Laser Cut Like a Boss: *Trainee Handbook*

Version 1

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Vol. I Issue I

What is this book?

This handbook was written by Annie Zeng, Ingrid Hagen-Keith and Mary Morse. Throughout the semester, we will be producing a set of laser cutting handbooks. The handbooks will touch upon basic topics, like how to create proper cut files and cutting with the specific laser cutters in the machine shop. They will also present more advanced topics, such as laser cutter-specific alternative joinery and cutting exotic materials.

This issue is targeted to new and developing laser cutting students. It briefly presents various topics involved in laser cutting. For more advanced discussions of these topics, read our future issues!

This is prototype 1 of our Trainee Handbook. We understand that it is not perfect, and we want your help to make it better. Please, read through this book, ask us questions, mark it up and give us feedback! Email the NINJAs at laser@lists.olin.edu.

Rough Table of Contents

The following list is the rough table of contents for this issue:

1. Cut Files
2. Cutting
3. Machines
4. Materials
5. Joints

The purpose of each section is to briefly introduce beginner concepts.

Safety

The laser cutter is a printer that can set your stock on fire and cause excessive flare-ups. In practice, the laser cutter is as safe to operate as any other machine in the shop if common sense, vigilance, and thorough training is internalized and practiced. The machine should be used and maintained with respect to promote safe usage.

LASER SAFETY

The Epilog and Trotec Laser Systems contain two lasers. They both enclose a class 4 CO_2 laser which emits intensive and invisible laser radiation. These lasers can start fires, cause damage to the skin, and are a hazard to the eye when viewed directly and from reflections. The second laser is a Red Dot Pointer which is considered safe if it is not viewed directly or through reflections.

FIRE SAFETY

Make sure you have easy access to and know how to operate the fire extinguisher before you execute any cut, especially with a new material. Do not ever walk away from a machine when it is executing a job.

FUME SAFETY

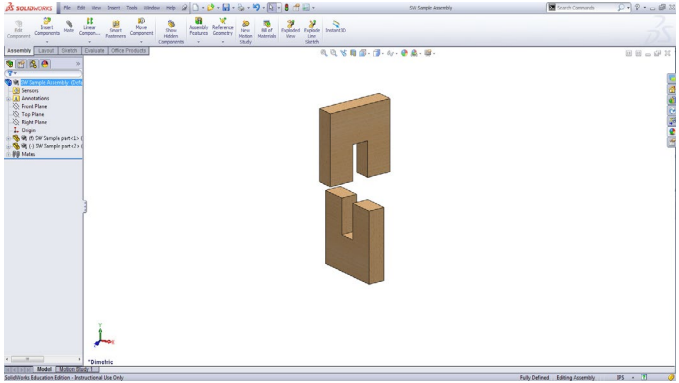
Make sure the air exhaust is open and functioning. If you see or smell excessive fumes during cutting, stop the job immediately.

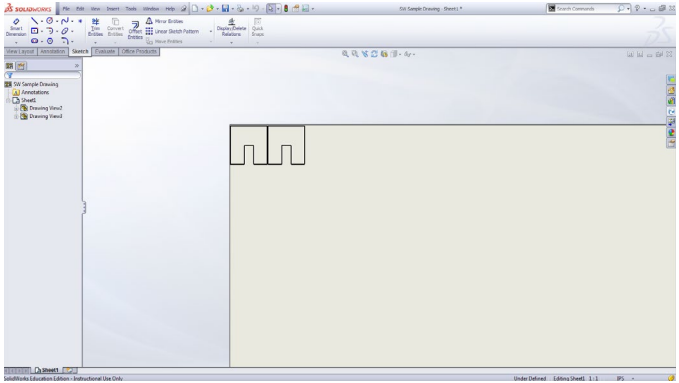
CUT FILES

Creating cut files for a laser cutting is pretty straight forward once acquainted with each software. In the following pages, we will **outline** the file creation methods for SolidWorks and Adobe Illustrator.

To improve further improve your skills, we suggest reading each machine's manual and a good amount of practice. Consult a NINJA or email lasers@lists.olin.edu for more advanced questions.

FILE CREATION IN SOLIDWORKS





STEPS

1) Model your parts with the appropriate tolerances.
2) Make a new custom drawing file that is the size of the laser cutter bed or smaller (just keep track of the size of your cut file).
3) Place your parts on the cut file with the view you want to laser cut. Do not overlap a part corner with the corner of a sheet. Do not import annotations. There should be no centermarks or centerlines in your drawing. Outlines of parts should be solid lines.
4) Ensure that hidden lines are removed.
5) Ensure that the scale of your parts is 1:1. This may involve a custom scale.
6) There should be at least 2 mm distance between parts.
7) Set the line thicknesses to 0.002 inches for vector lines. If the cut file includes only vector cuts, use the following steps to set up the file: Options-> Document Properties-> Line Thickness-> Set all line thicknesses to 0.002 in.-> OK

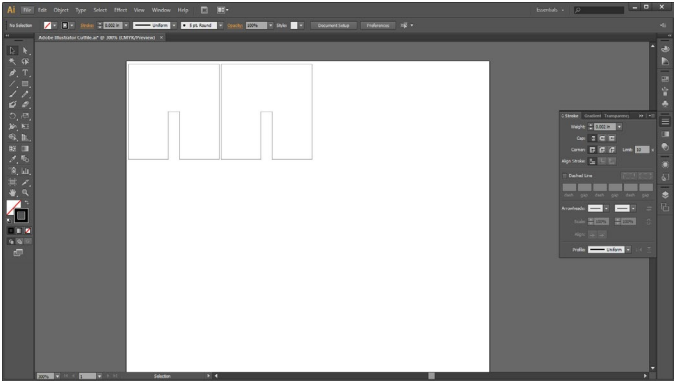
Tricks of the Trade

Rastered text can be placed into a drawing file using the Note button.

Vector cut text must be included at the part level: Sketch-> Text-> Select a curve that the text will be on and type->Extrude Cut-> All Bodies.

You can insert a **picture** into a SolidWorks drawing file using Insert-> Picture. You can then place the picture based on co-ordinates or grabbing.

FILE CREATION IN ADOBE ILLUSTRATOR



STEPS

1) Make a new Illustrator file that is the size of the laser cutter bed or smaller (just make sure you keep track of your sheet's dimensions).
2) Draw your parts using the line or pen tool. Do not overlap a part corner with the corner of a sheet. Ensure that the anchors of the lines are connected.
3) Ensure parts are 2 mm apart.
4) Set the stroke for desired vector cut lines to 0.002 in. If you want a rastered line, the stroke must be greater than 0.002 in.

Tricks of the Trade

For **rastered text** in Illustrator, just type and place as you please.

If you want to **vector cut text**, type your text. Then set the fill to empty and set the stroke weight to 0.002 in.

Convert images to greyscale so that your have an idea of what the **rastered image** will look like. Black sections will be darker than lighter grey sections. White will be rastered extremely lightly as a set of light dots.

trotec®

MACHINES

The machines in the shop are carefully maintained and should be treated with absolute respect. That being said, they are **tools** with an enormous capacity to do amazing things. This section describes how to print the **most basic** files. For more information, read the manual or experiment!

PRINTING ON THE EPILOG

The Epilog Legend is a powerful laser cutter ideal for experimentation with a high level of control. It can accommodate stock that is 32 in. x 20 in. The z-axis spans 9 in.

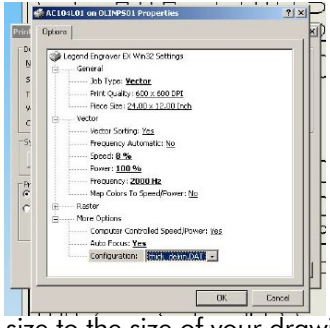
This laser cutter vector cuts or rasters based upon line thickness. Lines that are 0.002 in. or less vector cut while lines with a greater thickness will raster.

If you wish to increase the speed of your job, make the drawing file smaller. Just make sure you follow step 1!

To increase mastery on this laser cutter, read the *Color Mapping* section from the manual.

STEPS

1) Ensure that the resolution and scale are properly configured using: File-> Page Setup-> Set Scale to 100%.
2) If using the machine shop computer, double check that the line thickness are what you intended in your original cut file.
3) You may then proceed with the printing process: File-> Print. Choose AC104L01 as the desired printer. The number of copies will always be 1 copy.
4)Click Properties. This will open the Epilog Driver.



5) Set your piece size to the size of your drawing/Illustrator file. Ensure you have the correct job type. Please refer to the material sections in this book and "Safely experimenting with laser cutter settings" for more in-dept settings information.
6) Press Print. The Epilog will receive the order. Using the toggle wheel, select Jobs->View. Give the laser cutter a minute when doing this. If you can see your cut file, then press Jobs->Run. This will run the job with the settings you sent at the computer level. (See Focus section to get the ideal cut).

PRINTING ON THE TROTEC

The Trotec Speedy 300 is a straight-forward, intuitive machine with custom driver software conducive to creative manipulation. It can accommodate stock that is 29 in. x 17 in. The z-axis spans ~8 in.

This laser cutter vector cuts or rasters based upon line color. Lines with a RGB of 0, 0, 0 will vector cut while lines with an RGB value of 255, 0, 0 will raster.

Note that these RGB values must be used! If the numbers are even slightly off, the job will not print as you expect.

When creating cut files for this machine, your piece size should be limited to 28 in. x 16 in.

STEPS

1) Ensure that the resolution and scale are properly configured using: File-> Page Setup-> Set Scale to 100%.
2) If using the machine shop computer, double check that the line colors are what you intended in your original cut file.
3) You may then proceed with the printing process: File-> Print. Choose the Trotec printer. After pressing OK, the Trotec settings driver will open.
4) The settings driver will allow you to set the size, material, and settings. You will usually want the Process Mode to be set to Standard.
5) If your job involves rastering *and* vector cuts, you will want to set Halftone to on. If it involves only vector cuts, you should set the Halftone off.
6) In general, you will always want Cut Line set to None. See the Trotec manual if you want more information on this.
7) After all this, press OK. This will open the Trotec job control panel.
8) Drag and drop your job from the jobs queue into the workspace. To view your job's lines, click the checkbox at the bottom of the Jobs panel.
9) Note that on the Trotec, you move the head using the panel on the machine. The position of the laser head can be seen on the Trotec Jon Control software as well. This means that you can move the laser head to a specific location on your material and then drag and drop the job to snap with the laser head cross hatch. So exciting!
10) Connect with the laser cutter and then laser cut away after pressing Run.

CUTTING

Laser cutters are more advanced than a simple printer that you press and go. Through **manipulation of setting and setup** like speed, power, frequency/resolution, focus, kerf, and jigging, you can cut a variety of **complex, exciting** jobs like the Mary's pumpkin above.

This section will help you start thinking about laser cutting and settings **creatively.** The best way to learn is through thoughtful experimentation.

SAFELY EXPERIMENTING WITH SETTINGS

The laser cutter is a fantastic prototyping and manufacturing method. It gives a high level of control and is very user-friendly. That being said, there are dangers to using the laser cutter. Harmful fumes and particulates may be produced in the process of cutting and a fire could be started.

Fires do occasionally happen in the shop and it should not be a source of shame if they occur. They can be extremely dangerous, damaging to the laser cutter, and ultimately huge pain.

However, this should not preclude individuals from experimenting with the laser cutter. Experimenting should be done intelligently and with care. In the following pages, we will conceptually explain speed, power, and frequency/resolution. Once you understand these settings, it will be easier to think about setting experimentation in a safer manner than mere guessing.

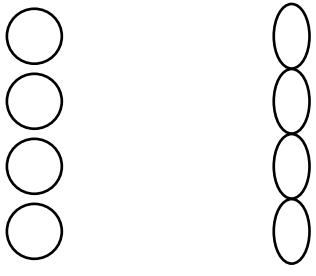
A laser cutter is an **energy transfer method** that can be used to melt, vaporize, or degrade a material. You can vary how long energy is transferred to a section of a material (speed), how much energy is transferred to a section (power), and the spacing of the energy transfer to the material (frequency or resolution for vector cuts and raster engraving, respectively). There are other ways to vary energy transfer but these are the most central to laser cutting.

SPEED

Speed indicates how fast the laser head moves. Lower speed allows more time for the laser beam to dwell on a particular spot which means more energy is transferred to the material. On the other hand, higher speed results in less time for the laser beam to apply a certain amount of energy on a particular spot on the material.

Speed is measured in m/min and is often expressed as %. Maximum speed differs for each type and model of laser cutter machine.

To reduce edge modifications like charring and thermal damage, you want to increase the speed so that the air assist can quickly access the recently cut zones.



Low Speed High Speed

Use the info-graphic above to help you think about speed as a parameter of energy transfer.

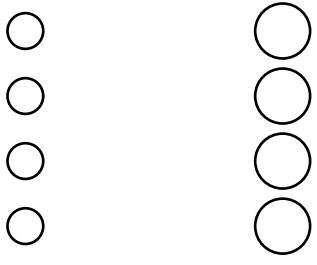
POWER

Power indicates the rate at which energy is transferred in the laser beam.

Power is measured in W, and it is often displayed as a percentage (%) of maximum power. Maximum power differs for each model of laser cutter.

Lower power applies less energy per pulse on the material; higher power applies more energy per pulse on the material.

In general higher power means deeper cuts than lower power.



Low Power High Power

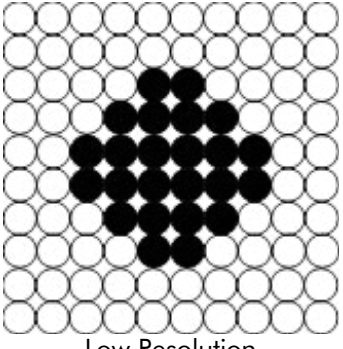
Use the info-graphic above to help you think about power as a parameter of energy transfer.

RESOLUTION (FOR RASTER ENGRAVING)

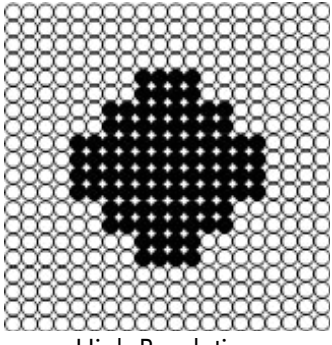
Resolution indicates the density of pulses (measured in dots/inch, DPI).

Higher resolutions give clearer and more detailed the prints.

Since each pulse applies the same amount of energy regardless of resolution settings, higher resolutions deliver energy at a higher density than lower resolutions. At particularly high resolutions, the dots printed overlap meaning most of the image is printed twice, making for a darker, deeper image.



Low Resolution



High Resolution

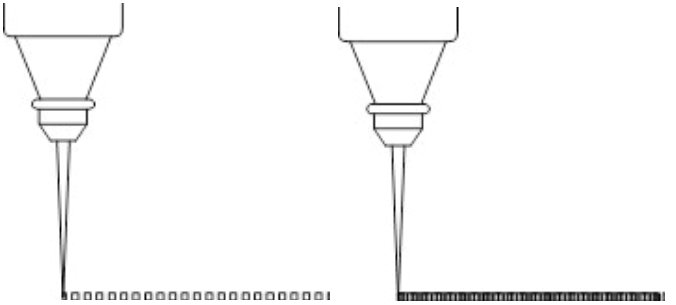
Use the infographic above to help you think about resolution as a parameter of energy transfer.

FREQUENCY (FOR VECTOR CUTTING)

Frequency indicates the number of pulses fired per second (measured in pulses fired/second, PPS, or Hz).

The higher the frequency, the denser the dots on each path, and therefore the more dense the energy applied on the material.

Both resolution and frequency are similar in that both are concerned with the number of pulses fired in an area. The major difference between the two is that resolution determines the quality of the image clarity or an area of a shape that is rastered, while frequency determines the quality of a line.



Low Frequency

High Frequency

Use the info-graphic above to help you think about frequency as a parameter of energy transfer.

EXTRA FACTORS AFFECTING ENERGY TRANSFER AND CUT QUALITY

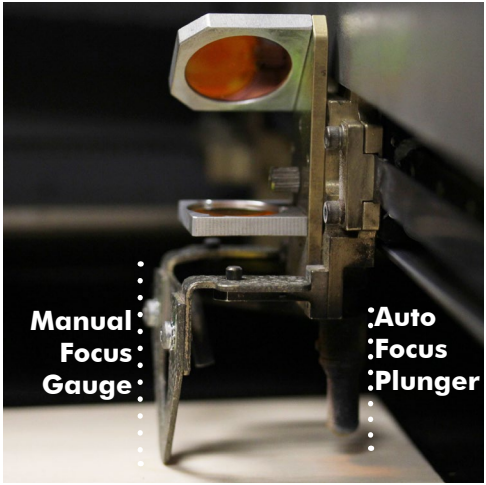
You can affect the outcome of a cut by also varying other conditions:

You can change the **number of passes** (i.e. the number of times you run the same job). This distributes the amount of energy necessary to complete a desired job over a longer period of time, which can avoid issues like charring or incomplete cuts.

As a job is running, you can stop it and **focus** on the material again. This ensures that the energy interacting with the material is the most concentrated on the top of the material.

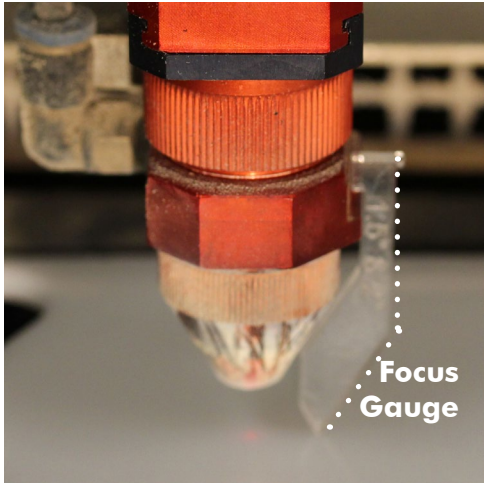
You can **mask** a material with painters tape. This reduces char or melt from spilling onto the material. Note that you may have to change the settings between a mask and un-masked material. Note in the image below that the char is only on the tape and not on the final pieces. Hooray!

MANUAL FOCUS - EPILOG



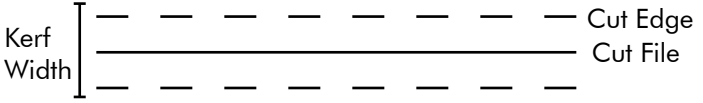
1. Mount the manual focus gauge onto the laser head.
2. First choose the location where you would like to focus. To do this navigate to the 'Service' on the Epilog LCD. Then select 'Move X/Y'. Now you can use the arrow keys to move the laser head. Press Enter to select a location.
3. Now press the 'Focus' button and use the knob to jog the table up and down. Raise the laser bed until the tip of the gauge just touches the surface of your material.

MANUAL FOCUS - TROTEC



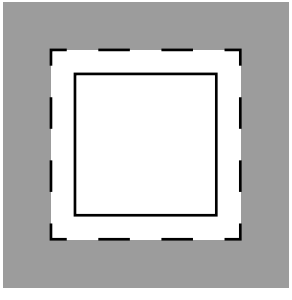
1. Hang the focus gauge from the ledge on the laser head.
2. Raise the material using the up and down arrows until the tip of the focusing tool just touches the surface of the material.

KERF

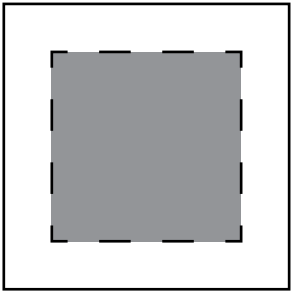


Kerf is the width of the cut made by the laser. It changes the finished size of your cut piece. If you are designing something with very tight tolerances you may want to adjust for the kerf. Kerf width changes with every cut, so it is important to take new measurements each time you are going to adjust.

Effect of Kerf

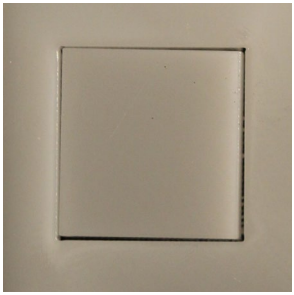


Holes get larger



Outer edges move inward

ADJUST FOR KERF



Cut a test square

Measure the square piece and the hole it left behind in the stock

The kerf width can be measured as the difference between the outer and inner measurements taken. Compensating for kerf is easy. Just add or subtract half the kerf width from the edges of your cutfile.

JIGGING AND FIXTURING

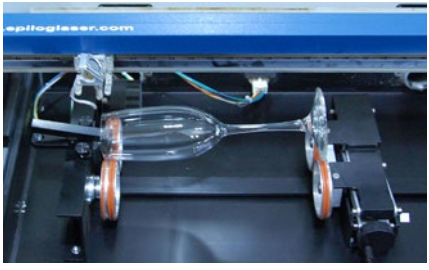
LIGHT MATERIALS

Thin, light materials should be taped down or secured with heavy objects at the edges to ensure that the air vent does not move the piece around while a job is running. Materials that tend to shift around in the bed can also be secured creating a negative mold (e.g. a circular cutout on MDF to hold a circular dog-tag).

WARPED MATERIALS

Warped materials are difficult to machine because the laser cutter cannot dynamically adjust its focus to compensate for thickness changes in material. This might be less of a problem for materials with a greater tolerance for the range of focus, as plastics. However, always try to smooth out warped objects before cutting or reduce curvature by weighing sections down with heavier objects. Either manually focus on the mid-plane between the maximum and minimum heights of the stock or refocus when you get to the warped section.

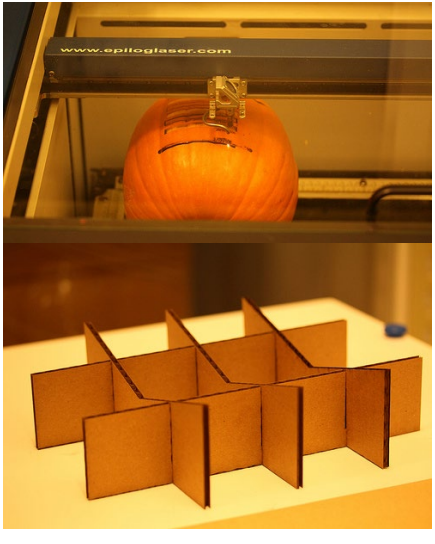
CYLINDRICAL OBJECTS



Cylindrical objects can be fixed and machined via an additional rotary device which is secured into the laser bed.

Credits: Epilog

IRREGULARLY-SHAPED OBJECTS



Custom jigs may need to be created for irregularly shaped objects. Luckily, you have access to a laser cutter, which is great for making a quick, cardboard fixture.

Credits: Mary Morse

MATERIALS

The laser cutter focuses primarily on cutting **planar stock**. Laser cutter can cut a variety of materials at a maximum thickness of about 1/4".

You cannot cut thick sheet metal, polycarbonate, vinyl, or PVC on the laser cutter as these materials produce toxic gases and can damage the machine.

This section introduces the **common** laser cut materials at Olin and discusses special techniques.

MATERIAL: ACRYLIC

- A transparent thermoplastic polymer.
- There are two main types of acrylic: extruded and cast which differ due to manufacturing technique. Extruded acrylic is often more even in thickness across the sheet than cast.
- Machines via vaporization.

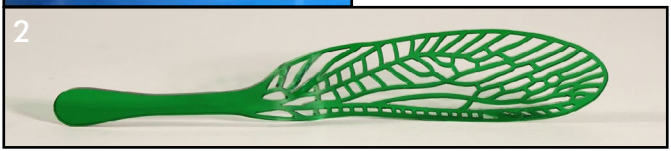


Fig. 1Engraved cast acrylic sign. Fig. 2 Intricate cut on acrylic. Then thermoformed to induce curvature.

Credits: Fig. 1 Epilog; Fig. 2 Danger Awesome

Tips & Tricks: Engraving Acrylic (Extruded vs. Cast)

- Use cast instead of extruded acrylic for rastering to have greater image contrast. Cast acrylic rasters to a frosted, white appearance.

- When engraving large areas of acrylic, fine horizontal lines from the scanning laser beam can make the image look grainy. Shift the piece from the optimum focus level by ~1.6mm so that the size of the beam is increased to achieve a blending effect.
- Flip the image of your raster file to engrave on the bottom of the material in order to view the image through the transparent piece.

Tips & Tricks: Vector Cutting Acrylic

- A glistening melt edge can be achieved on acrylic by vaporizing instead of melting the material. Use a high frequency/power and low speed combination to provide more energy to the cut zone. The shiny edge is a result of re-solidified melt, which reduces the mechanical integrity of the material.
- Unwanted markings (flashback) can occur on the back of your acrylic piece when it is cut directly on the metal bed. The excess laser energy is reflected off of the aluminum, onto the material. Avoid flashback by raising the stock a few inches above the bed before cutting.

ACRYLIC SETTINGS

Epilog 75W 32EX Legend

R or V?	Thickness	Speed	Power	DPI/Freq	Comments
R	All	100	30	600	
V	1/8"	25	100	N/A	
V	3/8-1/2"	15	100	N/A	
V	3/8-1/2"	6	100	N/A	

Trotec Speedy 300

R or V?	Thickness	Speed	Power	DPI/Freq	Comments

MATERIAL: DELRIN

- An opaque engineering thermoplastic material
- Ideal for laser cutting high precision, low friction parts
- Laser machined by vaporization of material similar to acrylic due to its low vaporization point.

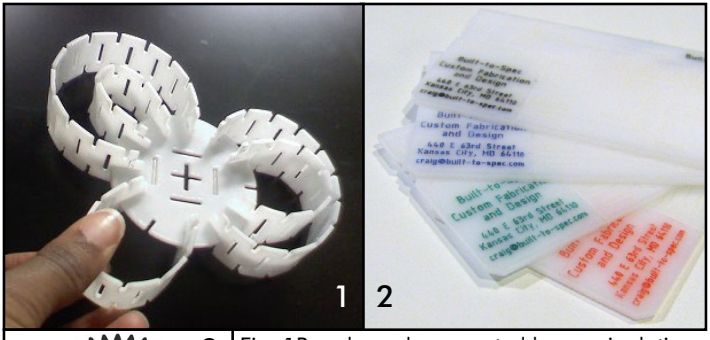


Fig. 1Rougher edges created by manipulating frequency allow friction hold. Fig. 2 Raster image contrast is provided with dry-erase marker blotting. W. 3 Laser-cut delrin can be used for high precision, low friction gears

Credits: Fig. 3 http://www.ulsinc.com/material-profile/delrin#prettyPhoto; Fig. 2 http://www.built-to-spec.com/blog/2012/05/12/adding-colored-etching-to-laser-cut-parts/; Fig. 1 http://makezine.com/2010/01/14/letters-from-the-fab-academy-part-1/

Tips & Tricks: Engraving Delrin

- Engraved delrin is always white. Engraved white delrin provides little image contrast. If more contrast is desired, the rastered area can be blotted with a colorful dry-erase marker. Prototype with this technique before finalizing designs.

Tips & Tricks: Vector Cutting Delrin

- Laser cut edges of Delrin are consistently smooth and have reasonable dimensional stability. Material should be machined at a high frequency/power and low speed combination similar to acrylic.
- It is important to place a material layer below Delrin or to prop it on a stand when vector cutting; otherwise, flash-back (see acrylic) will occur on the underside of the stock.
- Delrin is a slippery material. A rougher surface finish can be induced on your parts by decreasing the frequency of the laser cutter to create “teeth-like” features on cut edges for friction holds.

DELRIN SETTINGS

Epilog 75W 32EX Legend

R or V?	Thickness	Speed	Power	DPI/Freq	Comments

Trotec Speedy 300

R or V?	Thickness	Speed	Power	DPI/Freq	Comments

MATERIAL: MEDIUM DENSITY FIBREBOARD (MDF)

- A wood-composite combined with wax and resin under high temperatures and pressures.
- More homogeneous and therefore easier laser-machined than natural woods.
- Cut by chemical degradation (combustion), leaving a black carbon residue upon laser heating.

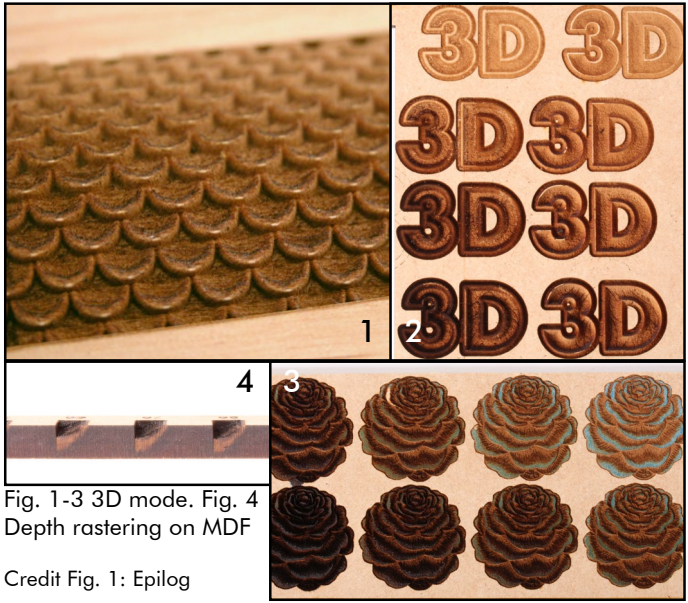


Fig. 1-3 3D mode. Fig. 4 Depth rastering on MDF

Credit Fig. 1: Epilog

Tips & Tricks: Engraving MDF

- Engraved MDF discolors to an orange-brown which gets darker with increasing laser energy density. Mask the material to avoid surface residue from resin and adhesives released from the material upon heating.
- MDF engraves really well with grayscales and in 3D mode if your laser system possesses this setting. Great variation in height and color result.

Tips & Tricks: Vector Cutting MDF

- Thinner sheets of MDF can be cut through with a single pass. However anything above ~3mm (~1/8") is best machined with multiple passes to improve cut quality.
- Soot which collects on the cut edges can be removed with a dry towel that does not leave fibers on the material, or even better with a chamois cloth or eraser.
- Similar to engraving MDF, it is useful to mask the material before vector cutting to reduce surface build-up of residue.

MDF SETTINGS

Epilog 75W 32EX Legend

R or V?	Thickness	Speed	Power	DPI/Freq	Comments

Trotec Speedy 300

R or V?	Thickness	Speed	Power	DPI/Freq	Comments

MATERIAL: CORRUGATED CARDBOARD

- A wood-based composite material made up of layers of corrugated paperboard.
- Mainly used for packaging and shipping.
- Since cardboard is a widely available material, it is ideal for quick prototyping.
- Since wood fibers have a burning point that is much lower than their melting temperature, cardboard is laser machined by chemical degradation.

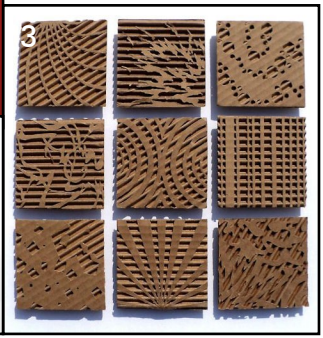


Fig. 1Direction of cardboard flutes creates aesthetic effect. Fig. 2 Lunch box of cardboard layers. Fig. 3 Selective removal of cardboard layers.

Credits: Fig. 1 http://www.instructables.com/id/Spherical-Corrugated cardboard-Lamp/; Fig. 2 Laser Brothers; Fig. 3 http://media-cache-ak0.pinimg.com/736x/c6/13/c4/c613c4d13227a981756ec7e368b4c419.jpg

Tips & Tricks: Vector Cutting Cardboard

- Laser cut edges of corrugated cardboard will be have some residual carbon leaving the edges a dark brown or black color. This will be difficult to eliminate entirely, but may be reduced by fine tuning the settings.
- The precision of the laser cutter allows you to select the individual layers which you cut through. You can vector cut a pattern out of the top layer of the corrugated cardboard, then selectively peel away certain parts. Wetting the top surface of the corrugated cardboard with a Q-tip may make peeling it away cleaner and easier. When peeled away dry, the material has a tendency to tear and leave small pieces that make the finished product look messy.

CARDBOARD SETTINGS

Epilog 75W 32EX Legend

R or V?	Thickness	Speed	Power	DPI/Freq	Comments

Trotec Speedy 300

R or V?	Thickness	Speed	Power	DPI/Freq	Comments

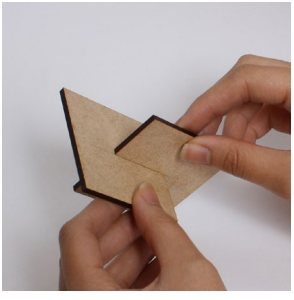
JOINTS

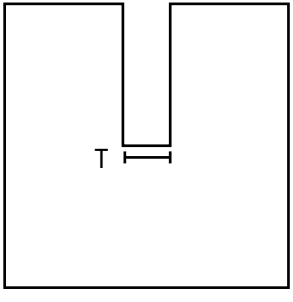
Through a combination of woodworking and laser cutting specific joints, you can create beautiful and mechanically sturdy **structures and mechanisms**, like Annie and Ingrid's lantern.

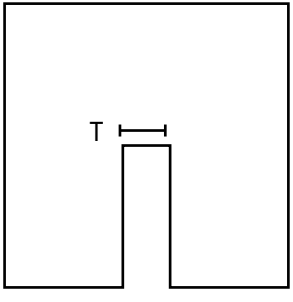
This section showcases three **beginner joints**: the slot, finger, and mortise and tenon joints. Get inspired by joints by exploring what the internet has to offer and examining woodworking or plastic joinery methods!

SLOT JOINTS

The slot joint is a very simple joint to design and construct. Finished pieces are assembled by sliding into slots at right angles to one another.



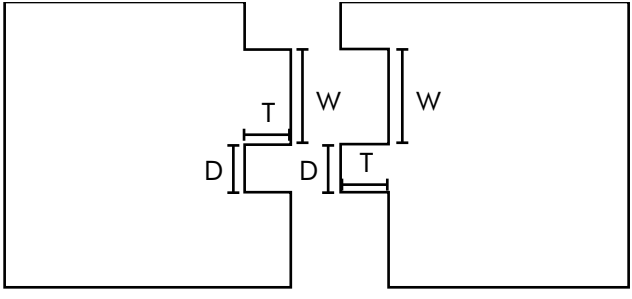




The only crucial dimension is the width of the slot, T, which corresponds to the thickness of the material being used.

FINGER JOINTS

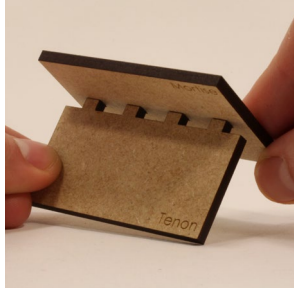
Finger joints are a simple way to join two perpendicular pieces of material at an edge. The joint can be secured by using

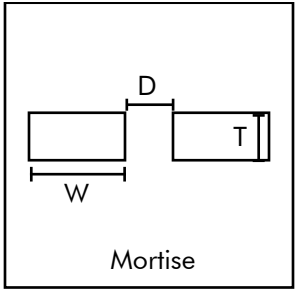


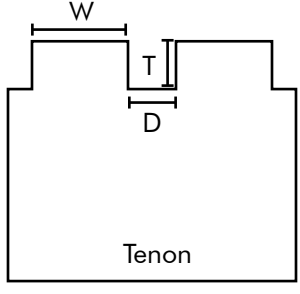
W - Width of finger
D - Distance between fingers
T - Thickness of material

MORTISE & TENON

The mortise & tenon allows you to attach two pieces of material at a right angle to form T shaped joint. The joint is often glued or press fit to create a strong, permanent connection.







W - width of mortise
D - Distance between mortises
T - Thickness of material

ADDITIONAL RESOURCES

- Epilog Legend 32x Manual: *http://www.epilogfiles.com/extt_manual.pdf*

- Trotec Speedy 300
  - Software manual: *http://www.troteclaser.com/en-US/Support/Documents/JobControl-Manual-EN.pdf*
  - Laser System manual: *http://www.troteclaser.com/en-US/Support/Documents/Speedy-300-Manual-EN.pdf*

- *CO_2 Laser Cutting* by John Powell

- *LIA Guide to Laser Cutting* by the Laser Institute of America

- For inspiration:
  - TLC: http://thelasercutter.blogspot.com/
  - Pinterest, MakeZine & Instructables
  - Laser Brothers Facebook Page
  - Snijlab: https://www.snijlab.nl/en/p/29/examples
  - University of Buenos Aires, Morphology and Digital Fabrication Lab: http://workshopmyt.blogspot.com/
  - University of Minnesota, College of Art: http://blog.lib.umn.edu/artdept/lasercutter/

BRAINSTORMING & FEEDBACK

MAINTENANCE

Maintenance is possibly one of the most significant aspects to laser cutting. A poorly kept machine and work area reduce cut/engraving quality and increase the likelihood of a fire hazard.

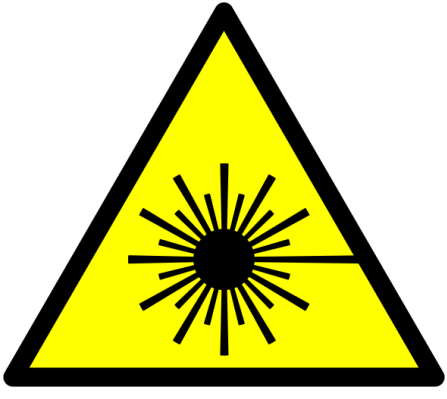
Clean-Up Checklist

All **WIPE-DOWN** procedures should be done with a wet paper towel, Windex, or isopropyl alcohol.

1. **WIPE DOWN** the periphery of the laser bed (ruler area).
2. **WIPE DOWN** the auto-focus plunger.
3. The external optics system can incur a build-up of debris from excessive flare-ups. This can reduce the quality of the cut produced. ONLY clean the mirror and focus lens if you have been trained to do so. If not, inform someone in the shop of the debris/residue.
4. **REMOVE** any small, residual pieces of stock from the cutting bed left from the job.
5. **EMPTY** the crumb tray.
6. **REMOVE** clutter around the machine to keep the area clear of combustible materials.

Wait! Before you cut, did you?

- Test your settings?
- Measure the kerf?
- Fix material securely to the bed?
- Focus?
- Turn on air filters/ ventilation?



Got a question or feedback?

Email the NINJAs at lasers@lists.olin.edu