INSTALLING A LASER DIODE ONTO MY HOME BUILT CNC ROUTER
By Graham Ham - February 21st 2019

I must first preface this story by stating that the LASER module, I first started with was a Chinese one I purchased of eBay, so most of the setup, Controller design and adapting to my CNC Router was initially done using this Laser. However as you will read the Chinese laser failed, as most of them do, and resulted in my purchasing an 8W Endurance. The Endurance worked perfectly and continues to do so, it is by far much superior to the Chinese one. The really nice part was to get the Endurance working required almost no modifications to the design I already had.

PREAMBLE
To start my story I must first go back to the start when I first got myself involved in CNC.
Right back over 10 years ago I was making things with manual machines such as a lathe, Milling Machine and Pedestal drill. I had heard about CNC but knew absolutely nothing about it or what I could do with it. So I started to investigate searching the internet, remember this was about 14 years ago so back then there was not much available on YouTube or for the home enthusiast. Anyway I came across a small desk top milling machine made by a company SHERLINE and they also happened to have an add on kit that gave it three axis CNC capabilities. So to cut a long story short I went out and purchased one of these machines. It was a kit so I had to put it all together fortunately the instructions were good and they had a local representative in Australia. So all good I had the SHERLINE CNC assembled, but wait, I had absolutely no idea how to make it work, well to cut another even longer story very short, three months later I was making my first cuts. Big hurdle overcome I progressed form there over the next few years making many things fulfilling a desire I had to make various clock design to give as gifts for family and friends. So now armed with a few years of knowledge and experience of basically figuring all the CNC stuff out I felt limited by the size of projects I could do with the Sherline. I then started to investigate CNC Routers and the possibility of building one myself. Well that was a daunting prospect that literally took me nearly another two years getting up the courage to do it. Anyway I did, I started by searching eBay for some necessary parts like linear rails and ball screws etc. The initial parts arrived and I spread them out on my work bench thinking, well now I have gone this far I might as well tackle the design and building of my own CNC Router. I would sit in front of the TV each night with a pad and pencil sketching design ideas tackling one stage at a time. First the Bed so I built that, then the Gantry and I built that, then finally the Z Axis. In the mean time I started ordering other components such as stepper motors, controller, VFD Spindle motor and all the parts to custom build a windows based computer to make it all work. Three months later to my extreme delight I had it fundamentally working. Still a way to go tidying it up and calibrating but non the less imagining just what I could now do and the larger projects I could tackle. That was back in 2011 and since then I have refined my CNC router with various modifications and enhancements such as fitting Closed Loop Stepper Motors, completely re-designing and replacing the Z axis to make it more rigid etc.

MAIN STORY
So now this leads me to more recent years, I kept reading about CNC LASER engravers and cutters so I started to investigate these and found machines such as the K40 and K60 available on eBay at very affordable prices. But wait, on more in depth investigations I was reading extremely negative stories about these machines from people who had purchased them. Admittedly there were some good stories but almost all cases the K machines almost never worked straight out of the box and needed work plus the software supplied was crap. All other LASER engraving/cutting machines were way too expensive costing $10,000+. So I shelved that whole idea and thought about a plan B and looked again to eBay, I found solid state LASER diode assemblies/modules that could be fitted to existing CNC machines that would engrave and cut various materials at very affordable prices. Wow this was the answer, it would give me LASER engraving and cutting plus I could use my existing CNC router and software, exactly what I needed. But wait, not quite the same as the likes of a K40 but non the less a start at least and that's all I might need to suit the type of projects I work on. I thought it would be really nice to have basic LASER engraving and some cutting ability added to my CNC.
So boldly stepping into the project of adapting a LASER to my CNC I went ahead and ordered a 5W laser off eBay from a Chinese supplier. In the mean time I had to figure out how to make it all work. Fortunately there were various YouTube videos to at least give me ideas and a start. I am an Electronic Engineer so understood about TTL and PWM, so I set about finding an easy solution to controlling the LASER's power, I found I could purchase very cheaply a PWM motor controller with a digital display so this would solve that problem nicely. I purchased one and found all I needed to do was place a 180 Ohm 5W resistor across the motor terminals and viola I had a variable TTL pulsed signal, (I have an oscilloscope to be able to see this). It was a negative going pulse but that was easy to fix with a TTL inverter. I already had a 12VDC 6A Power Supply along with a digital Volt/Amp meter so I just had to purchase an appropriate enclosure to house it all in and I was ready to start putting together the Laser Controller box. The benefits of having a CNC Router is that I was able to CNC cut and engrave the front and back panels of the enclosure to make it look professional.

So the next thing was to figure out turning the laser ON and OFF from the MACH3 controller and as my controller had various spare output ports I assigned one of them to do just that. Then as I use Vectric Aspire to do all my CAD/CAM work I went back to YouTube and found some good tutorials about writing, or I should say modifying, an Aspire Post-Processor to handle the laser. Now I must preface all this by saying that I was figuring all this out as I went along so it all took some days and a lot of patience. An Aspire G-Code Post-Processor file is easy to write/modify as it is simply

straight ascii text so windows text editor is all that is needed. I will include the text printout for this at the end of this document.

So the Laser arrived and I fired it up, wow that was exciting to see the big blue rectangle on the opposite wall of my work bench. Naturally I was wearing the protective goggles received with the laser. So holding a piece of paper I set about playing with the focus and holding the paper close to the Laser lens it started to burn. Now I knew I was in business and proceeded with much enthusiasm.
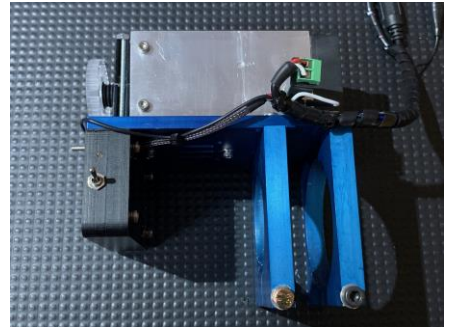
I now made a mounting fixture to attach the Laser Module to my CNC routers spindle, ran the required wires, Power and TTL from where I was going to position the controller to a location on the Z axis to plug in the Laser when fitted. I finished off the Laser Controller box and connected it all up to my CNC controller.

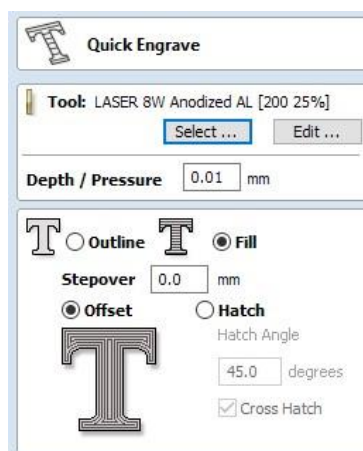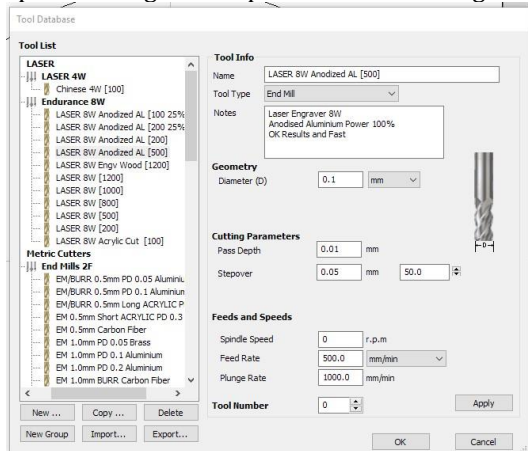The Original Laser Mount   The TTL and Power Connectors   The mount now with Endurance fitted.

I now created a very basic text file in Aspire switched over to the CAM section and first had to setup an appropriate cutter that would emulate a Laser. Referring back to what I had already seen on YouTube I knew to select an End Mill as the basic tool but put in values for the tool diameter and feed rate etc to suit it actually being a Laser. Oh btw there is no speed setting as the spindle is not rotating so speed is set to 0.

Most tools I created for the laser are the same except for the feed rate that varies for different materials and job requirements. Note that the Diameter I set to 0.1mm, that's about what I figure the focused Laser is. Pass Depth is 0.01 and that you see matches the Quick Engrave Depth/Pressure. Remember the Z Axis is not actually moving at all. If for instance I wanted multiple passes I simply would set the Depth to whatever multiple of 0.01mm I wanted for the number of passes. For example for 3 passes it would be 0.03mm Depth. This just tricks the G-Code generator to doing multiple passes without actually moving the Z Axis. Adjust the Stepover to suit the laser after running some tests.

It was now time to test it out hoping that I had got all the basics figured correctly. Keeping in mind I had already run some individual connection and operational tests as I assembled every component and interfaced them. Including focusing the Laser at a fixed height above the work piece surface. This I did with the PWM at very low power enough to trigger the Laser and a low brightness blue dot. In my initial setup I just used a piece of white paper.

Now I was ready to run my first real test so I loaded the G-Code I had created with Aspire, placed a piece of scrap wood under the Laser and set its focus height, set the Laser Power to 50% and hit the START button in Mach3.

To my amazement and Joy the router X and Y axis started to move and then the laser fired into life, some burning but not a lot. Now I knew I was on the right track so wound the PWM to 100% and ran the test again, this time lots of burning and smoke and I felt elated to see the result of my first engraving test. This is MDF so not the ideal material to start with but I only needed to see if it worked or not.

Now I discovered the common problem "though I didn't know it at the time" associated with G-Code generated for a Laser engraver and that is burn spots at the start of each new pass or movement. So back to researching this and yes as we know this is created due to the lag in when the laser is told by the G-Code to fire and movement of an X-Y or X+Y axis starting. This is very indicative of G-Code created for a Mach3 CNC controller. Anyway research told me to incorporate

an M10 and M11 command within the Post-Processor to turn the Laser ON and OFF this would remove the delay. Well no in my case, these commands don't work because they are designed to work with Mach3 controllers using a Parallel Port control not USB as mine was. So much more investigating and I found a whole set of macros that would turn individual ports of a Mach3 controller ON and OFF, these are M101 and M201. M101 turns output port 1 ON and M201 turns it OFF. These macros are not normally included in a Mach3 installation but can be easily downloaded and installed into the Macro Directory of Mach3. There are others like M104 and M204 I use to automatically turn my vacuum exhaust system ON and OFF. You configure the allocation and how these ports toggle H>L or L>H within Mach3 Ports settings. You can also create specific versions of Mach3 for different purposes such as CNC Machining or CNC Laser that have their own individual settings for port configurations and XYZ motor tuning. This makes switching from Routing to Laser very easy without having to reset anything each time you do. I edited the Aspire Laser Post processor I created to incorporate the new macros for the laser ON/OFF control. They worked and greatly improved or should I say reduced the burn spotting. But not totally to my satisfaction, so I went back to the drawing board. I figured I needed to incorporate some other way of inserting a delay between when the laser was told to turn on and when it actually did. I now reverted to thinking of a hardware solution. What if I used a physical delay timer to logically delay

the laser ON signal by a small amount 100mSeconds or so or better than that make it variable so I had control depending on the job being engraved. As I am from an electronics background and used to working with logic circuits I designed and built a delay using a 555 timer IC and some TTL AND gates to facilitate exactly what I was after. Well after some time prototyping I had a circuit working and installed within my Laser Controller and it works really well virtually eliminating the burn spot problem. Also making it variable made it customizable. I am including a circuit diagram with this document. The top of the box includes a fan for cooling.

Now, I know what some of you are thinking why not just use an Arduino. Well yes I likely could have but in this case I used what I had on hand, however if I was to do it again I probably would use an Arduino, that would be elegant. Something to put onto my to-do list.

After proving the prototyped delay circuit I made engraved a PCB to make a much nicer final version. CCT diagram at the end of this document.
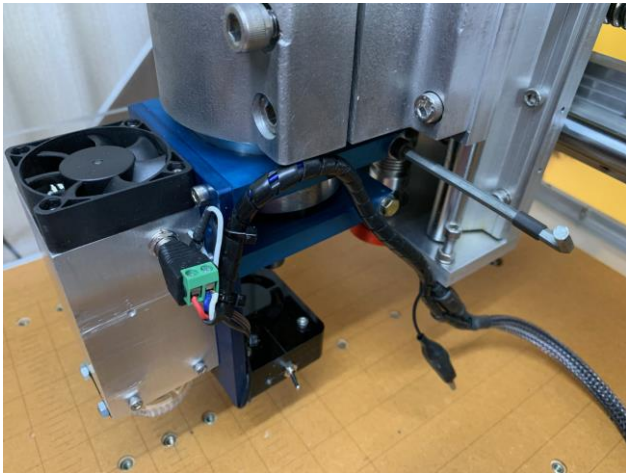
Now I was ready to do some serious testing and everything was going really well. I was able to engrave onto wood and bamboo, engrave anodised aluminium, cut through 2mm black acrylic. However while recently in the process of engraving some black anodised aluminium plates for my car the first one was good but something was going wrong. The engraving became less distinct an almost invisible. No settings had changed but I could see that the laser had lost intensity. Some basic testing on my workbench proved that this Chinese Laser had totally failed after what would have been very few hours of total use. I always knew this was a possibility as Chinese Lasers don't have a great reputation for reliability and adhering to their published specifications. I decided that I wasn't going to wast another A$400+ on another Chinese one so started to investigate what else was around. I remembered that I had heard the name **Endurance** either or both on YouTube videos or on one of the CNC Face Book channels I subscribed to.

Endurance to the Rescue

Then further looking into Endurance I was overwhelmed by all the positive support it had amongst its users plus the abundance of posted YouTube videos. This was an obvious choice to make so without any further hesitation I placed my order for an 8W laser. The communication back from George was almost instantaneous and within a couple of hours the process was complete. So now all I could do was to wait for my Endurance Laser to arrive, then after about 10 day there it was in my hands. That's pretty amazing since it travelled from Russia to Australia.
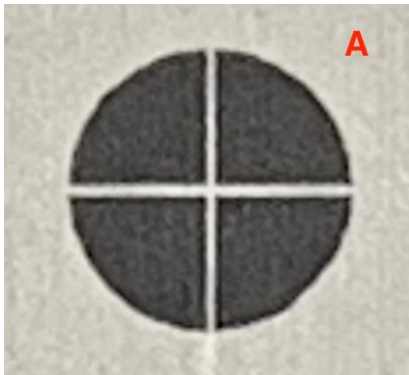
I eagerly unpacked my Endurance Laser and everything looked to be perfect. I took it to my workbench, connected it to my bench power supply and applied 12VDC then putting on the protective glasses touched the TTL line to +12VDC the lase fired up and wow so bright, glad I had my green glasses on. My Bench power supply was having a problem handling that amount of amps as it was only rated at 3A max so its current limiter cut in.

So it was now just a simple exercise to fit the Endurance to a new mount I had just finished making in preparation. You will see in the photos this is aluminium that I anodised blue. All I had to do was a slight modification and I was able to attach the Laser module with a couple of M3 screws. Then I extended the power and TTL wire with some plugs to connect to my existing controller wires just behind the Z axis.
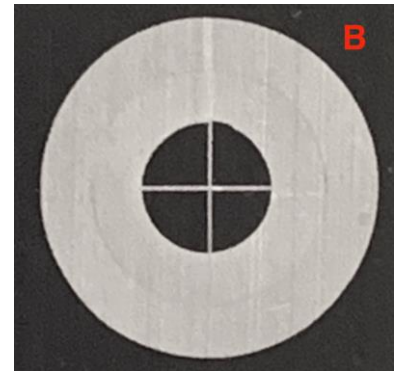
It was time for the first tests, first to see if my existing Power and TTL laser Controller was compatible with the Endurance. Well I was again pleased to find that everything Worked perfectly. The Mach3 macros turned the laser ON and OFF plus the PWM control I had put together worked as it should. I now roughly set the focus and I was also amazed to find that with the endurance I was starting to burn with the power set to only 8% where as with the previous Chinese Laser this needed to be set at around 30%, that's a big difference.

Now it was time to get it all focused correctly and to do this I set it height to 30mm above the surface of a piece of black anodised aluminium with the PWM power set to 2%. Once I got this set I ran a simple engraving test pattern of a donut circle and a cross into the black anodised aluminium at full 100% Laser Power. The engraving itself was perfect but I noticed a problem (that I had also seen with the Chinese Laser) in that the Horizontal line was slightly wider than the Vertical line ref image "A". This is because the laser Diode itself actually generates a rectangle light beam
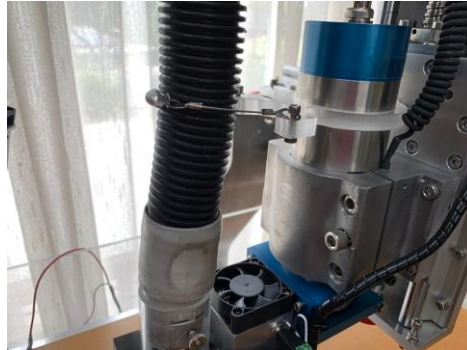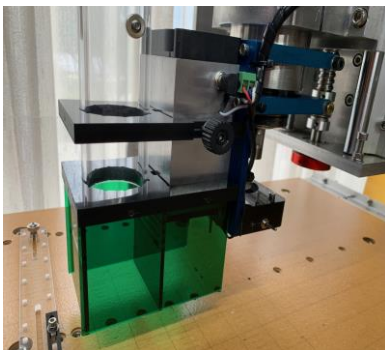

So I reduced the height of the laser lens above the work surface from 30mm to 12mm and re focused the Laser. I ran the same engraving pattern again and now both the Horizontal and Vertical lines appeared to be exactly the same width ref image "B", well as much as I could see under a magnifying glass. I was really satisfied I had found to optimum settings. The thing about focusing and testing with black anodised aluminium the edges are so crisp that anything that is not quite exact will show. Sorry these images are magnified so quite grainy.

So now I was able to run some serious practical tests. I finished the job of engraving the black anodised aluminium plates for my car that turned out perfect. I then did some cutting tests on Black acrylic. Was able to easily cut through 2mm in one pass up to 4.5 mm in 2 passes. More than adequate for my needs. I engraved some wood and bamboo with equally satisfying results. The Endurance 8W laser had proven itself to be everything I had read about it and beyond my best expectations.

Subsequent to this I also designed and made my own fume extraction and protection shield.

Just a few example photos of recent tests and projects.

2mm Black Acrylic

4.4mm Black Acrylic

Black Anodised Aluminium

Etched Glass Edge lit with LED Strips (This is another story)

Bamboo Name Pendants and Bamboo Cutting Boar

This is the Circuit Diagram of my LASER Controller incorporating the 12VDC 6A Power Supply, PWM Laser power control module and my own designed Laser delay trigger logic circuit. Not shown is the Digital Volt/Amp Meter.

Following is the LASER Post Processor text file I wrote/edited for Vectric Aspire

The lines beginning with a + are comments.

```
+=================================================
+ Vectric Aspire Machine Output Configuration file For LASER Control
+ Adapted by Graham Ham
+ gedwardham@bigpond.com
+=================================================
+ NOTES:
+ Controls LASER Power ON/OFF without delay
+ Use instead of M10 and M11 that dont work with USB Controller
+ M101 and M201 Macros:
+ Configure Spindle to be on Output #1 - Pin#? = Laser Laser Control ON/OFF
+ Output #3 Used for Vacume/Fume Extraction or could be used for Air Pump
+ Place Macros M101 and M201 into Mac3 Macro Folder for whatever Profile you are using
+ You may also need to place M104 and M204 into the same folder if they are not already there.
+ eg mach3/macros/mach3-laser
+ M101.M1s turns Output #1 ON "ActivateSignal(Output1)"
+ M201.M1s turns Output #1 Off "DeactivateSignal(Output1)"
+ M104 turns Output #3 ON (Vacume)
+ M204 turns Output #3 OFF (Vacume)
+=================================================
POST_NAME = "Mach3 Laser mm (*.txt)"
FILE_EXTENSION = "txt"
UNITS = "MM"
+------------------------------------------------
+    Line terminating characters
+------------------------------------------------
LINE_ENDING = "[13][10]"
+------------------------------------------------
+    Block numbering
+------------------------------------------------
LINE_NUMBER_START    = 0
LINE_NUMBER_INCREMENT = 10
LINE_NUMBER_MAXIMUM = 999999
+=================================================
+    Formatting for variables
+=================================================
VAR LINE_NUMBER = [N|A|N|1.0]
VAR SPINDLE_SPEED = [S|A|S|1.0]
VAR FEED_RATE = [F|C|F|1.1]
VAR X_POSITION = [X|C|X|1.4]
VAR Y_POSITION = [Y|C|Y|1.4]
+VAR Z_POSITION = [Z|C|Z|1.4]
VAR ARC_CENTRE_I_INC_POSITION = [I|A|I|1.4]
VAR ARC_CENTRE_J_INC_POSITION = [J|A|J|1.4]
VAR X_HOME_POSITION = [XH|A|X|1.4]
VAR Y_HOME_POSITION = [YH|A|Y|1.4]
+=================================================
+    Block definitions for tool path output
+=================================================
+------------------------------------------------
+  Commands output at the start of the file
+------------------------------------------------
begin HEADER
+ M101 turns Output #1 ON (Laser)
+ M201 turns Output #1 OFF (Laser)
+ M104 turns Output #3 ON (Vacume)
+ M204 turns Output #3 OFF (Vacume)
"M201"
"M204"
"T1"
"G17"
"G21"
"G64"
"G0Z0"
"G0[XH][YH]"
"M104"
+------------------------------------------------
+  Commands output for rapid moves
+------------------------------------------------
begin RAPID_MOVE

"G0[X][Y]"
+------------------------------------------------
+  Commands output for the first feed rate move
+------------------------------------------------
begin FIRST_FEED_MOVE
+ M101 turns Output #1 LASER ON
"G1[X][Y][F]M101"
+------------------------------------------------
+  Commands output for feed rate moves
+------------------------------------------------
begin FEED_MOVE
"G1[X][Y]"
+------------------------------------------------
+  Commands output for the first clockwise arc move
+------------------------------------------------
+begin FIRST_CW_ARC_MOVE
+ M101 turns Output #1 ON
+"G2[X][Y][I][J][F]M101"
+------------------------------------------------
+  Commands output for clockwise arc  move
+------------------------------------------------
+begin CW_ARC_MOVE
+"G2[X][Y][I][J]"
+------------------------------------------------
+  Commands output for the first counterclockwise arc move
+------------------------------------------------
+begin FIRST_CCW_ARC_MOVE
+ M101 turns Output #1 ON
+"G3[X][Y][I][J][F]M101"
+------------------------------------------------
+  Commands output for counterclockwise arc  move
+------------------------------------------------
+begin CCW_ARC_MOVE
+"G3[X][Y][I][J]"
```
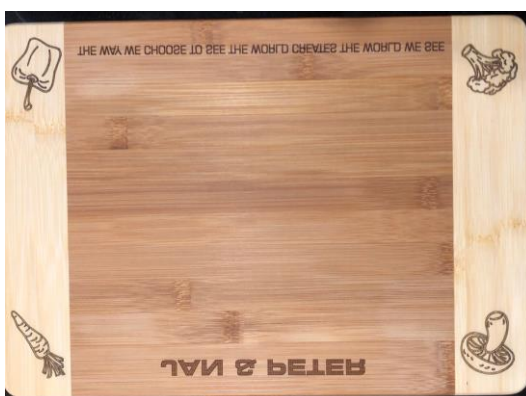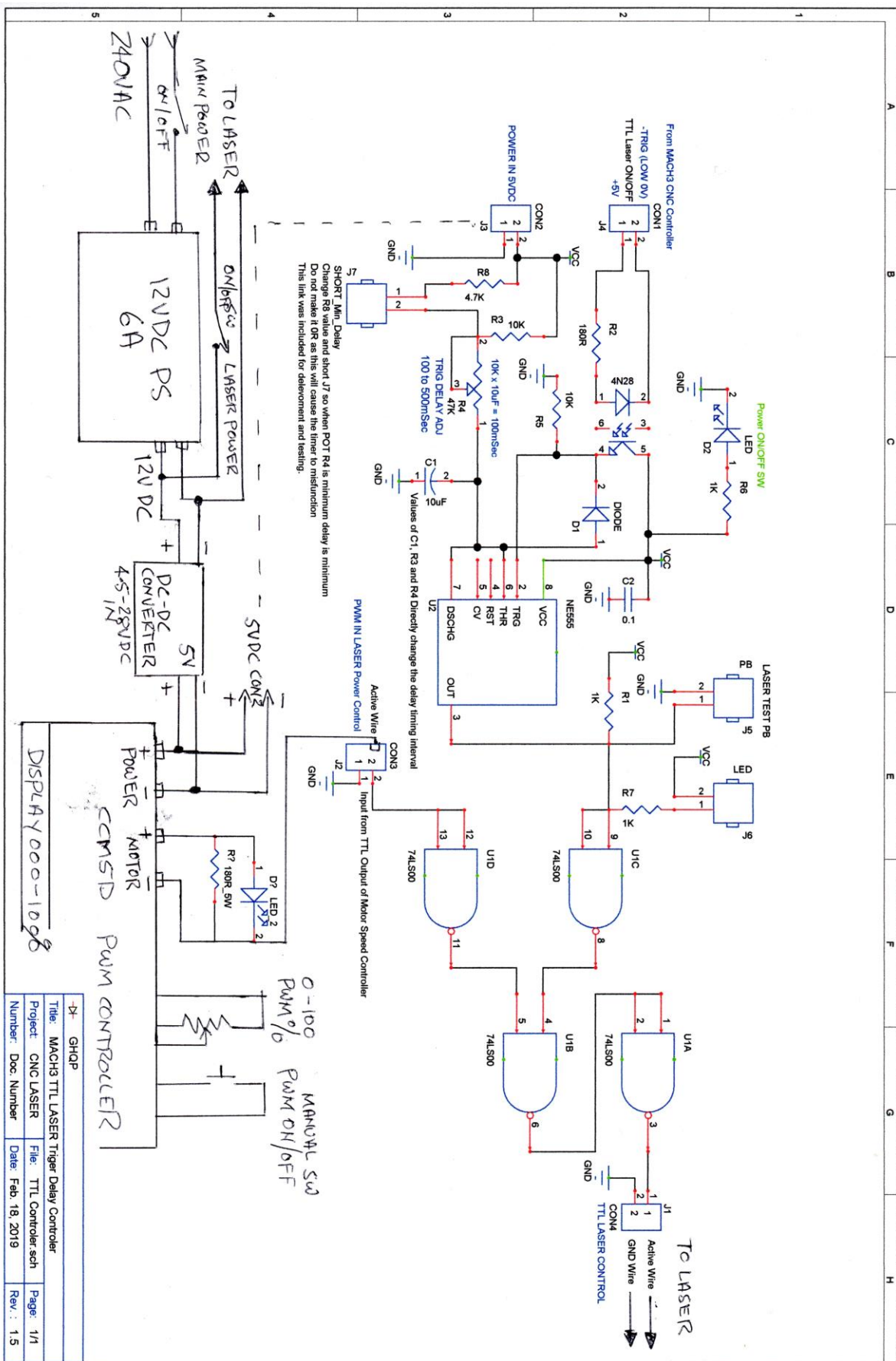
```
+ --------------------------------------------------
+  Commands output for Retract Moves
+ --------------------------------------------------
begin RETRACT_MOVE
+ M201 turns Output #1 OFF
"M201"
"G4 P0"
+--------------------------------------------------
+  Commands output at toolchange
+--------------------------------------------------
begin TOOLCHANGE
"[N]T[T]M6"
"[N] ([TOOLNAME])"
"[N]G43H[T]"
+--------------------------------------------------
+  Commands output at the end of the file
+--------------------------------------------------
begin FOOTER
+ M201 turns Output #1 OFF (Laser)
 "M201"
+ M204 turns Output #3 OFF (Vacume)
"M204"
+"G0[ZH]M30"
"G0[XH][YH]M30"
```