

# *Pic Engrave Pro 5*

Spindle and Laser 

Standard and GRBL Gcode Generator  
for  
Image Engraving

February 2015



Photo courtesy of Mr. Jeffery Woodcock.

## Acknowledgments

PicEngrave Pro 5 has been written and developed to convert images to gcode for engraving with a variety of different methods with cnc machines equipped with either rotary spindles or lasers.

A special acknowledgment is made of the contributions of Mr. Jeffery Woodcock, master machinist, inventor, and highly skilled artisan, who doggedly invented, developed, and pioneered the use of low power laser diodes to engrave true gray scale images in various materials, which has never been done, and in a way that is impossible to do, with high powered CO<sub>2</sub> and similar gas discharge lasers.

Jeff's laser diode engraving method is truly unique in the both the cnc and art worlds, and without his willingness to freely share information and his invaluable advice, this software would not now be available to those who desire to participate in his new, modern form of creating art.

Special appreciation is also due to Mr. Dave Gabry, who designed a unique, yet simple to build, electronic circuit to convert cnc stepper control signals (as output by Mach3, Linuxcnc, and other cnc controller programs) into an analog signal for the modulation of laser diodes, as described later in this paper. Dave's circuit, and its unique use, is a first, too, having not been previously done by any others as far as is known to this author.

More information and examples from these two pioneering gentlemen may be found posted on various internet forums, most notably of which are:

ArtSoft (<http://www.machsupport.com/forum/index.php/topic,23584.0.html>)

Vetric (<http://www.vetric.com/forum/viewtopic.php?f=16&t=13405>)

Hobbycncart (<http://hobbycncart.com/forum/63-151-4>)

And lastly, though far from least, my special appreciation goes to my wife, life partner, and mother of my children for her limitless love, patience, and understanding of my long hours locked away in my office and shop writing and testing this program.

John Champlain

February 2015

## Instructions

PicEngrave Pro 5 (PEP5), +Laser, will generate a gcode file from five popular image file types, either color or gray scale. Supported file types are: jpg, bmp, png, gif, and tif. Original program © July 28, 2004. All Rights Reserved.

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### Image File Selection

The 'Select Image' button opens up a standard MS Windows file directory window. Select an image file and click '**Open**'. The image will be displayed on screen along with buttons for various functions.

If the '**Cancel**' button is clicked without an image being selected, a pop up message will display. Click '**OK**' and repeat the selection process, or exit the program.

The selection process may be repeated at any time as long as the '**Select Image**' button is displayed.

If PEP5 is being used in demo mode, all images will be watermarked. Upon verification of purchase via [www.picengrave.com](http://www.picengrave.com), a registration key code will be emailed to you. Enter the registration info using the '**Register Program**' button, and then reselect an image and the watermarks will be removed. You may use the same registration key code to install and register the program on all computers that you own and/or personally use.

Please note: If you do not receive the registration email within a couple of days following purchase completion, please make sure you did enter your email address correctly, or check your email spam folder.

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### Image Selection and Preparation

PEP5 has some basic editing features to allow you to adjust your images to improve your engravings. There are many good programs available with additional editing features should you desire to do more than is possible with PEP5. Two of our favorite free photo editors are: GIMP (<http://www.gimp.org/>), and: Irfanview (<http://www.irfanview.com/>).

When editing an image for engraving, some experimentation may be needed for best results. Color images can be viewed in gray scale by selecting the '**View Gray Scale**' check box. This will assist you in more closely judging what your final engraved image will look like.

Hint: Some images, especially those scanned from a print or film, may exhibit small "white marks" randomly scattered throughout the image. These are usually caused by dust on the surface of the scanner glass, and/or scratches and other damage in the original print. If you are

engraving lithophanes, these "white marks" will be magnified by the size and shape of your engraving bit. For better results, they should be retouched using your favorite image editor's tools before you proceed to generate a gcode file. Using sharp pointed engraving bits with shallow angles (less than 30°) can help to minimize this issue with lithophanes.

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### **Rotate Image and Flip Image**

After an image has been selected, and before it is loaded for conversion, it may be rotated and/or flipped to re-orient it. The '**Rotate Image**' button will rotate the image 90° to the right each time it is clicked, and the '**Flip Image**' button will flip the image horizontally.

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### **Loading an Image**

With an image displayed on screen, clicking the '**Load Image**' button will load the file into your computer's memory and prepare it for conversion to gcode.

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### **Generating Gcode**

After an image has been loaded, a '**Generate Gcode**' button will appear. When clicked, this button begins the actual generation of the gcode file. The '**Generate Gcode**' button will disappear at the end of this process. You may still repeat the image selection process, or proceed to the next step.

Please Note: In some modes, PEP5 will optimize the gcode to eliminate some unneeded gcode lines where the 3rd axis (Z) depth is not changing. This is accomplished by the use of a proprietary and unique gcode generation algorithm that will not reduce the resolution of your final engraved images. The final gcode can be significantly smaller (depending upon the initial image) and will run faster than gcode produced by other competing programs. This optimization will be done with a different algorithm if laser gcode is being generated.

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### **Saving a Gcode File**

When the '**Save Gcode**' button appears, clicking it will generate and save a gcode file to a preselected folder on your computer. PEP5 will not overwrite a previous file without warning.

'**File Extension**' should be changed to suit your cnc controller gcode file naming requirements. The name of the gcode file can be entered when you save a gcode file.

**'Gcode Directory'** This is used to determine where the gcode file will be saved on your computer. If the file directory does not exist, it will be created by your MS Windows operating system when you save the gcode.

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### **Program Configuration Settings**

When visible, the **'Show (Hide) Settings'** button will allow you to select or change picture engraving parameters. Settings may be changed at any time until the **'Generate Gcode'** button appears.

### **Choose Engraving Profile**

PEP5 allows you to save your customized configuration settings in six different profiles for later reuse. The profiles are saved on your computer as plain text files with a file extension of **'.ini'**. When a profile is selected, the last settings saved for that profile will be automatically loaded and used to setup and generate the gcode files. After changing any setting, the profile is updated by clicking on the **'Save Settings'** button. If you change a setting, but do not wish to change the saved profile, click on the **'Hide Settings'** or the **'Close'** button, and the profile will not be saved to your computer, but the changed setting will be still used to generate the gcode for that session. Selecting a profile will display the settings that are available for setting up that particular profile, and will hide those settings that cannot be used.

**CAUTION:** Manually modifying the profile files may cause PEP5 to malfunction.

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### **Gcode Setup**

#### **'Metric Mode'**

Enabling this option will clear all setting and setup PEP5 to work in metric units. If you accidentally clicked this option, do not click the **'Save and Close'** button, unclick the metric option, then reselect the profile you want to use, and your previous settings should be restored.

**'Feed Rate'** Enter a number that is suitable for your machine and the material you are engraving. It is recommended that you start out with a slower rate until you see how your machine responds to engraving operations, and then increase the rate until you achieve acceptable performance.

**'Pixel Resolution'** sets the engraved pixel size of your images, and is the distance that the X and Y axes move between pixels and scan lines. It affects the final size of an engraved image. The default resolution for all images is 0.010 inch / 0.254 mm.

'**Max. 3rd Axis Depth**' determines how deep black colors will be engraved. If the colors have been reversed by the '**Lithophane Gcode/Negative Colors**' option, then white colors will be the deepest. The correct depth for engraving will vary depending upon the engraved material type, bit style and size, and other engraving and machine setting parameters. In some cases this setting must be a negative number. Experimentation is needed to determine what works best for your engravings. For lithophanes, a depth of minus 0.1 inch is a good starting value for DuPont Corian and similar materials with a total thickness of about 0.15 inches.

'**Min. 3rd Axis Depth**' is used to set the shallowest depth of an engraving, and in some cases also needs to be a negative number that is less than the '**Max. 3rd Axis Depth**' value. It is usually used to compensate for surface height variations in the material being engraved, and sets the "zero" point of the engraving depth. Normally it should be set to 0.0.

Note: all engraving depths are negative with reference to the top surface (Z0) of the engraved material.

'**3rd Axis (Z) Safe Position**' should be set so the tool bit will clear the upper surface of your work piece and any fixture clamps or other obstructions. For laser engraving it is usually set to 0.0.

'**X Start Position**' and '**Y Start Position**' determine the offset from the initial image zero (X0/Y0) position you have selected for an engraved image.

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### Gcode Options

'**Insert G61/64**' is included so Mach3 users can select Exact Stop (G61) mode and turn off Constant Velocity (CV) mode (G64) when a straight sided edge is to be engraved. This will minimize the rounding of edge corners sometime caused by a Mach3 CV setting. Using CV mode during actual image engraving will reduce engraving time and smooth out machine movements.

'**Spindle On/Off**' inserts M03 and M05 commands to start and stop your engraving spindle/laser relay if your controller is set up for automatic control.

'**Comment Gcode**' will record key engraving parameters and options to the beginning of each gcode file for future reference.

'**Start Comments**' and '**End Comments**' are characters used by your gcode controller program to indicate program comments that are not actual gcode control commands. Refer to your controller documentation to properly enter these characters.

'**End w/ G28**' will insert a G28 gcode command as the last command in a gcode file. It is used by some Arduino GRBL controllers in place of Mach3's M30.

'**Axis Letters**' may be set to your choice of 'A', 'B', 'C', 'F', 'S', 'X', 'Y', or 'Z', depending upon the engraving profile and other options you have chosen.

'**Initial Image Zero**' sets either the lower left, or the center, of your image as the initial X0/Y0 starting point.

'**Precode**' and '**Postcode**' buttons allow the inclusion of specific gcodes that may be required for your controller program to operate properly. Click on the buttons to manually enter your codes. When the '**Close**' button is clicked, your codes will be saved to a file for use each time the program runs.

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### Engraving Angles

These settings determine the path angle your spindle or laser will traverse when engraving. When allowable, the '**Left - 45°**', '**Right - 45°**', '**Horizontal**', and '**Vertical**' angles may all be selected (or any combination of them) at the same time. Selecting more than one of these options will increase both the size of the gcode file and the total engraving time, but doing so may also improve your image's engraved quality. Some angles are not available for some engraving profiles.

'**Horizontal 2X**' and '**Vertical 2X**' check boxes will double the normal number of engraved lines for a finer engraving resolution, without affecting the finished engraved image size. Only one 2X option can be selected at a time, and not in combination with any other angle option. Selecting either of the 2X options will unselect the other angle options. As an example, if the '**Pixel Resolution**' is set to 0.01 inch, then the 2X angle options will engrave an image with a line-to-line spacing of 0.005 inches while maintaining a pixel-to-pixel spacing on each line at 0.01 inches. This can be especially useful to improve the engraved quality and details of lithophanes.

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### Engraving Options

'**Engrave Ellipse**' option will allow you to select an area of the picture to be engraved within an elliptical or circular shape that you set and position with the slider controls. All pixels of an image that are outside the ellipse will be ignored when the gcode is generated. The X0/Y0 reference points of the gcode will be set to the left side and bottom edge intersection point of the ellipse if the '**Initial Image Zero**' option is set to the '**Lower Left**' of the image, and will be centered within the ellipse if the '**Center**' option is selected.

'**Ellipse Edge**' when selected will engrave an elliptical border to the '**Max. 3rd Axis Depth**' if the '**Rotary Spindle**' profile is selected. It is not used with laser profiles.

'**Engrave Edge**' will engrave an edge around the perimeter of straight-sided images at a depth corresponding to the '**Max. 3rd Axis Depth**' setting, and at the width of the engraving bit. This helps in reducing cutting forces on the cutting bit when beginning an image, and reduces the jagged appearance sometimes caused by the bit around the perimeter of an engraving, especially a lithophane. Edges are engraved in five passes, each of increasing depth, until the '**Max. 3rd Axis Depth**' is reached. This option selection is only usable for rotary spindle engraving.

'**Crop Image**' option works similar to the 'Engrave Ellipse' option except it is used to reduce (crop) the engraved size of straight sided images.

'**Edge FR**' should be set to use a slower edge engraving feed rate than that used for images to minimize cutting stresses and bit breakage. This feature is set separately for spindle and laser engraving.

'**Lithophane Gcode/Reverse Colors**' option reverses the depth of cut for light and dark pixels of images for lithophanes and mirrors, which are usually engraved as negative images.

'**Skip White Bkgnd**', when enabled, skips over the generation of gcode lines for all duplicate white background pixels, reducing engraving times.

'**Use Feed Rate Change**' This feature is unique to PEP5, and can be used with both spindle and laser engraving. When used with spindle engraving, it will reduce bit loading when heavier (deeper) cuts are made. When used with laser engraving, it will increase the burning of darker colored pixels.

When enabled, each gcode line will have a feed rate command added to the end. The feed rate value is calculated with a proprietary formula using the gray scale value of the pixel to be engraved, and the percentage value entered into the '**% Feed Rate Change**' text box. A typical value for laser engraving most wood types will range between 10% and 40%. Some experimentation will be needed to determine the best value to use. Using this control should result in a better contrast of laser diode engraved images, and possibly less bit breakage when spindle engraving.

'**Extended Edge**' When higher power laser diodes are used at higher feed rates, abrupt axis direction changes can introduce vibrations in the laser beam at the edges of images, causing the laser to burn pixels out-of-alignment. Using the extended edge option will reduce power to the laser to its minimum value, and "extend" the axis movement beyond the edge of the image before direction reverses. When using this option, be sure to allow for the additional tool travel distances when you place your work pieces on the machine table.



## Laser Options

**'TTL Laser Gcode'** Using TTL control, there are two options. With **'TTL Laser Gcode'** unchecked, the gcode is formatted similar to "Analog Laser" gcode, with X, Y, and Z moves on the same line. A machine should run smoother with this format. When **'TTL Laser Gcode'** is checked, the gcode is formatted with the Z move on separate line from the X and Y moves. This may result in a slower machine operation, but may be better for some types of engraving, such as impact.

For TTL engraving, images must first be dithered so they are composed of only two colors, usually black and white. A dithered image is similar to the halftone images printed in magazines and newspapers. The dithering algorithms included in PEP5 are used to prepare an image for TTL laser engraving. As the laser scans across a dithered image, it is either at reduced power, or fully off, for all white pixels, and is fully on at its preset power for all black pixels. TTL mode is useful for some materials (such as leather) which burn so easily as to not be able to show well defined shades of gray. This mode does not require an analog laser driver, so a TTL only driver can be used with good results.

For a more detailed explanation of dithering, users should read the paper on image dithering also appended to this document.

**'Rapid Retract Height'**, when set to a positive number, is useful with some types of analog controllers, such as a rotary encoder. Normally it should be left set to 0.0.

**'Laser Edge'** engraves an outline around the perimeter of an image at a feed rate set by the **'Laser Feed Rate'** value, before laser engraving the image. If the **'Width in Pixels'** is set to other than 1, additional passes will be made around an edge, each offset 1 pixel from the previous pass.

**'Laser Edge Power Command'** Enter the command that your system uses to turn on the laser to the power level desired. Ex: Z-.0255.

**'Laser VFR Power Control Commands'** set the minimum and maximum laser power commands that are used when engraving images using a variable feed rate instead of a variable laser power. VFR mode is useful for gray shade engraving of mirrors, and for engraving gray shade images with a TTL laser controller.

## Special Functions

'**Align X/Y Axes**' PEP5 produces gcode that engraves bi-directionally. Some machines have excessive backlash will not engrave images well. To improve engraving, PEP5 allows either X or Y movements to be offset in one movement direction, thus aligning the pixels more accurately. Once set for a particular machine, the settings will remain in use for every image until changed.

To set, engrave a small dithered image using the TTL profile and adjust the correct axis offset as determined by observing the placement of the dithered points (pixels) in the image.

'**Rotary Axis Setup**' This function, when enabled, will generate gcode that can be used with a 4th axis rotary attachment for engraving on cylinders. It will only be optional if the '**Horizontal**' engraving angle is first selected, and only with an "A" axis.

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'**Save Settings**' button updates all of your preferred settings to a configuration file on your computer that is automatically loaded for reuse each time the program starts up. CAUTION: Configuration files (\*.ini) should not be manually edited.

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## Edit Image Button

When the '**Edit Image**' button is clicked, a separate program that operates only within PEP5 will open. This program will allow you to reduce or increase the size of an image, change its aspect (width-to-height ratio), and adjust its sharpness, brightness, contrast and gamma properties. Edited images will need to be saved on your computer for subsequent opening in PEP5. It is not necessary to first open an image in PEP5 in order to use the editing function, but it will be necessary to 'reselect' an image if it has been edited and saved after having first been selected and opened in PEP5.

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## Add Text

This is another separate program that runs only within PEP5 to add text to an image. Full control of the text and font are possible before saving the image. For multi-line text, add each line separately to your image.

Hint: For best results, add text only AFTER all other editing is completed.

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## Gray Curve

'**Apply Gray Curve**' will lighten the mid-range gray shades in an image. This is useful to compensate for some woods and other materials to over-burn, creating darker engravings. The

higher the value set on the slider control, the greater the lightening effect. On large images it may take a few minutes to finish before the effect can be viewed, especially on slower computers.

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### **Working With Lasers**

Laser diodes (LDs) with a power output of between 1 and 2 watts are being used more and more to engrave very detailed images into various types of wood and other suitable materials with cnc routers. The LDs replace conventional engraving spindles. This use of LDs with cnc machines is in its infancy, and new developments are occurring frequently.

Setting up and using LDs requires specialized equipment, knowledge, experience, and safety precautions to prevent harmful injuries to individuals, animals, and property. The improper and unsafe operation of high power laser diodes can cause permanent injury to individuals and animals, and property damage, even at significant distances from the LDs.

Information concerning how to physically setup and use LDs is appended to the end of this document. Readers are also encouraged to search the Internet for more information on their availability, lawful use, and, more importantly, their safe use requirements.

Please always work safely, and never apply power to a laser diode without assuring that all individuals within sight of a powered laser diode are wearing specifically approved laser safety glasses. Never look at the beam of an LD without wearing special safety glasses, and never, under any circumstances, aim the beam directly into anyone's eyes, even through safety glasses. Permanent blindness will result.

### **Analog Control**

With analog control, as the laser scans across the image area, its power will increase and decrease (modulate) in proportion to the gray shade value of each pixel in the scan line. Higher power burns darker pixels and lower power burns lighter pixels while the scanning velocity of the laser remains constant. Analog control requires the use of a digital to analog converter (a DAC) to generate a varying control voltage that is compatible with some LD controllers specifically designed to modulate the power to the LD. Commonly a signal range of 0 to 5 volts DC is used.

Analog control signals can be generated either by an electronic circuit, or by a mechanical encoder connected to a stepper motor (which is the method developed and very successfully used by Jeff Woodcock, mentioned earlier in this paper.

The electronic DAC accepts step and direction signals directly from the parallel port of a computer running a cnc controller software program (such as ArtSoft's Mach3). It then outputs a signal voltage that is proportional to the number of step signals being output.

Constant power can now be used in two different modes: TTL or VFR (a newly developed method).

### VFR Control

VFR (variable feed rate) control is a newly developed unique method of engraving true gray shade values. This method can also be used with a laser diode driver that supports only TTL input if an analog controlled driver is unavailable. The laser power remains constant during a file run, and the axis speed will change so the laser burns darker at slower speeds for pixels with darker shades, and moves faster for those with lighter shades. Some versions of Mach3 may not support variable feed rates on each gcode line, and you may need to upgrade Mach3 to a newer version for a smooth axis movement.

The use of PEP5 for cnc control of LDs is at the sole risk of the LD owner/operator, and no liability will be assumed or assigned to PEP5 or its author for any problems that arise from such use.

### Rotary Engraving

This version of PEP will generate gcode for use with rotary attachments for both milling and laser engraving. The rotary attachment must be set up as an A axis only (see following diagram), B and C axes are not supported at this time.

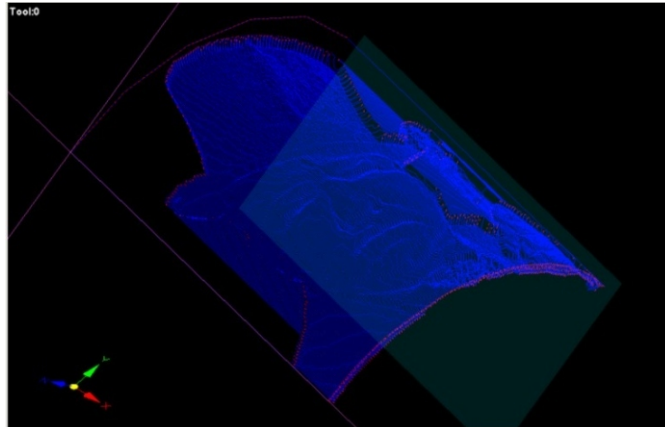


The 'Right Hand Rule' convention is used throughout:-  
Take your right hand, make a fist, point your thumb in the positive direction of an axis, the direction of your fingers gives you the positive direction of rotation around that axis

Source: <http://www.cnc-toolkit.com/support.html>

Please note before reading further: The rotary gcode generated by PEP5 is different than that produced or converted by other software. It uses a built-in scaling functions of Mach3 (G51/G50

gcode commands), and the gcode file may not run properly in other cnc controller programs. Please test carefully before actual use. To view the tool path properly, Mach3 must properly configured to display rotary tool paths. Your feedback to improve this function of PEP5 will be greatly appreciated.



**Mach3 Rotary Toolpath Display**

Use the '**Rotate Image**' function of PEP to correctly orient your image for rotary engraving before generating a gcode file. The 2<sup>nd</sup> axis (normally 'Y') will be converted to the rotary axis 'A'. Enter the diameter of the work piece being engraved, and PEP5 will calculate and display the percentage of the circumference the image will wrap around the work piece. Use the Edit function of PEP to resize your images if more or less wrap percentage is desired. Click the 'Apply' button to calculate and display the wrap percentage and setup PEP to generate rotary gcode.

For rotary engraving, PEP will insert a G51 A-x.x command at the beginning of the gcode file, where x.x is a negative scale factor that sets up Mach3's scaling factors for rotary engraving. Be sure that the A axis is designated as a rotary axis in Mach3 (Config>General Config...>A Axis is Angular must be checked), and that your rotary axis is properly configured. A G50 code will be entered at the end of the gcode file to reset Mach3.

Rotary gcode as produced by PEP5 will display A moves in the code as though the code is for a non-rotary engraving, but the A DRO in Mach3 will properly display A axis moves in degrees scaled 0° to 360°.

The setup and settings for rotary engraving must be reapplied each time rotary engraving is desired.

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## **Comments**

Hint: a careful observation of the first couple of passes of an engraved edge may reveal whether or not the surface of the material is flat and even, helping to avoid non-engraved areas when the 3rd axis depth is engraving at a zero depth. This is especially useful when engraving lithophanes. The engraving bit should always be zeroed to the thinnest part of your material (or slightly below) for best engraving results.

PicEngrave Pro 5 +Laser is frequently updated as experience and user reports validate reasons for improvements, and this document may not cover all settings and options of the current release version. The latest version of PEP5 will always be posted here:  
<http://www.picengrave.com/> .

The feed rate must be higher than zero (0) before a gcode file can be generated.

Never apply power to a laser diode without first assuring that all persons and animals within sight of the laser are wearing appropriate safety glasses. Laser diodes can instantly and permanently damage eyesight, and possibly cause total blindness, even if not being viewed directly should the laser beam be reflected from some surfaces into someone's eye(s). This can occur even at a significant distance (possibly miles away) from the laser beam's source. The user/operator of any laser equipment assumes all liability for their safe use, and no liability will be assigned to, or assumed by, the author of this paper or PicEngrave software. Users of PicEngrave Pro 5 assume all liability for its use. Please work safely and carefully.

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This software is made available with no guarantees as to its suitability for any use. All risks remain with the user.

Thank You.  
John Champlain and Jeff Woodcock  
[www.picengrave.com](http://www.picengrave.com)

# Analog Laser Diode Setup for Gray Scale Image Engraving

[www.picengrave.com](http://www.picengrave.com)

A special appreciation goes to Mr. Jeff Woodcock, and his son Jeffery, for their assistance and photos.

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This brief paper describes two control systems (mechanical and electronic) currently in use to control a 1 to 2 watt, 445 laser diode for image etching.

## Safety

The power levels of the laser diodes (and actually all laser diodes, and commonly available laser pointers as well) that are used for image engraving can be instantly dangerous to the safety and eyesight of users and bystanders when used recklessly and without proper safety precautions. All users and others within sight of an operating laser diode, regardless of separation distance, must at a minimum wear the correct type of safety glasses specified for the laser light wavelength in use. Suitable safety glasses are available from many sources, and laser diode owners and users must never operate a laser diode without first assuring that all persons within the viewable range (which can be a considerable distance away) are properly equipped with, and wearing, approved safety glasses.

All laser machines should be fully enclosed within a housing specifically designed to completely prevent the laser beam from being seen by anyone when in operation.

Under no circumstances will the author of this document be held responsible for any injury to the reader or others, or for any damage to surrounding property. All responsibility for safe laser diode operations remain with the user.

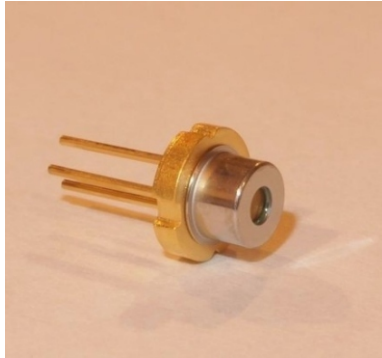
## Safety Glasses

Typical safety glasses look like the following image, and are available from many sources. Assuring the suitability of any specific pair of safety glasses for eye safety is the user's sole responsibility.

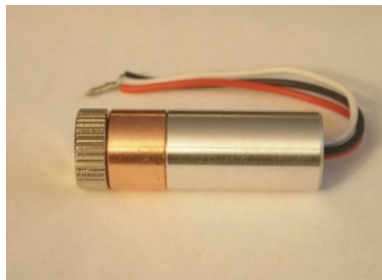


## Laser Diodes

Laser diodes are available with different wavelengths and characteristics. While some of them may be suitable for image engraving, the type of laser diode we are using very successfully is the 445nm diode with 1 to 2 watts power rating. These emit a bluish beam that can be focused with a suitable lens to a dot point that is about 0.005 to 0.007 inches in diameter.



For our use, these diodes must be installed in a suitable housing (below), which has an easily adjustable focusing lens.



If you're looking for a complete laser photo engraving solution to use with our software programs, visit J Tech Photonics website here: [jtechphotonics.com](http://jtechphotonics.com)





## Lenses

Lenses we use to laser engrave photos are the AR coated 3 element glass, or J Tech's high quality precision G2 lens. The G2 lens that is included with there laser systems give you 30% more power then the 3 element glass and will allow you to cut materials, or engrave fine detailed photos.



445nm Glass Collimating Lens/M9P0.5 Metal Frame

## Heat Sinks

Laser diodes produce a lot of heat at the power levels and duration needed for image engraving, so an adequate heat sink is required.



Typical Heat Sinks

You may choose to custom fabricate a heat sink to fit your particular installation. A spare CPU aluminum heat sink might be easily machinable to fit the 12mm diode housing, and cooled with a small brushless computer cooling fan. With this design, or similar, the fan will not only cool the heat sink, but if arranged as shown below, can also blow smoke away from the lens.



Heat sink made from a spare aluminum CPU heat sink

Much information about laser diodes can be found on the Laser Pointer Forums: (<http://laserpointerforums.com/>).

## Control Methods

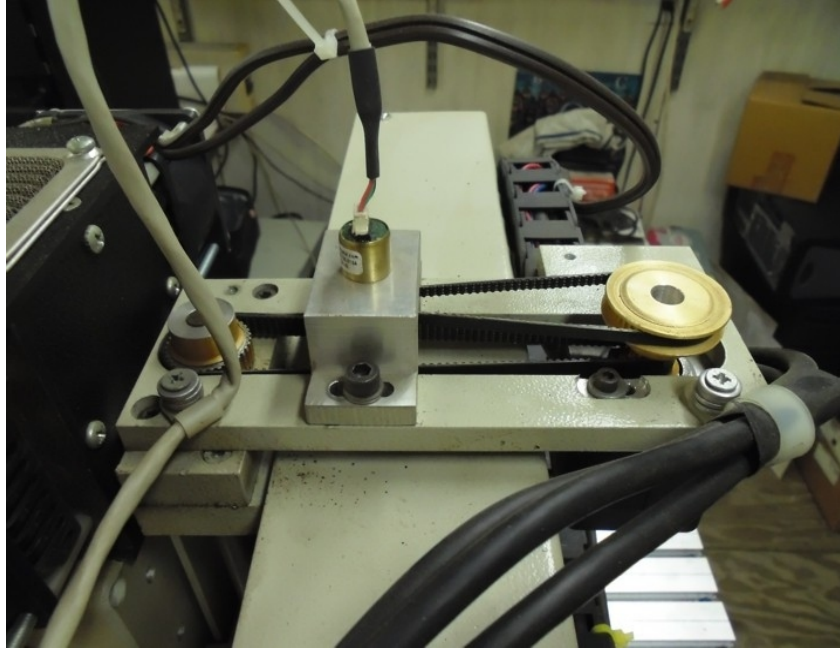
### Electro-Mechanical Method

Jeff Woodcock, who developed laser gray shade image engraving, or etching, uses a US Digital MA3 electromechanical rotary encoder coupled to the Z axis of his routers to produce a proportional 0 to 5 vdc voltage signal to vary the power to his 445nm laser diodes. The 5 vdc power for the encoder is simply obtained from a spare USB port on Jeff's cnc computer.



(<http://www.usdigital.com/products/encoders/absolute/rotary/shaft/ma3>)

The output from the encoder is connected directly to the signal input of an analog laser diode driver. The encoder is connected to the Z axis stepper motor of Jeff's router with timing pulleys and a short timing belt.



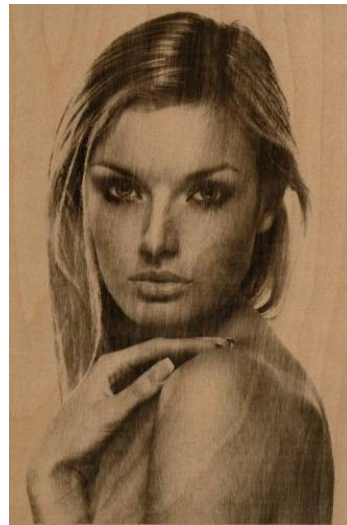
An Instructable of Jeff's Shapeoko 2 set up similar to this photo is here:  
<http://www.instructables.com/id/Shapeoko-2-Arduino-UNO-R3-grbl-9g-8bit-Raster-Phot/>

In Jeff's current setup shown in the photo above, the stepper motor pulley has 40 teeth and the encoder pulley has 12 teeth, for a ratio of 3.33:1. The Z axis drive uses a separate set of pulleys with a drive ratio of 2:1, so the Z axis moves only  $\frac{1}{2}$  the distance called for in the gcode. This arrangement provides a 0 to 5 volt signal with a Z movement of just -0.0128 inches. This reduction of the Z axis movement prevents any significant change of the laser's focal point on the material being etched. Jeff's encoder setup provides 256 encoder positions of 0.0001 inches each, or, in other words, 256 theoretical gray shades in an engraved image.

To burn his images, Jeff sets up PEP4 so the Z axis "Minimum Depth" (image zero point) is at -0.0037 inches from where the encoder output voltage will roll over to 5V (which is where the laser just begins to burn the wood); Jeff zeros the Z axis on his machine there. Then he sets up the "Maximum Depth" in PEP4 to -0.0256 inches. The Z axis "Safe Position" setting is then set to .0035 inches, which gives a safety margin of 0.0002 inches from the position where the encoder will roll over to full on power. With these settings, PEP4 will produce a gcode file with a full 256 shades of gray resolution.

With Jeff's setup, the Z axis can also be used to set the focal point of the laser for different material thicknesses without needing to manually refocus the laser lens.

To rapidly pulse the laser on and off (for black and white images, or TTL), the Z axis direction pin is reversed so the encoder "jumps" to full output (5 volts) instantly for the black colors of an image, and back to 0 vdc for white. Jeff sets the encoder .0005 inches from the rollover point and zeros the machine's Z axis there and sets up PEP4 with a minimum depth of .0000 inches and maximum depth of -.0015 inches with a safe position of .0005 inches. This allows the encoder connected to an analog laser driver to also work in TTL mode.



**Two of Jeff's images engraved on wood.  
Please note: the level of shading demonstrated in these  
two images cannot be obtained with more powerful CO2 lasers.**

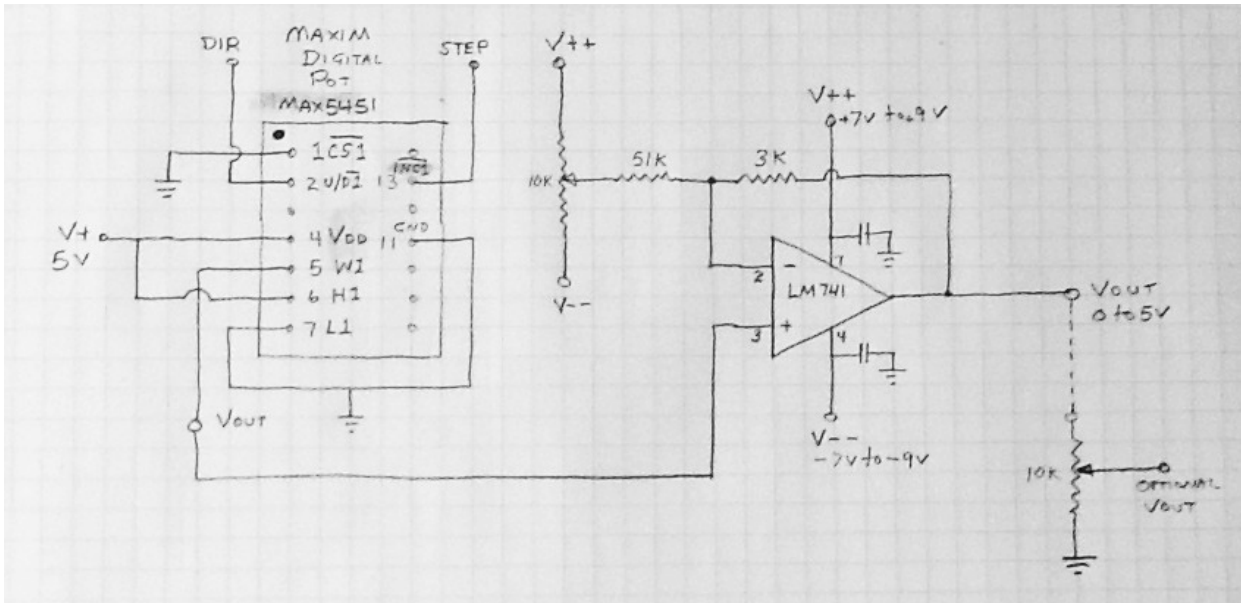
The rotary encoder could also be setup with a separate stepper motor and operated as a fourth linear axis if modifications to a router's Z axis are not desirable. In this case, the gcode is generated with an A, B, or C axis letter in place of the Z.

### **Electronic Control Method**

A digital to analog (DAC) control circuit, first suggested by Mr. Dave Gabry, and first used by Jeff Woodcock, uses a Maxim digital potentiometer (p/n: MAX5451EUD).

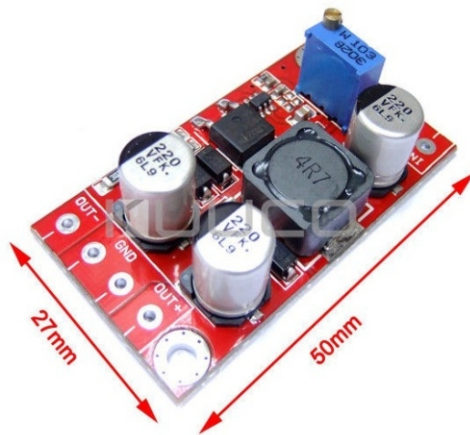
The Maxim chip is difficult to solder to a pc board since it is available as a surface mount component only. Adapters are available from Digikey to convert the chip to a standard 14 pin dip, but a delicate soldering skill is still required to mount the Maxim chip to the adapter. At a nominal cost, the Maxim chip can be ordered through Proto-Advantage professionally pre-soldered to a 14 pin dip adapter. Contact them for current pricing and information.  
<http://www.proto-advantage.com/store/designservices.php> -

Below is the circuit diagram as presently being used by the author. It includes parts to allow trim adjustments of the zero and the full output voltages.



(Note: unmarked bypass capacitors shown at pins 4 and 7 of the op amp are 0.1 $\mu$ F ceramic capacitors.)

An LM741 operational amplifier is used as an output circuit. This output circuit uses a dual voltage power converter with both positive and negative voltages. This converter is powered by the same 5VDC power source that is used for the digital pot. These small converters are available from several sellers on EBay.

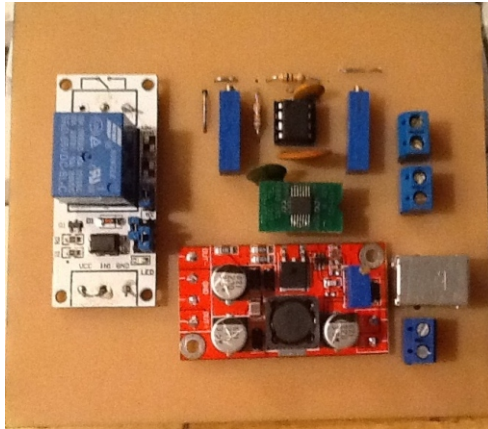


Input Voltage 3-6vdc / Output Voltages 5-32vdc (plus and minus)

The MAX digital pot incorporates an automatic power on reset that sets the “wiper” to midscale (position 127).

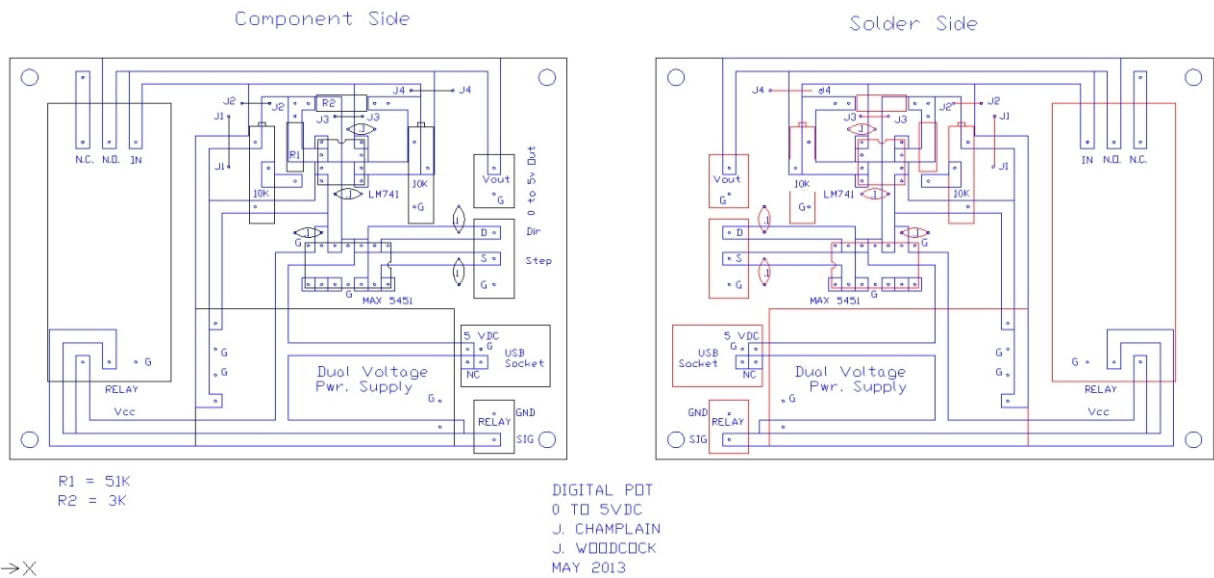


To initialize the circuit for use, a stepper signal corresponding to midscale (in the author's setup this is C-0.0127) is manually output to the DAC, followed by applying the supply voltage to the DAC. Then a step signal of C0.0 is output, after which power can be turned on to the laser diode control, and engraving operations can begin.

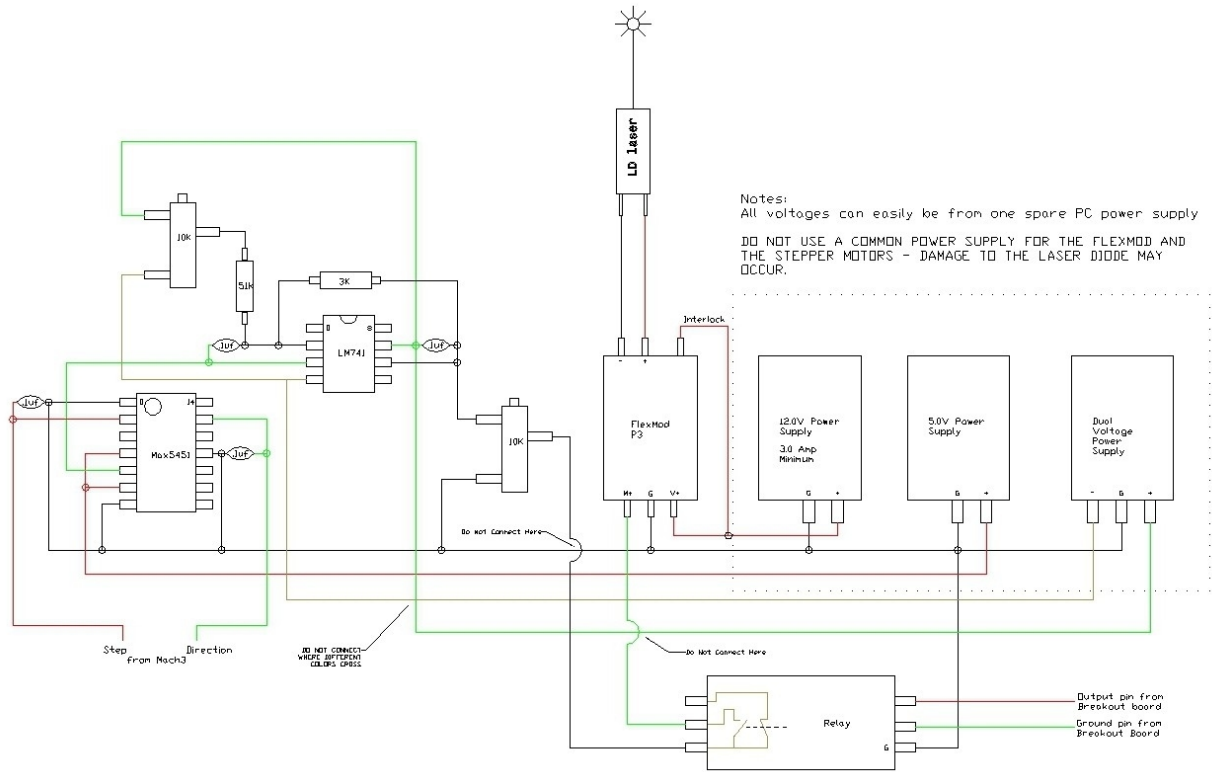


Author's Prototype DAC.

Author's Prototype PC Board Layout



→X



MAX Digital Potentiometer Layout Diagram

### Maxim Digital Potentiometer – MAX5451EUD+

<http://www.digikey.com/product-detail/en/MAX5451EUD%2B/MAX5451EUD%2B-ND/1779842>

### Logical Systems 14TSSOP to 14DIP Adapter

<http://www.digikey.com/product-detail/en/PA-SSD3SM18-14/309-1112-ND/3911357>

### Laser Diode Driver

A laser diode driver with a 0 to 5 vdc modulation input is needed. A search on eBay should turn up a few suitable analog modulated models. Please note that TTL only drivers are not suitable for gray scale engraving.



I also use a small relay circuit so I can turn power on and off to the laser with Mach3 spindle commands (M03/M05). I have it wired so the 0 to 5 volt signal from the DAC is removed from the driver input when I want the laser to be completely off. The relay below was purchased from eBay, and may not be available now, but any similar unit should work.



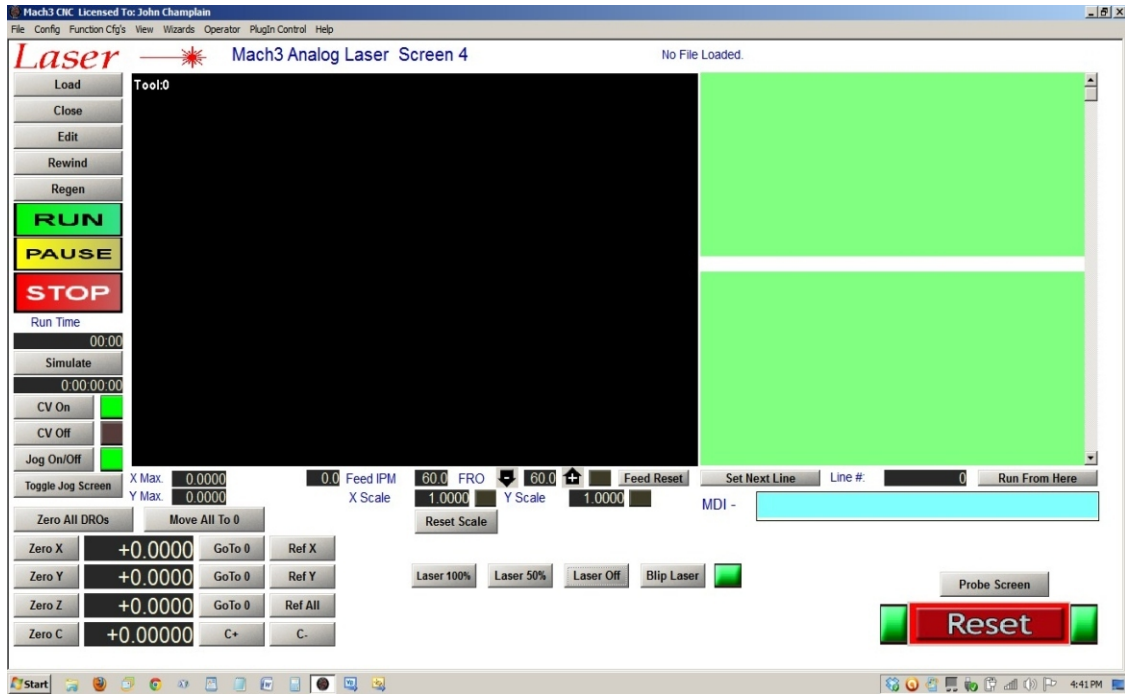
### **Mach3 Setup**

I use the "C" drive to control my lasers. This leaves the Z axis available to manually raise and lower the diode to maintain focus for different wood thicknesses, which is very convenient. I have C velocity and acceleration settings set to maximum, and the 'steps per' set to 10,000, giving a range of 0.0 to -0.0255 steps, in 0.0001 inch increments.

The relay is controlled from a Mach3 output pin using the standard M03/M05 spindle codes.

The Mach3 standard screen can be used for laser diode work, but I prefer my own custom screen set that allows me the needed flexibility in laser control without the clutter of un-needed controls.





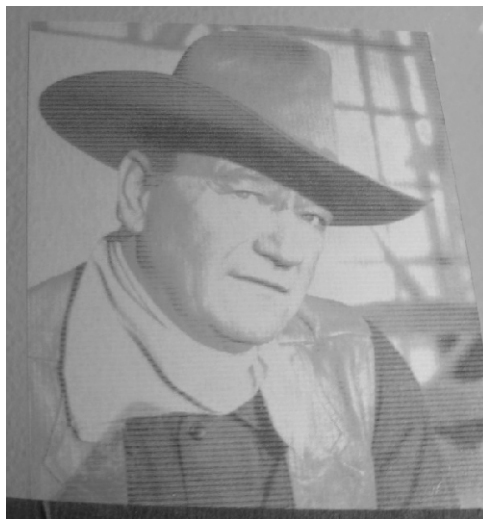
Readers are encouraged to visit this forum ( <http://hobbycncart.com/forum/63-151-1> ) to read more about the use of laser diodes for image engraving. It is an active forum, and new members are welcomed and encouraged to participate. The freely shared collective experiences of forum members can make it much easier for beginners to avoid costly mistakes when setting up a laser diode engraving system. My very special appreciations also to good friend, Tweakie, to whom I give credit with getting me interested in laser diode image engraving originally. ( <http://www.cooperman.talktalk.net/> )

Work Safe, and Enjoy,  
 John Champlain  
<http://www.picengrave.com/>  
 Last revision: February 2015

Photos courtesy of Mr. Jeff Woodcock



By J. Woodcock on white artist canvas



Mirror engraved by the author  
with variable feed rate  
(please note: the horizontal banding is due to a machine defect)

# Image Dithering Introduction

May 2012

## Image Dithering

Dithering is a process whereby each individual pixel of a digital image is scanned and converted to one of two colors<sup>1</sup>, using a mathematical algorithm. Simply stated, dithering of digital images can be compared to the half-tone process long used for print media.

Different dithering algorithms have been published, and while all will process a digital image in a similar manner, each will produce a different result. Experimentation of which to use with a specific image is needed. The Lena image below has been dithered with arguably the most popular algorithm, the Floyd-Steinberg.

## Examples



Lena - Original



Lena -Gray scale



Lena - Dithered

## Dithering Tips

1. Use caution if re-sizing a dithered image. The resizing algorithms used by many graphic manipulation programs can introduce undesirable visual artifacts and banding. It is advisable to re-size a copy of the original image first before dithering.
2. After dithering, if the dithered image is too dark, adjust the brightness, contrast, and/or gamma of the original image appropriately using your favorite graphic program, and

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1

Colors used are usually black and white, although any combination of two colors could be used. PicDither uses only black and white.

process with PicDither again.

3. For best view of your dithered images, proof print them at 100% scale using an ink jet printer. Most laser printers and video monitors will not display an accurate representation of dithered images.
4. To avoid compression artifacts, dithered images can be saved only as an uncompressed BMP file composed of black and white pixels only.
5. Dithering time will be greater for larger images.

### Dithering Examples



Gray scale

Threshold

Floyd-Steinberg

False Floyd-Steinberg



Burkes

Jarvis, Judice and Ninke

Stuki

Sierra



Two-row Sierra

Sierra Lite

Atkinson

Random

As the name implies, the Random dither should not repeat a pattern.