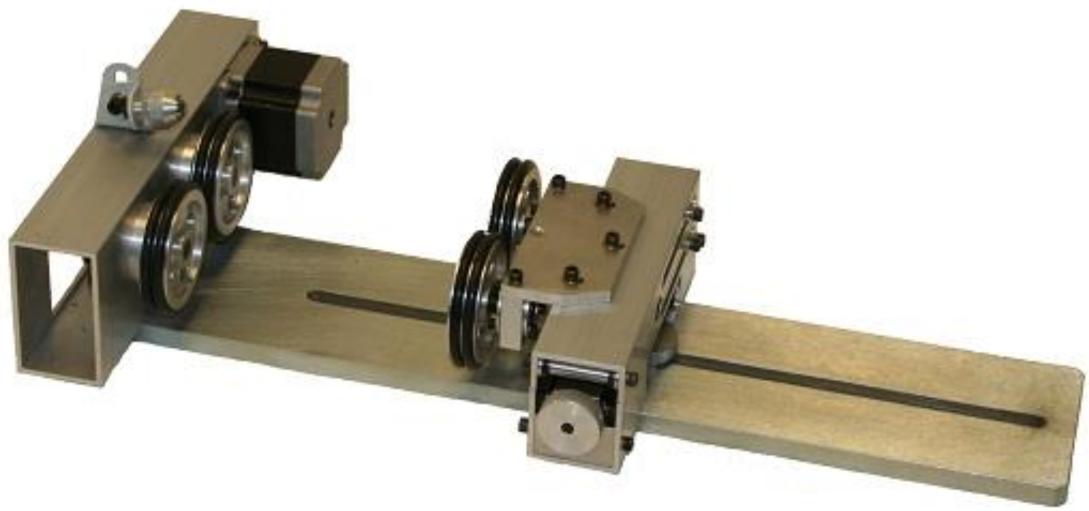
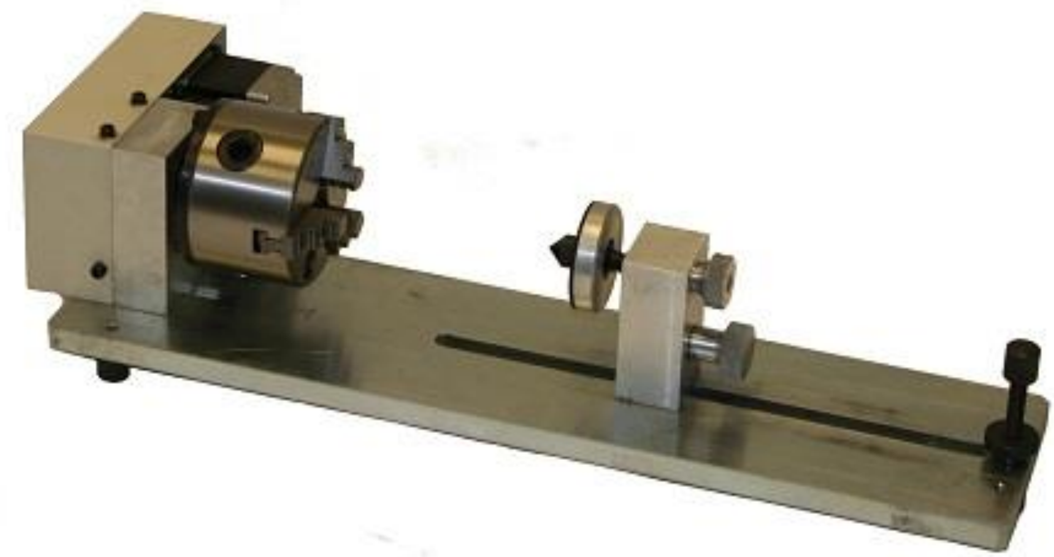
Setup and Modifying Rotary Attachments





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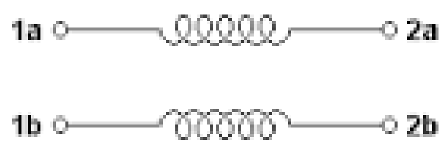
This tutorial is used for:

1) Understanding the stepper motor system
2) Setting up the DIP switch positions of the Step Amplifier
3) Wiring the Stepper Motor to the Step Amplifier
4) Modifying the Roller Rotary and Chuck rotary
5) Tuning the amperage

Why is it called a stepper motor?
Answer: Stepper motors have that specific name because they move from one position to the next position as taking steps. Each stepped position is done by energizing the next coil windings in the direction that we want the motor to move. Many control systems don't want continuous motion, but rather want to move to a position and hold there. The stepper motor is designed to hold in a position.

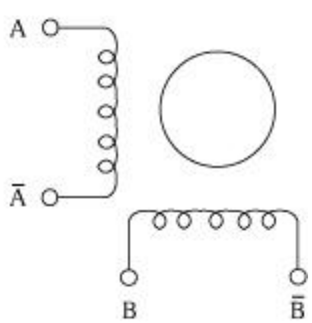


Clockwise Rotation

Index	1a	1b	2a	2b
1	+	–	–	–
2	–	+	–	–
3	–	–	+	–
4	–	–	–	+
5	+	–	–	–
6	–	+	–	–
7	–	–	+	–
8	–	–	–	+

If the steps are continuously being commanded, then the stepper movement appears to be a smooth, continuous rotation.

There is not only one style of stepper motor. A stepper motor could have 3, 4, 5, 6, 8, 9, 10, or 11 wires. The most common stepper motor is the Bi-Polar stepper motor with 4 motor wires. The wires leads are normally labeled as A, A-, B, and B-. This is a simple way to identify the coil A as separate from coil B. The wires could be a variety of colors but are often red, black, yellow, and white.

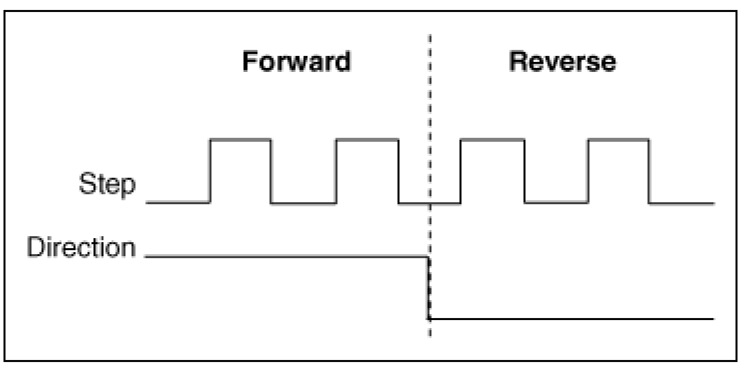


How do I connect the motor to power?
Answer: We cannot connect the motor wires directly to the AC or DC voltage source. The stepper motor requires an amplifier to energize each coil according to the main motion controller. The amplifier might also be called a "Microstep Driver". If using a 4 wire (bipolar) motor, then you must use the matching 4 wire (bipolar) amplifier.

We show the example stepper motor amplifier here. This amplifier is the Leadshine M542 microstep driver. The Leadshine M542 amplifier has many typical features including:

1) Pulse/Direction motion command
2) Enable signal for safety
3) Control the maximum amperage to each coil
4) Wide voltage range for power
5) Divide the full step into smaller fractional positions. (micro-stepping)

The Pulse and Direction signals work together to create motion for the stepper motor. The “Direction” signal tells the motor to go Forward or Backward. The “Pulse” signal tells the amplifier to take another step. The typical voltage levels for these signals are 5 volts DC.



Many control systems do NOT use the “Enable” pins of the amplifier. These two pins are usually left empty.

This amplifier requires a DC power supply connected to the GND and +V pins of the connector. This microstep driver has a power source range of 20VDC to 50VDC. For slow moving systems, it is acceptable to use the low end of the range at 20VDC. For moving at higher speeds, the stepper motor will need higher voltage to maintain no loss of the step command to the position desired. Some stepper motor systems can be powered by standard 24VDC power supplies. Motion systems with high speed expectations will often use 36VDC or 48VDC. While selecting the proper voltage of the power supply, we also make sure that a sufficient amperage will be provided.

The stepper motor has a specific electrical resistance within the coil. Given the resistance and drive voltage, we can calculate the unrestricted amperage that would flow through the coils. The amplifier can limit the current delivered to the stepper motor coil so that the motor does not overheat and has better control. The microstep driver should have a chart of the possible "Current" settings, showing RMS amperage and Peak amperage.

Peak	RMS	SW1	SW2	SW3
1.00A	0.71A	On	On	On
1.46A	1.04A	Off	On	On
1.91A	1.36A	On	Off	On
2.37A	1.69A	Off	Off	On
2.84A	2.03A	On	On	Off
3.31A	2.36A	Off	On	Off
3.76A	2.69A	On	Off	Off
4.20A	3.00A	Off	Off	Off

The microstep driver can limit the current being delivered to the motor. Why not just let the amplifier send the maximum amperage? Would this have the most holding torque? The problem is that the high amperage would overheat the motor and likely cause damage to the coils. Why not just use the lowest amperage setting? The low current would save power, but would not provide the holding torque needed to maintain position. The higher current may also be needed during acceleration and deceleration movements. The true solution of how much voltage and amperage to use are found within the application of the machine. Does the motor need to hold a very accurate micro-step position? This would be a balance of moderate current, given the motor characteristics. Does the motor need to run at high speeds? High speed motion would require high input voltage. Does the motor have reasonable acceleration demands? Rapid accelerations require high dynamic torque and a high current.

Once we decide what amperage value to use, we need to move the switch positions of SW1, SW2, SW3, and SW4. A desired RMS current of 0.71 Amps would have SW1=On, SW2=On, SW3=On. We also see that the SW4=Off and sets the amplifier at half current during stopped state.

We also see here that the microstep driver is set for SW5=Off, SW6=Off, SW7=On, and SW8=On. We can check the table that is printed on the M542 faceplate and find that these setting produce a microstep configuration for 1600 steps per revolution.

We are using the stepper motor in the application of artwork and technical drawings. The most critical function of the stepper motor is to hold the accurate position. The motor holds the position by energizing the coil. To move a full step, the motor would turn off the previous coil and turn on the next coil in the step sequence. The M542 Microstep Driver is capable of taking a normal motor step and dividing it into partial movements. In order to make the partial movement, the amplifier keeps power on the previous coil and applies some power to the next coil. Applying full power to Coil A+ and Coil B+ would cause the motor settle at half way between the two coils. This is called "Half-Stepping". Most stepper motors are built to have 200 full steps per rotation. By moving with half steps, the motor will effectively have 400 positions per rotation. The M542 Microstep Driver can create fractional positions that produce 400 steps per revolution … or 25600 steps per revolution. Check your application for what microstep value to use.

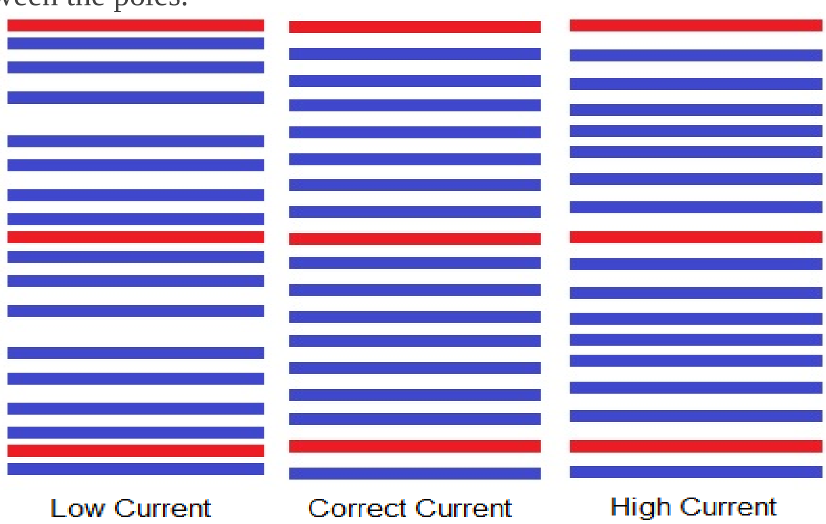
Clockwise Rotation ↓

Index	1a	1b	2a	2b
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1
5	1	0	0	0
6	0	1	0	0
7	0	0	1	0
8	0	0	0	1

Clockwise Rotation ↓

Index	1a	1b	2a	2b
1	1	0	0	0
2	1	1	0	0
3	0	1	0	0
4	0	1	1	0
5	0	0	1	0
6	0	0	1	1
7	0	0	0	1
8	1	0	0	1
9	1	0	0	0
10	1	1	0	0
11	0	1	0	0
12	0	1	1	0
13	0	0	1	0
14	0	0	1	1
15	0	0	0	1
16	1	0	0	1

The M542 microstep driver should have a chart of the possible "Pulses/Rev" settings, showing the number of steps that are micro-stepped during a full rotation of the shaft. Instead of the natural 200 steps per revolution, the Stepper driver can produce up to 25,600 fractional steps per revolution. The concerning problem is, "Can the stepper motor truly move in evenly spaced fractions of a step? Is every step measurable as 1/128th of a step?" Let us assume that the step driver is set for 3200 micro-steps per revolution. This means that every full step is divided into 16 micro steps. If the motor starts off at only energizing the Coil A, this is known as being on the magnetic pole for coil A as it is in positive energize state. Moving a full step would put the motor on the pole for coil B… then pole for coil A-… then pole for coil B- … and then back to the pole for coil A. The problem with microstep drivers is that the true position of the motor shaft depends on how much current is being used to produce a magnetic field. If the current is set too low, the motor shaft may float around or not move off of the pole enough. If the current is set too high, the motor shaft may have a propensity to pull between the poles.



This graphic shows a position representation for a motor with 8 microsteps. The odd spaced shows that a low current for the coils will not be strong enough to correctly pull the (blue) shaft position between the (red) poles. Having too high of current applied will cause an unwanted result of motor shaft position as well. A properly tuned motor and microstep driver should be able to work together to attain the consistent spacing between magnetic poles.

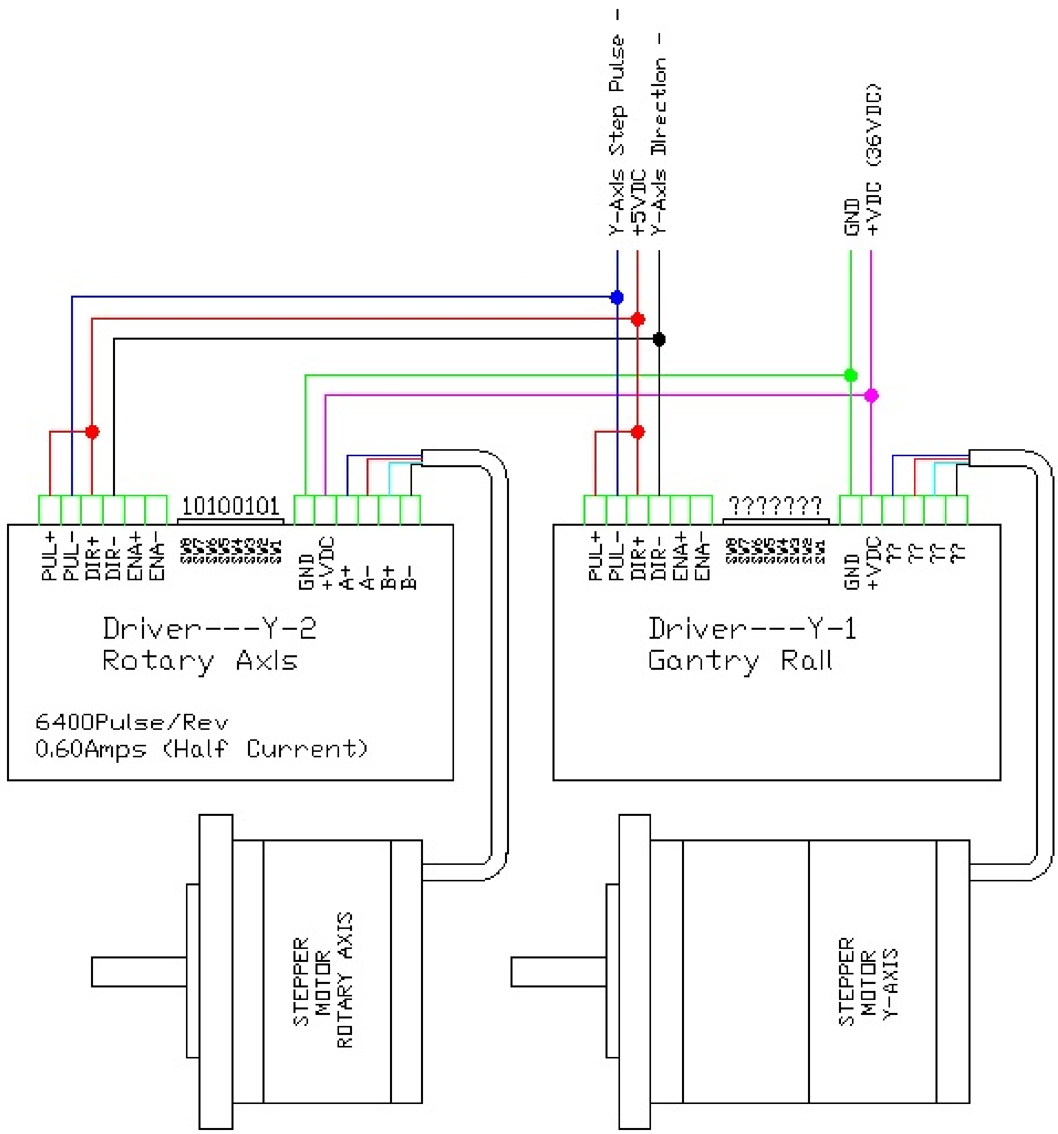
Wiring the motor to the amplifier

Pulse – The command signal to tell the stepper amplifier to move to the next position. It is typical that the stepper amplifier will move on the rising edge of the step-pulse waveform.

Direction – The command signal to tell the stepper amplifier of what direction to move.

Enable – Commonly not used. Would disable the motor output.

Switch settings – Read the chart on the front of the amplifier to select and set the desired amperage, resting status amperage, and micro-steps.



Amperage: Suggested to use the value of 1.63 amps

Micro-steps: Suggest to use a setting between 1600 and 6400. It really depends on the motor, drive gear, driven gear, and roller diameter.

Modifying the Roller Rotary attachment

Tools you may need for making this modification: Allen wrenches, screwdriver, thin tape measure (Harbor Freight), gear puller, heat gun.

For the roller style rotary attachment system, we found that a modification of the drive and driven gears is a large improvement for all product diameters.

Driven pulley at the chuck shaft = C
Drive pulley at the motor shaft) = M
Drive Ratio = R
(Driven pulley at the chuck shaft) / (drive pulley at the motor shaft) = Drive Ratio C / M = R

Normally:	Best Test:	Common Parts:
45 / 25 = 1.8	72 / 18 = 4	70 / 18 = 3.8888

The new gears ratio is mathematically an improvement by factor of 2.16. The actual improvement is better due to the precision of the gear reduction as compared to inaccurate positioning as attempted by high micro-step values on the stepper amplifiers. This situation yields that a combined 70/18 gear ratio and reasonable micro-step amplifier of 3200 steps are the best solution.

The limit to why we cannot use a pulley larger than 72 teeth (on the roller rotary attachment) is because of the aluminum housing of the rotary frame. We found that MXL pulleys larger than 72 teeth do not fit inside the aluminum housing. We found that a 70 tooth mxl pulley is commonly found on eBay, McMaster Car, and Grainger. When selecting the new pulley, make sure to specify the inside and outside flanges, bore diameter, and number of teeth.

Be careful when removing the original pulley from the stepper motor shaft. The original gear is likely to have been heated and pressed onto the motor shaft. Do NOT use a screwdriver or other pry bar to pry the gear off. Do NOT use a hammer. If you do not pull the gear off correctly, you could bend the stepper motor shaft or damage the shaft bearings. Either of these will ruin the stepper motor. Even when using the proper gear puller, it is unlikely that you will be able to remove the old pulley without damaging it. The following picture shows a “9-piece Gear Pulley Removal” kit and is available on eBay for about $23.

What is the "thin tape measure" for?
Answer: The "thin tape measure" is used to measure the size of belt that you will need. After the pulleys are mounted onto the shafts, you will need to install a belt. The belt size depends on the design of the rotary fixture. The easiest way to identify the belt size is to wrap the tape measure into the path that the belt would take and then observe the measured length. My measurements were nearly 381mm and I found that I needed an MXL belt with 187 or 188 teeth.

My rebuild project included tests with each gear ratio. I found that a roller rotary with gear ratio of 4 and only 1600 micro steps will perform better than a chuck rotary with gear ratio of 1.6 and 4000 micro steps. The mechanical gear reduction produces better fractional position accuracy than the attempted micro-stepping.

Modifying the Roller Rotary attachment

For the chuck style rotary attachment system, we found that a modification of the drive and driven gears is a great improvement for products with large diameters. The gear reduction is ever important as the product diameter increases.

If using the chuck style rotary, then change the Drive gear and driven gear to get the highest ratio possible.

Driven pulley at the chuck shaft = C
Drive pulley at the motor shaft) = M
Drive Ratio = R
(Driven pulley at the chuck shaft) / (drive pulley at the motor shaft) = Drive Ratio C / M = R

Normally:	Best Test:	Common Parts:
45 / 25 = 1.8	160 / 18 = 8.8888	120 / 18 = 6.6666

The new gears ratio is an improvement by factor of 4.1666.

A chuck rotary with gear ratio of 6.6666 and only 1600 micro steps will perform better than a chuck rotary with gear ratio of 1.6 and 6400 micro steps. The math here may appear that the two rotary systems work nearly the same, but practical application proves that the amplifiers do NOT hold a true fractional position of the micro step. The best results were found by implementing the largest mechanical gear ratio and a reasonable electrical micro step.

Assemble with a snug fitting belt. Set the micro steps to 1600

Many people think that since the motor is connected and turning... it must be working correctly. Raw functionality does not imply that the motor is performing well. The best performance of the stepper motor will depend on the application of the motor amperage, micro-stepping, reduction ratio, pulse units, direction of travel.

Getting the best results:

@ Start with amplifier DIP positions at the lowest amperage setting.
@ Turn the laser machine on
@ Run a test engraving. (Letter "R", 6mm tall, Ariel font, 150 DPI, low power) these settings should help you see the row spacing.
@ Use a strong magnifying glass or microscope to see the regular spacing of the engraved rows. (I use a 30x jewelry eye loupe as my magnifying glass). If the spaces between each row are even and consistent, then your adjustments are done.
The spacing between rows will be irregular if the motor driver amperage settings are too low or too high. This basically means that the motor driver is not yet matched with the characteristics of the motor.
@ Turn the laser machine off.
@ Modify the stepper motor driver's DIP switches 1-2-3 to increase to the next higher amperage settings

Trouble Shooting:

Monitor the temperature of the stepper motor. If the stepper motor gets hot, the amperage is too high. If you still feel that the amperage is needed to get the most accurate movement and position, then look at the setting for using half-amperage during motor resting/holding status.

"I have tried different amperage settings, nothing gets better or worse." Answer: The stepper amplifier may be damaged.

Why would I need to adjust the amperage of the stepper motor driver? Answer #1: The amperage was never set correctly by the factory. Answer #2: The transistors inside the stepper driver are wearing out.

Getting the correct fractional position is especially important when engraving at low resolution (175 DPI) such as sometimes used with glass and marble (memorial stones)

Question: I modified the microstep count number. The number of micro steps was 6400... and now it is 1600. My problem is that my laser image is elongated on one axis... maybe squished on the other axis.
Answer: After modifying the mechanical gear ratio or the electrical microstep ratio, you need to calibrate the software to understand the new configuration.

Does my rotary attachment have a home position? Answer: Not really

I connect my rotary attachment and find that the artwork comes out as engrave upside-down. What is the easiest way to fix this problem? Change the motor wires on the stepper amplifier. The motor wires should be labeled as A, A-, B, and B-. You will need to switch the wires that are on the A and A- terminals. Do NOT switch the wires of the B and B- terminals. * if you have a 3-phase hybrid step amplifier, then your motor wires will be labeled as U, V, and W. Switching motor wires of U and W will change the direction of the rotations.

Ray Scott