Analog Laser Diode Setup  
for  
Gray Scale Image Engraving  

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

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.

Laser Diode Source
We have only purchased our LDs from eBay seller DTR, (http://stores.ebay.com/dtr-lpf?_trksid=p2047675.l2563 ). He has proven to be a very reliable dealer, and has been very supportive and helpful to us. Other dealers of laser diodes and accessories can be found with an internet search.
Lenses

The lens we favor is a low cost glass lens especially coated for the 445nm wavelength. Acrylic lenses are not usable at the power levels these diodes produce. A power increase can be obtained (30% has been claimed by some) by using the more expensive single element G2 lens, but, from our personal testing, there does not seem to be enough usable power increase to be worth the additional expense for our uses, and they actually do not work as well for image engraving as the following lens.

445nm Glass Collimating Lens/M9P0.5 Metal Frame

http://stores.ebay.com/techhood?_trksid=p2047675.l2563

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](image1.png)

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

![MA3 Miniature Absolute Magnetic Shaft Encoder](image2.png)


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 with a similar installation is here:

In Jeff’s current setup, 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 ½ 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 C02 lasers.

The rotary encoder could also be setup with a separate stepper motor and operated as a forth 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 - http://www.proto-advantage.com/store/designservices.php - professionally pre-soldered to a 14 pin dip adapter. Contact them for current pricing and information.
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 0.1μF ceramic capacitors.)

A 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
Maxim Digital Potentiometer – MAX5451EUD+

Logical Systems 14TSSOP to 14DIP Adapter

**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 models are not suitable.
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.

![5V Relay Module 1-Channel](image)

**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.

![Mach3 Analog Laser Screen 4](image)
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/

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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)