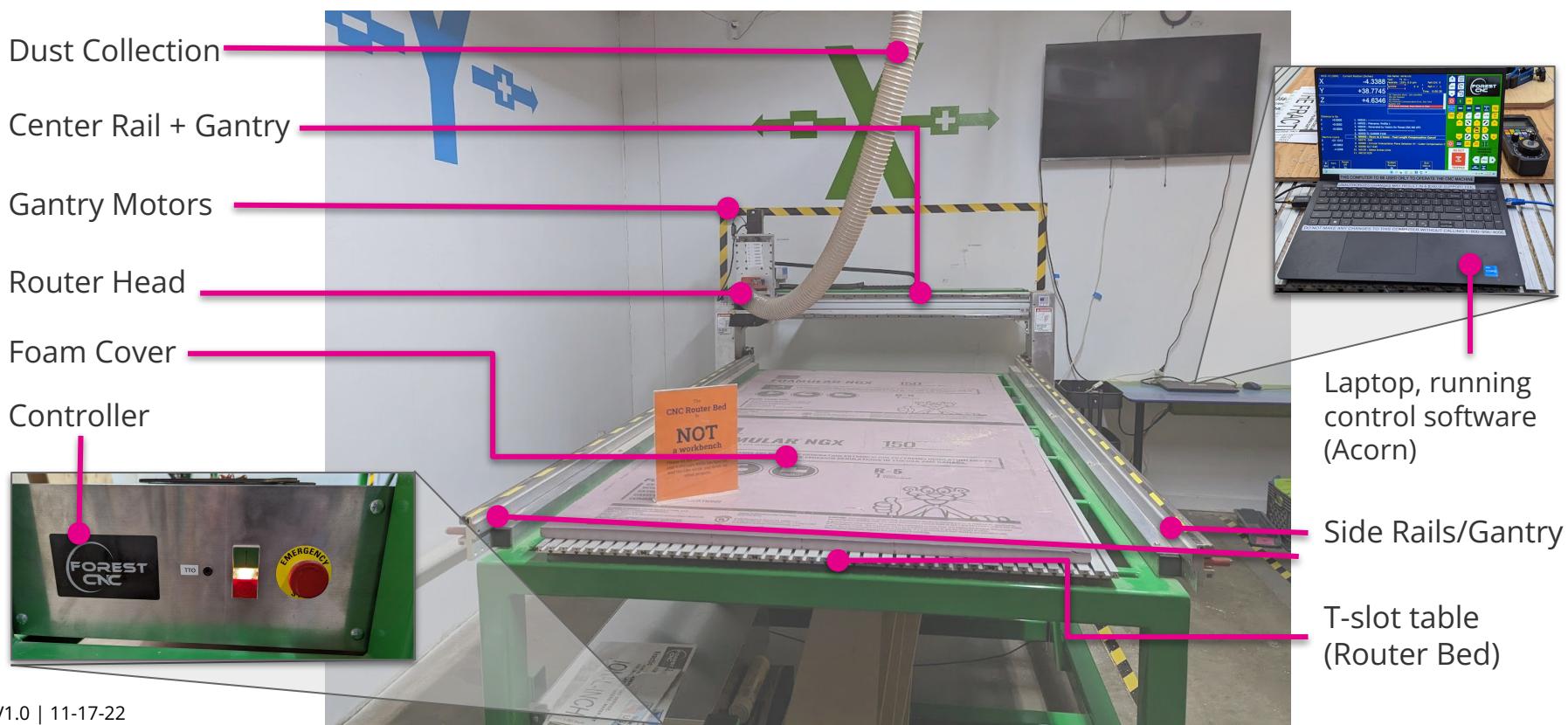
Tell the machine where to start the job on all 3 axis

Where/what is x_0, y_0, z_0 ?

The home position is the default origin point on a CNC, set when the machine is started up.

Anatomy of the Tool

Forest Scientific CNC Router (AMT375)



Forest Scientific CNC Router (AMT375) Pendant



Don't forget to turn off pendant when done using CNC Router to avoid draining the batteries.

Collets

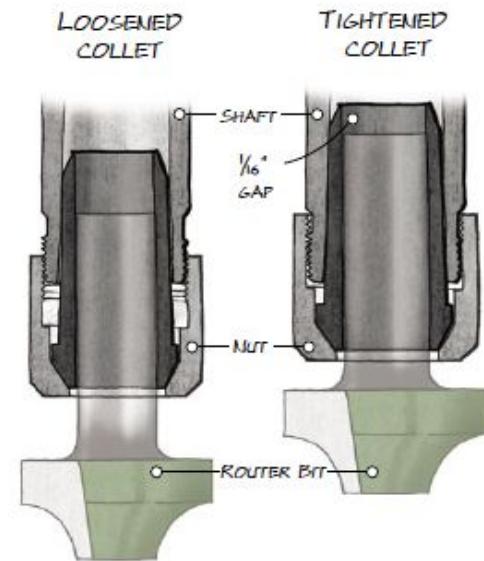
- A collet is a cylindrical sleeve that tightens around the router bit to secure it in a router
- Collets come in different sizes. Ace stocks: $\frac{1}{4}$ " and $\frac{1}{2}$ " collets.
- Ace collet requirements are Milwaukee brand Collet and Nut Assembly.



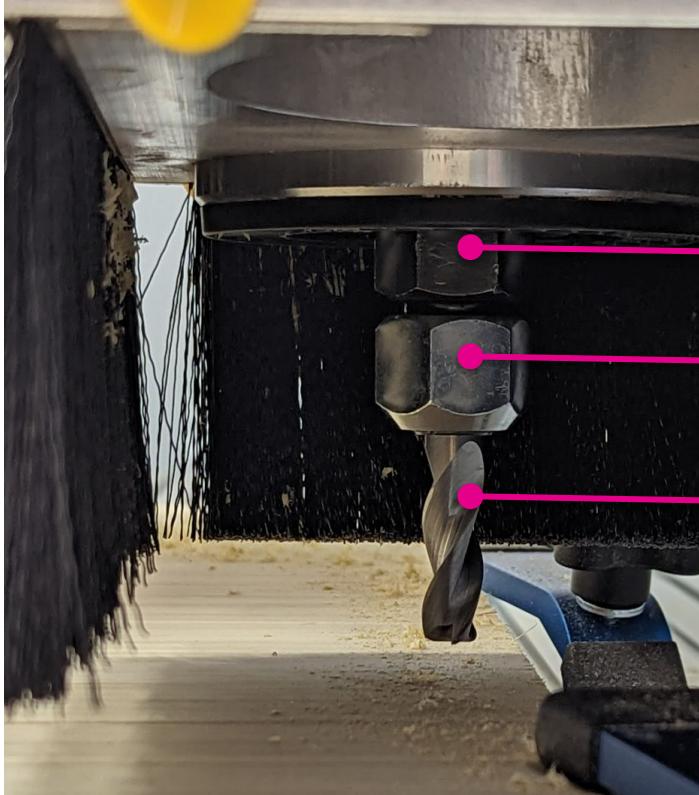
Collets



Milwaukee Collet and Nut Assembly



Collets



**View of collet and bit assembly in place
on the router head**

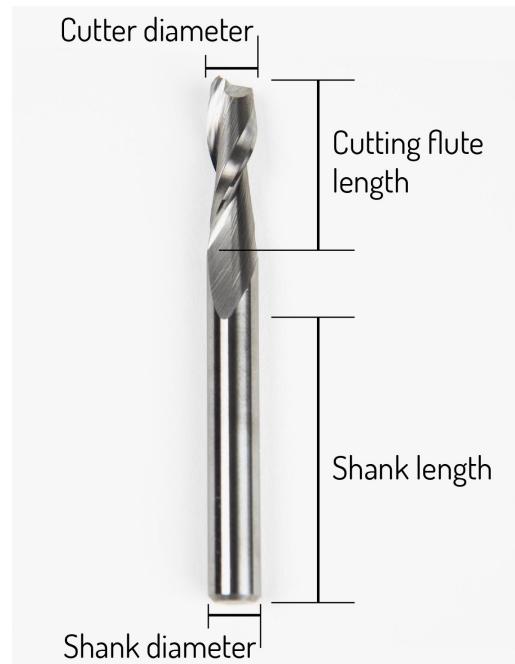
Chuck

Collet & Nut

Router Bit (Endmill)

Major types of bits that can be used

- *Endmill* and *Router Bit* are interchangeable terms for the same thing.
- Major types of bits that can be used:
 - Square (or flat)
 - Ball
 - V
 - Compression
 - Upcut
 - Downcut



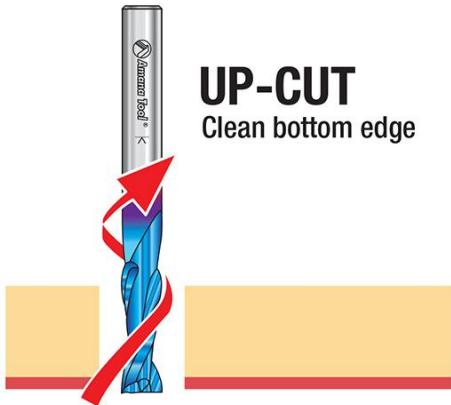
Router Bit/End Mill Dimensions-Anatomy

Up-Cut, Down-Cut and Specialty bits

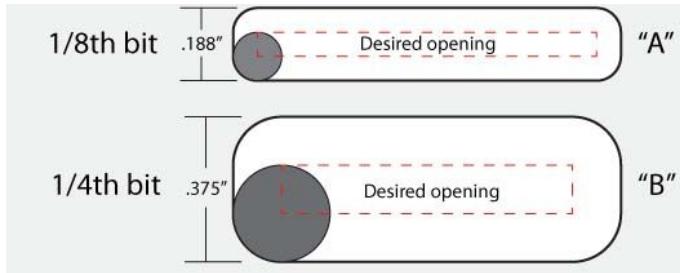
Up-cut spiral bits clear chips through the width of the cut (called kerf) and allow faster feed rates than down cut spirals.

Down-cut spiral bits push wood chips down for a cleaner top surface (better surface finishing). They require slower feed rates.

There are specialty bits such as compression, straight flutes



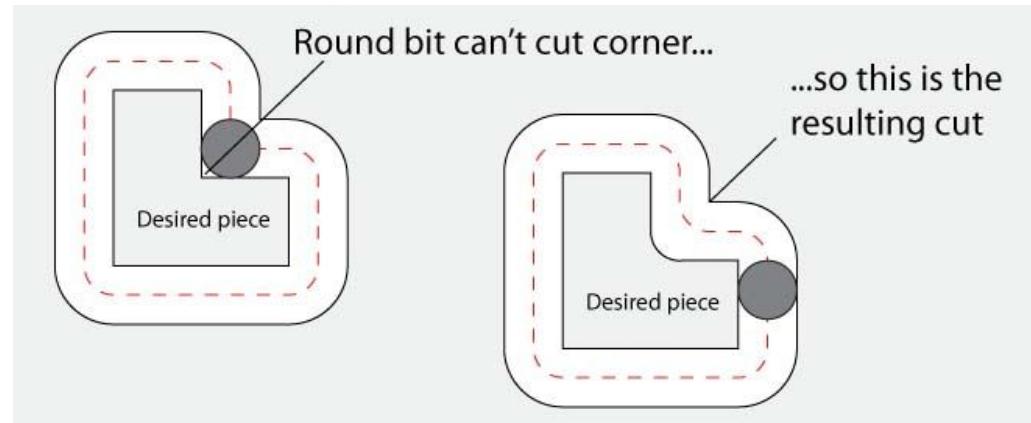
Inner corners and 90° cuts



Bits are round, which results in rounded corners with a curvature to the corner that relates to the diameter of the bit.

The bit or tool will leave a circular profile in every internal corner.

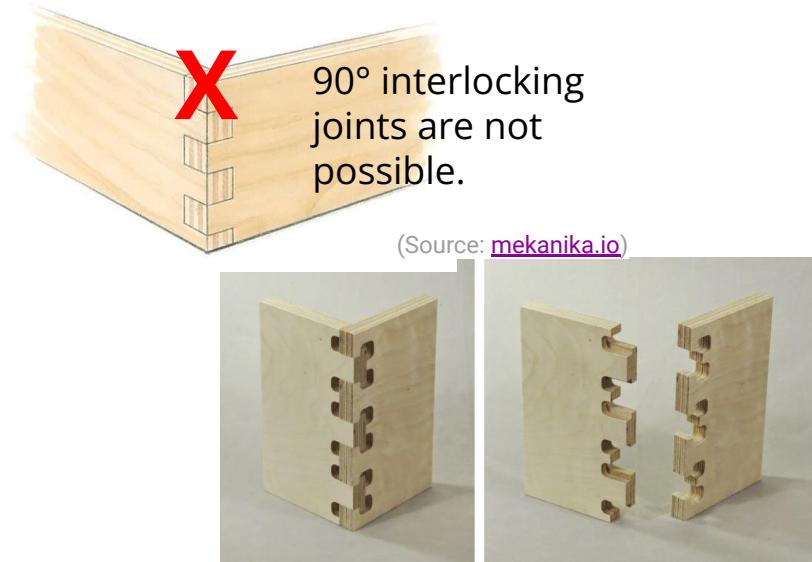
Round things
cannot make
square internal
corners.



(Source: [Hammer Space Community Workshop](#))

Dogbones

Dogbone corners describe the shape of a corner that is extended outside the cut area to create a perfect 90° corner.



What bits CANNOT be used on the CNC



End mills (also referred to as Router bits) with **BALL-BEARING** guides are NOT allowed for safety reasons.

Ball-bearing guides are not only unnecessary in CNC Router, they are unsafe.

The fear is the machine puts too much pressure on the bearings causing them to fail and become projectiles.

When in doubt ask #workshop on Slack

Fixturing

Why we need to hold stuff down

Why? **SAFETY**

*Spinning blades can push stuff
around and fling it at your head*

Why else? **Better results**

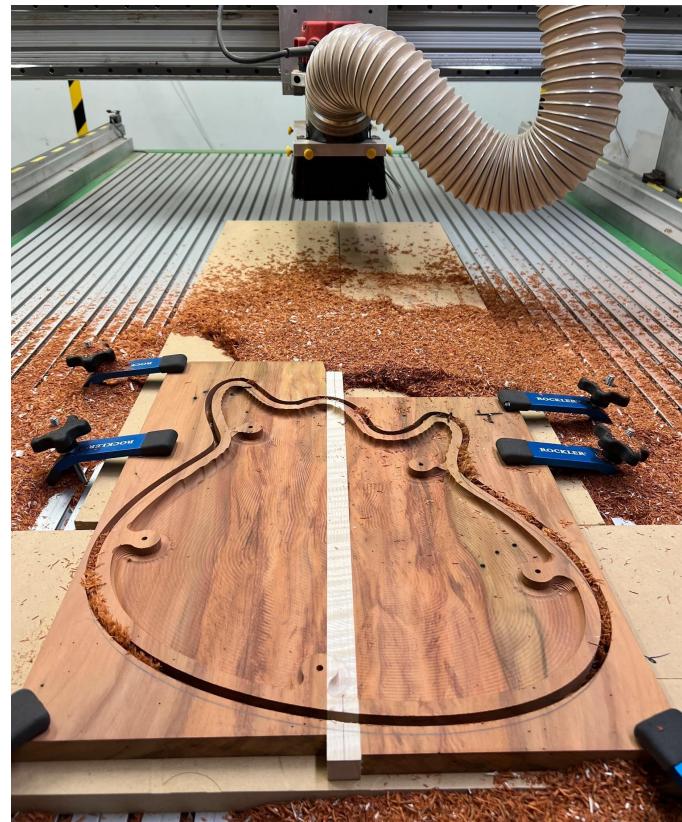
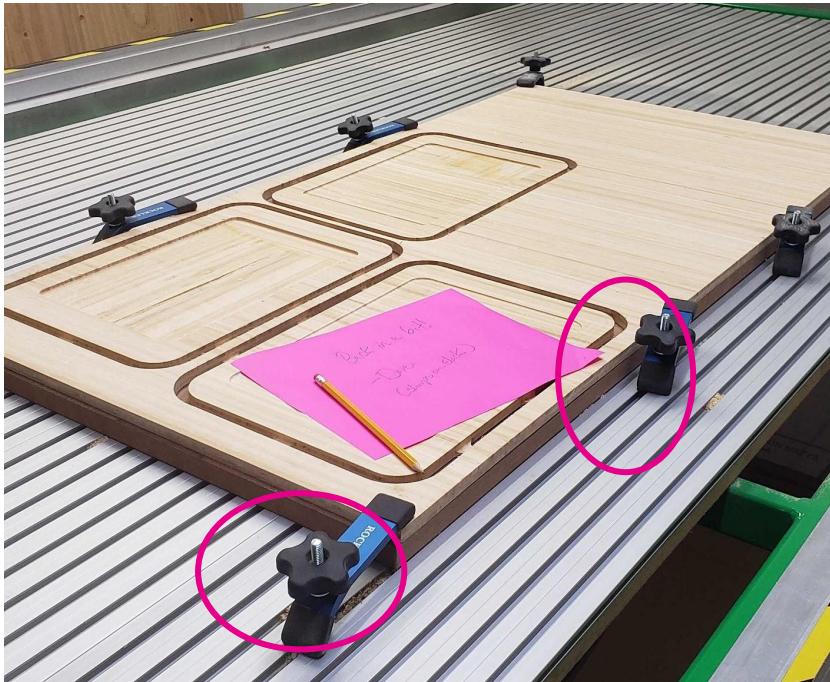
- How you design your file is part of holding down your material
- Small parts can pop out
- Parts can move and give you a bad cut



Never walk away while CNC router is running

Fixturing

Fixturing is securing the workpiece.

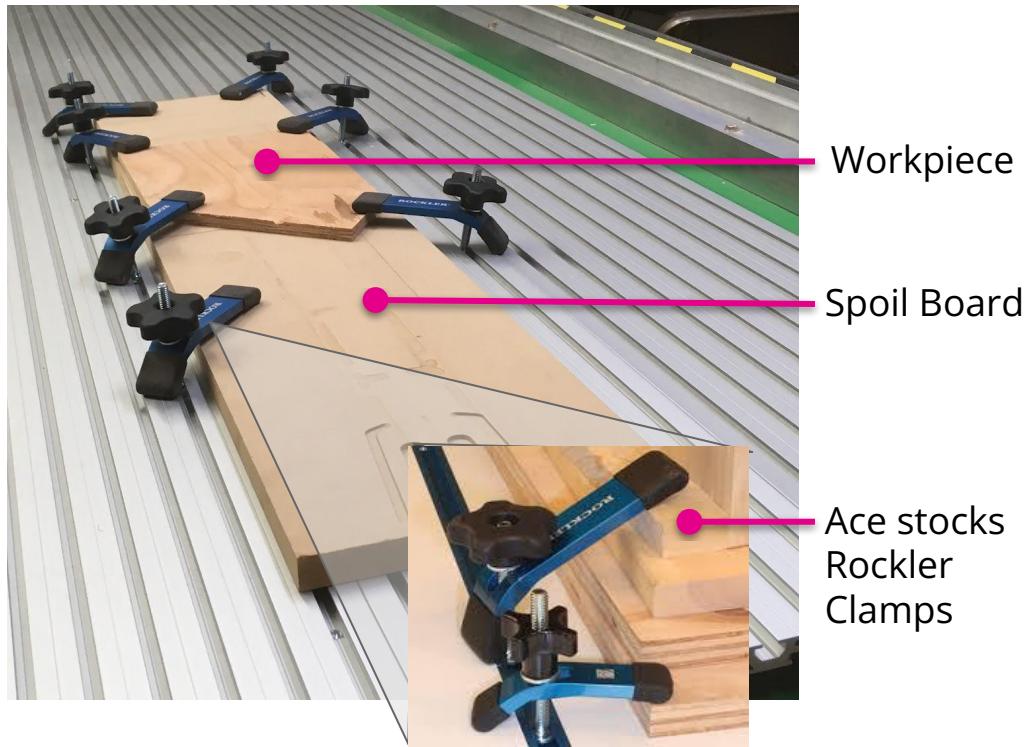


Why the T-Slot table rocks and is your friend

- Table is nice and flat
- Easier to get accurate parts
- Fast fixturing
 - T-slots are used to anchor clamps and other fixturing to hold down workpiece



T-slot table gets its name because slot is shaped like an upside down "T".



(Source: NewWoodworker.com)

Different Methods of Holding Stuff Down

T-slot clamps



(source [grizzly tools](#))

Tabs



(source [fab academy](#))

Onion skin



(source [woodworkers guild of america](#))

Plastic Nails



(source [Avid CNC](#))

Double-sided fixture tape
(acceptable when used correctly)



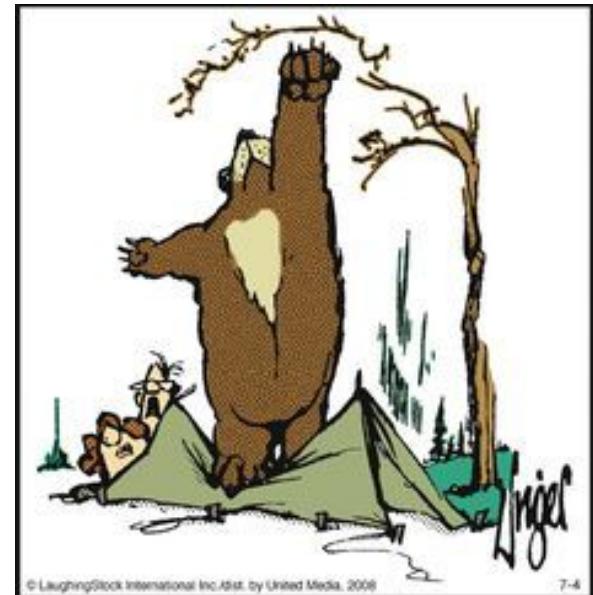
(source [Philadelphia luthier](#))

What NOT to Use to Hold Stuff Down

Forbidden at Ace: Metal screws (drywall, construction screws, etc)

- Why we don't want to use screws
 - Metal screws can mess up the t-slot table
 - Because bears...

While metal screws (such as brass) may be perfectly safe in other shops, we don't use them in this shared environment because it reduces the risk of messing up our equipment and errs on the side of safety.



© LaughingStock International Inc. Artist: United Media, 2008

7-4

"Did you have to hang the food
right above the tent?"

Always Use a Spoilboard

What is a **spoilboard**?

A base surface for cutting to prevent damage to the CNC t-slot table.

Sometimes called a waste board. It's a surface that gets 'spoiled.'

We use MDF. *If you need another type of material, it must be pre-approved by Team Workshop or authorized rep.*

The minimum thickness requirement is $\frac{1}{2}$ "

Plan on bringing your own spoilboard. Ace has a limited selection for sharing.

How to Use a Spoilboard

Position spoilboard in-between your workpiece and the T-slot table.

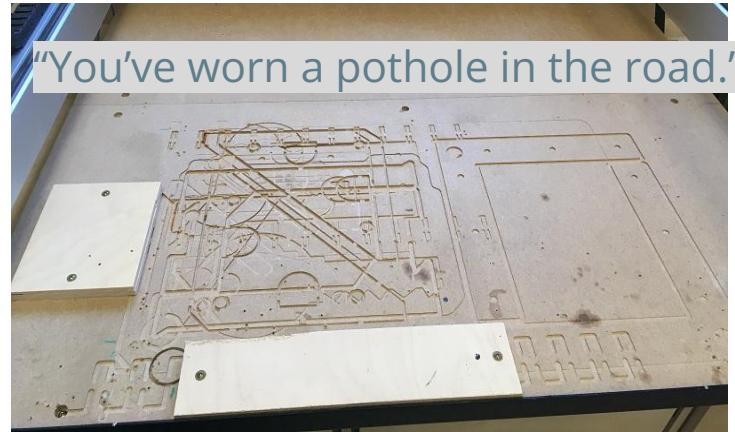
The spoilboards' purpose is to prevent damage to the t-slot table.

Minimum thickness (0.5in or more)



Spoilboards will develop **hotspots** after multiple uses.

Hotspots are worn out areas of a spoilboard, like potholes in the road.



(source festoolownersgroup.com)

Spoilboards might not be perfectly flat

Does this matter for you?

- If profile cutting, probably not a big deal.
- If doing more complex cuts then yes.

How can you make the spoilboard flat?

- Talk to Team Workshop about this advanced technique.

Spoilboards wear out over time and become distorted (potholes).

Jigs are an advanced technique

A **jig** is a type of custom-made work-holding device.

Why use jigs?

- More accurate
- Makes positioning easier
- Multiple parts at once in known locations
- Allows you to cut from weird shapes that might not be a stock board
 - Cutting parts out from multiple sides



Workflow & Basic File Set up

Recap: What is CNC?

Let's review: What does the acronym **CNC** stand for?

Computerized **N**umerical **C**ontrol

- CNC means automated control of machining tools, and those instructions are written in G-Code.
- The generation of G-Code can be accomplished in special software programs such as Fusion360 and vCarve.

CNC Workflow: From Idea to Final Product

Come up with your idea

Create model

Make the Tool Path

Export G-Code

Ideate. Some makers start with pencil and paper to sketch out their initial idea.

Create a model in VCarve or Fusion360.

Make the tool path that the router will follow to make your awesome thing.

Save G-Code to USB or network drive.

Upload G-Code

Setup your workpiece on Router

Follow “Run” Checklist and Hit GO

Clean Up

Upload G-Code to the CNC Router's computer

- Following Ace practices,
- set up spoil board and
 - clamp down your workpiece (material)

Be sure to run through the file paths **before cutting** to ensure your file behaves as you expect.

Follow shop policy to clean up

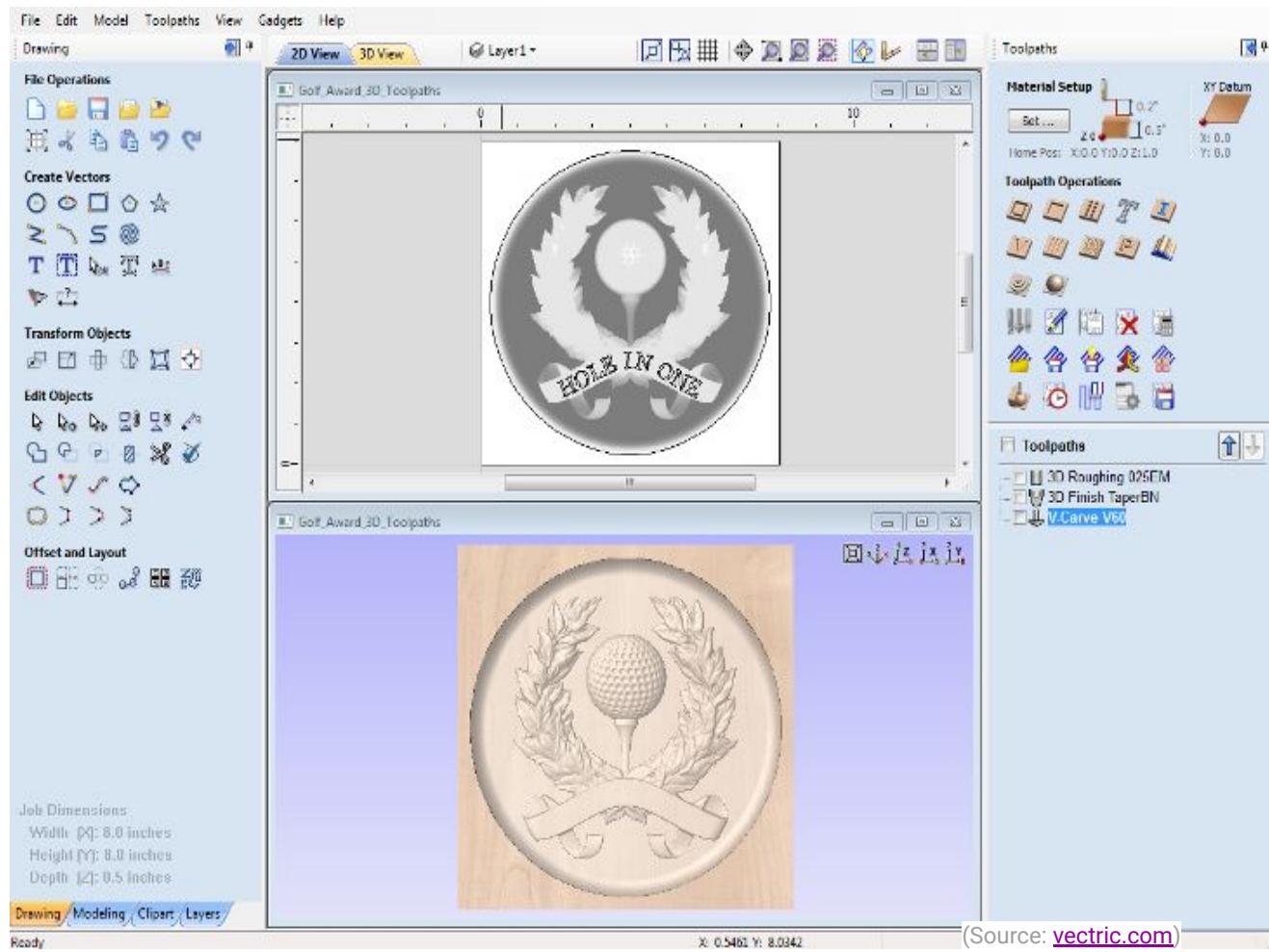


VCarve

Feature: Easy to Learn, Simple, and Good for 2D Cutting

OS: PC only

Cost: Free and Paid versions*

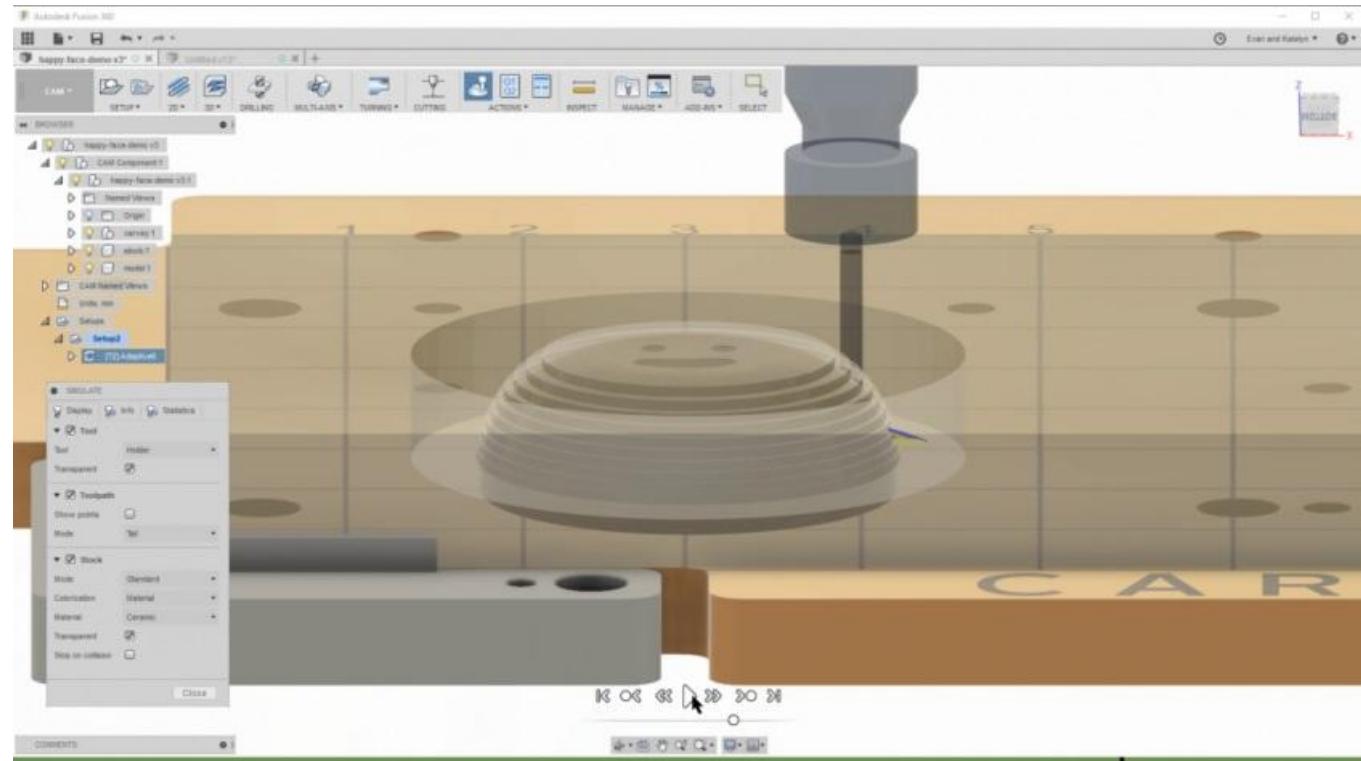


Fusion 360°

Feature: Simple though complex design with a large feature set for design

OS: PC or MAC

Cost: Free and Paid versions



Fundamentals of Tool Paths

Tool Path: the user-defined coded route which a cutting tool follows to machine a part.

- **Spindle Speed :** rotational speed of the cutting tool in revolutions per minute
- **Feed Rate :** the speed at which the gantry will move in each axis while cutting
- **Step down :** the distance in the z direction per pass that a cutting tool is plunged into the material
- **Step over :** the size of overlap between cutting passes

Wordy needs work

Applying speeds and feeds

High level overview of what good chips are

Sharing Speeds and Feeds to start cutting

Cutting is more than using a set formula of speeds and feeds. We are collecting starting speeds and feeds for different scenarios to support each other successfully cutting. See the wiki for the collection and contribute to the list when we learn great starting speeds and feeds for our machine.

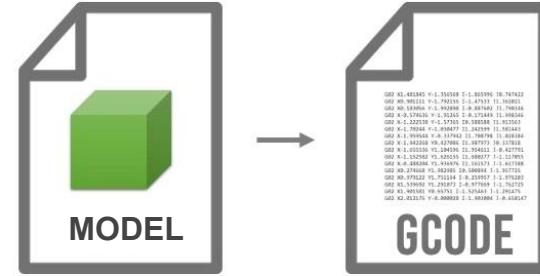


DEMO: Export G-Code

You don't have to actually "write" code, but ***you have to generate code based off your toolpath in your software.***

To transfer the file to the CNC router:

- Use a thumb drive or
 - Transfer over the Ace network using the public files.



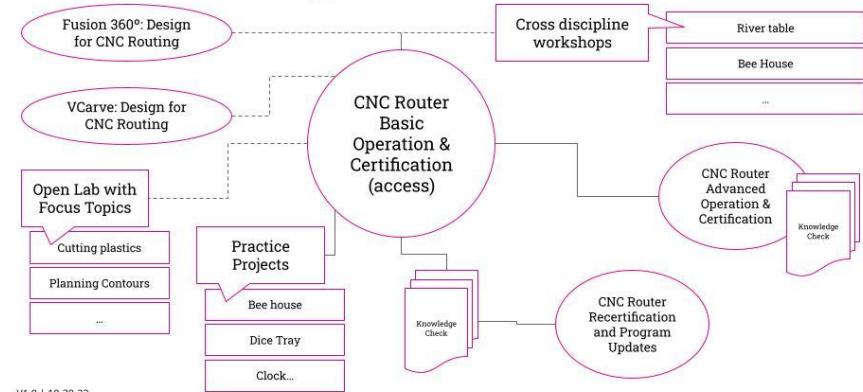
Important parameters:

- Forest Scientific post processor
 - Consistent document Units (Units of measurement, inches, mm, etc.)

Where to Learn how to Create Design Files

- Classes at Ace:
 - Classes are still In Development
 - Online Resources through Ace
 - Wiki page
 - Slack
- Teach Yourself:
 - YouTube Videos
 - Google
 - Books
- Class at other Institutions:
 - Online courses
 - Community colleges

CNC Router Program - Education Overview



15 min. Break

Safety and Best Practices

Keep Clear Zone



- All CNC machines present hazards from the high speed rotating cutting tools.
- **Stand clear** whenever CNC Router is operational.

*Always be present
and never leave
CNC router running
unattended.*



Safety and Best Practices

- Why does Ace Require Certification?
- What is the Dress Code?
- PPE

- eyes: always wear your safety glasses
- ears
- lungs

Key Use Behavior

- ❖ Secure work pieces as trained
- ❖ Do not use hands, push sticks, tape (on top) and so on
- ❖ Always take out your bits when finished
- ❖ Park machine when your job is done
- ❖ Always use dust collection method(s) appropriate for your materials when cutting
- ❖ Keep the pendant in hand during entire job

- Never leave the router running unattended
- Always mind the keep clear zones

How Cyclone Dust Collection Works

Saw dust can be very harmful

Point out the parts of the system re: cyclone

Gate, power switch,

Repeat the take your dust every time policy

Mention N95's and Respirators

Be sure to check that the flue is open for the dust collection.



Using the CNC Router

Start Up Checklist

1. Ensure you are meeting all dress code and shop safety requirements
2. Remove the t-slot table cover and signage and store under the machine
3. Clear and prepare your work area
4. Turn on the CNC router laptop
5. Power on the main switch on the CNC Router - hold down the green button for 5 seconds
6. Start-up the CNC Control software and verify the connection
7. Run the home sequence (hit cycle start)

Start Up Checklist

- 1 Close hallway door & turn on Honeywell filter.
- 2 Turn on system with main switch.
- 3 Confirm chiller is on, water is flowing and temperature is in the safe zone.
- 4 Confirm air compressor is running.
- 5 Log in to Laser Access Box by tapping your fob.
- 6 Check/replace the filter.
- 7 Do a draw test with a sheet of paper.

Do all of these steps **every single time** before you start laser cutting

Shut Down Checklist

- 1 Move the laser head to the back of the bed, then center.
- 2 Tap your fob to log out.
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10 If the room is stinky it is OK to leave the Honeywell on.

<replace infographic for laser with one for CNC router>

<https://wiki.acemakerspace.org/laser-cutting/>
Go to #laser on Slack with questions



*Do all of these steps **every single time** before you start using CNC Router.*

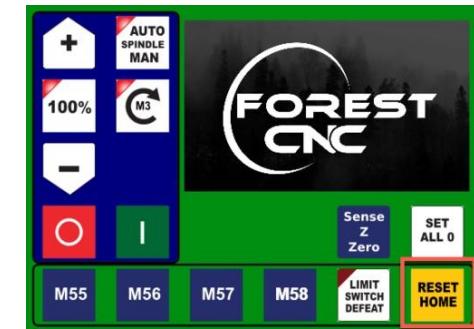
Start Up Checklist

8. Secure your workpiece (see fixturing)
9. Add your collet and bit
10. Set up Dust Collection (steps for this on wiki) -
11. Verify the speed on the router head for your job
12. Set and verify the origin on all axis for your file (gcode) (see run/operate guide; covered in Wiki and printed in class handout). Check all three axis.
13. Import the GCODE from your design and check the graph*
14. Turn on the Cyclone
15. Check for safe use (see policy), take a breath, think though your job, and Run the job

*Do **all** of these steps **every single time** before you start using CNC Router.*

Turn on the machine

1. Check Estop - cannot be engaged
2. Press green button (hold for 3 seconds)
3. Start up the Centroid software on the Ace computer. (Icon Pic)
4. Hit reset button (pic)
5. Confirm the homing program is loaded in the CNC Control Software- red button (Pic)
6. Hit cycle/start to home machine (Pic)



Importing your job into the CNC Control Software

Click Load (or Press F2 key)



Navigate to file

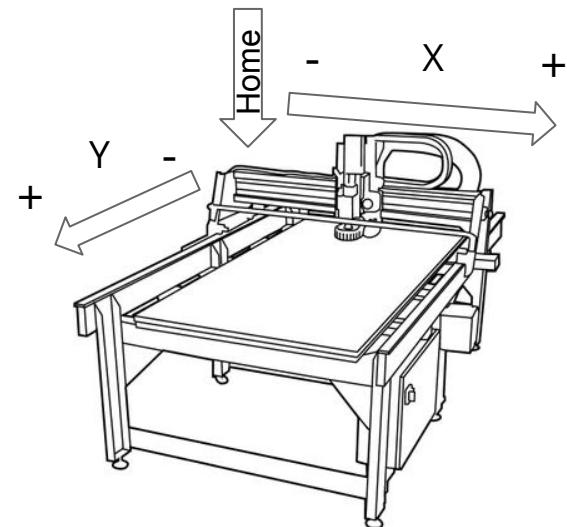
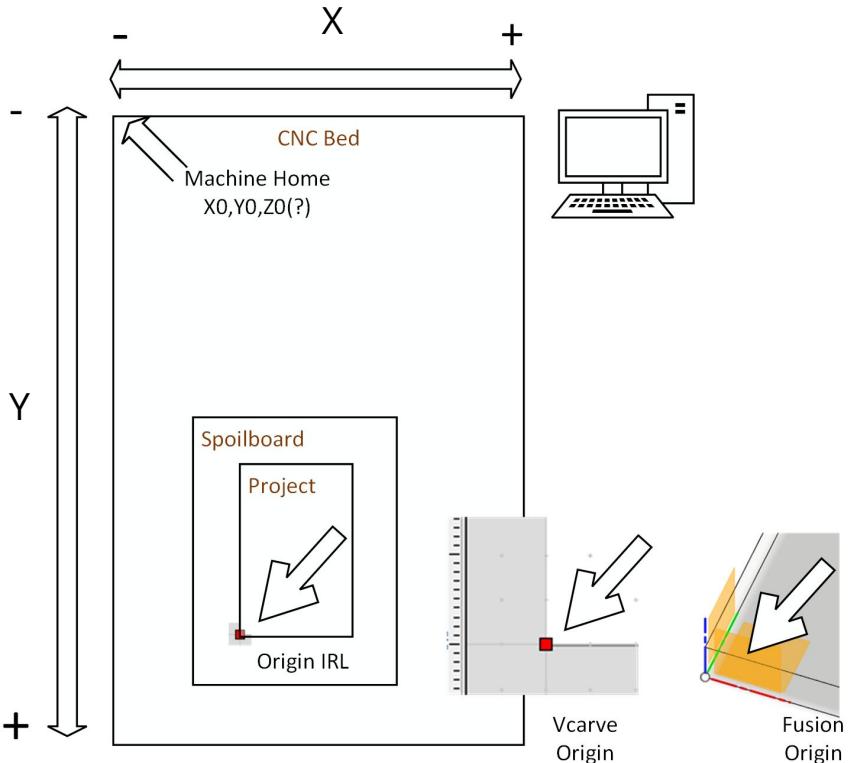
Click Okay

Install Collets and Bits

- Use Controller to bring the router head to the easiest spot to install the collet and bit without leaning on the rails/gantry
- Install collet (demo + video)
- Install the bit (demo + video) - beware of over-tightening



Design Origin X, Y



Move head to X and Y Origins

Raise Z (Z+) well above any fixturing or clamps to start the process (Slide)	
Use the Controller to move the router head with bit near the X or Y origin of your design.	(Picture) (wall chart shows setting X and Y movement) (Slide)
As you get close, jog the head (10% jog speed) for fine grained control.	(Picture of Jog speed on controller)
To accurately adjust your X or Y position, lower Z (Z-) close but DO NOT TOUCH the top of your project.	
Adjust the X axis and press the yellow X= button on the controller. Controller display and the computer should say X=0.00	(Pic) (Slide)
Adjust the Y axis and press the yellow Y= button on the controller. Controller display and the computer should say Y=0.00	(Slide)



Move head to Z Origin

Do the Paper Test: Get a small scrap of paper and place it under the bit.	Short Video
Turn the jog increment to 1x on the Controller and slowly lower Z, and check after each step until the piece of paper just bites a little on the bit. If you can't pull it out jog up Z+ (video)	
Press the Yellow =0 button on the controller. Verify the controller and the computer show Z=0.000.	
Raise Z (Z+) to get it off of the board before you start your job	

Cut!

1. Put on your Ear, Eye and lung protection.
2. Double check the bed is clear
3. Make sure the safety zone is clear
4. Take a deep breath, all good?
5. Start the Cyclone
6. Press the green Cycle start button on the controller to start cutting **(talk about these things first)**
 - a. Oh, no, hit the Red button to stop the job. (bit broke, project moved, etc))
 - b. If you need to look at your project or just , pause and check your jobs, hit tool check. **(need to write up the risk). (move to post mortem))**

Take note of chip size and sound

This is a complex action and you will get better with first-hand experience.

- Contextual to material
- Car analogy - Good loud and bad loud

Shutdown and Clean Up

- Remove the collet and bit
- Park the router (run park operation)
- Turn off the main switch to power down the system. DO NOT USE ESTOP to shut down the system
- Remove all material from the Router bed
- Use a shop vac and cleaning tools to clean up all your dust, including the router bed, underneath the bed, and all surfaces
- Cover Router bed with foam cover
- Vacuum out the cyclone filter. Bag your sawdust from the cyclone can and vacuum.
- Bag your trash, and take it home, including the sawdust - Reminder waste board can be easily broken down on the panel saw.

DO NOT TURN OFF THE COMPUTER

Start Up Checklist

- 1 Close hallway door & turn on Honeywell filter.
- 2 Turn on system with main switch.
- 3 Confirm chiller is on, water is flowing and temperature is in the safe zone.
- 4 Confirm air compressor is running.
- 5 Log in to Laser Access Box by tapping your fob.

<FPO. Graphic of CNC Poster Coming Soon.>

- 6 Power down system using main switch.
- 7 Remove all material from laser bed.
- 8 Use shopvac, brushes and pipe cleaners to clean honeycomb and always vacuum underneath the bed.
- 9 Carefully wipe down interior of the laser with microfiber cloth or duster. Don't use spray cleaners anywhere! (It's OK to use a damp cloth as long as it is water only)
- 10 Bag your trash, take it home.
- 11 DO NOT TURN OFF THE COMPUTER.
- 12 If the room is stinky it is OK to leave the Honeywell on.

<https://wiki.acemakerspace.org/laser-cutting/>
Go to #laser on Slack with questions



Resources

Troubleshooting Resources

- Check the Wiki
- Check Slack
- Google is your friend
- Find a mentor

Time to get Certified!

Certification

- You **must** pass the Knowledge Check to qualify for certification
 - This is an open web test you can take as many times as needed to pass
- Certification and Shop Basics **is** required
 - If a member has a certified guest, that certified guest can operate the CNC

<https://www.acemakerspace.org/cnc-router/cnc-router-knowledge-check/>

Once you have passed the test your certifications will be added to your Ace account and you will get a nifty email confirming this. Then you will be good to go! You can also check your member profile in the Ace Member Directory to see all of your certifications on file.