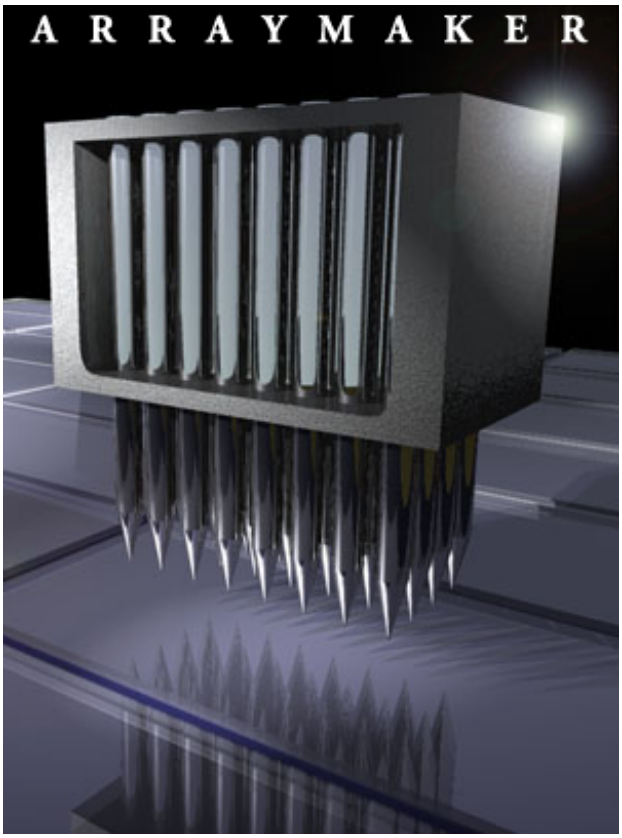


The MGuide

A complete guide to building your own microarrayer.

Version 2.0

http://cmgm.stanford.edu/pbrown/mguide

Joseph DeRisi, Vishy Iyer, and Patrick O. Brown

Biochemistry Department
Stanford University
University of California San Francisco

Copyright © 1998-1999

Introduction

This document is meant to assist those who have decided to undertake the task of building a microarrayer. These machines are used for the high density deposition of nucleic acids onto solid substrates such as glass slides. Although these descriptions are highly specific with regard to the type of equipment specified in the parts list, this guide may also be of use to those who wish to design customized solutions. Check our website for ongoing improvements, modifications, and updates.

We hope that you will find this guide useful, and any comments, questions, or critisims are welcome. Login to the Microarray forum at our website.

The MGuide is maintained at:
http://cmgm.stanford.edu/pbrown/mguide

The construction of this machine involves motion control systems. These systems utilize powerful electric motors and positioners, which can cause significant personal injury if misused. Be aware that the systems described in this document have only limited feedback capacity. Keep the travel length clear of debris, tools, and fingers at all times. Place warning stickers where appropriate, and restrict access to the construction area.

Part I: Building the machine.

Ordering Parts

You have decided to build a microarrayer for your laboratory or department, and you are now considering the parts list. (See the appendix of this document for the parts list. Also check the website for recent changes.) Although we have tried to be very detailed, there are undoubtedly several small items which are missing, but are likely to be available around the lab or at any hardware store. Also, this guide assumes you have access to common tools. The tools we have found to be the most handy include Visegrips, English and metric hex sets, wire strippers, soldering iron, a level, and a multimeter. Most of the tools are also listed in the parts-list. The vendors which we have cited are only suggestions. We have made little attempt to find the best deals, and it is likely that the total cost can be reduced by obtaining discounts. As you will discover, some of the parts are custom machined. If your department has a machine shop, a significant savings can be achieved by having the necessary items made locally. For this reason, the CAD files for these parts are available for download. The files are available in Portable Document Format (".pdf"), which virtually any modern computer can display and print. If you are into CAD programs and own your own CNC mill, you can contact me for the (".dxf") files.

Setting up the Work Area

Now that you have put in the purchase orders, packages have begun to arrive. Typically, the larger items have the longer delivery times, therefore, you are likely to be faced with several boxes of small parts. We recommend buying a decent toolbox and workbench organizer to keep track of the various nuts and bolts which will accumulate. In terms of space, you will need an area at least 10' x 6' to set up the machine. A small table placed directly next to the arrayer will also be handy.

Remember to level the stand before putting the table on it.

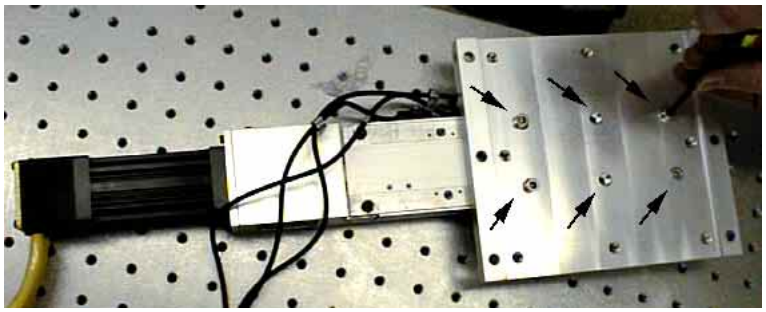
Vibration Isolation Table

The vibration isolation table will arrive packaged in wood crates. To open these crates, we recommend investing in a $5 crowbar. Pry off the lids, and take care not to cut yourself on the nails and staples. The stand can be put together in a few minutes by bolting the three pieces together with the supplied hardware. If the arrayer is to be set against a wall, leave the open side of the stand facing outward. Important: Be sure to level the table using the adjustable feet before mounting the table.

Remove the protective plastic wrapping from the table, and, with a few of your labmates, heft the table onto the rubber mounts of the stand. Make sure the table is leveled and centered on the stand.

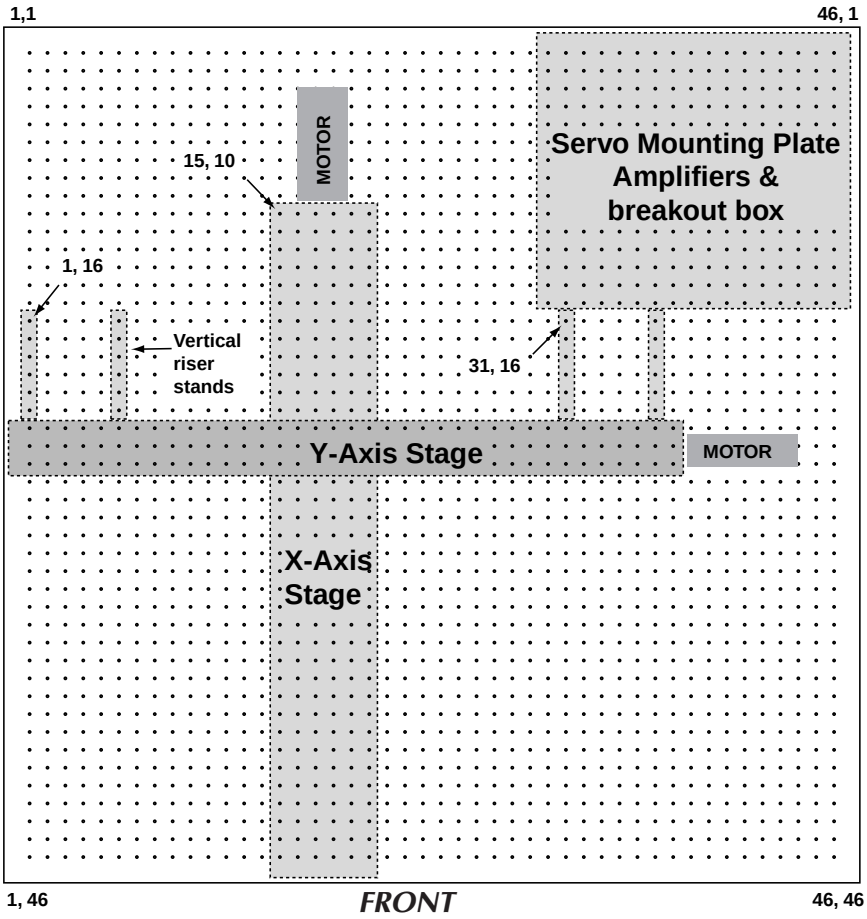
X-, Y-, and Z- Stages

Hopefully, all of the motion control parts have arrived. Depending on the way Western Technology is packaging these items, the Parker motors may or may not come connected to the stages. If they are not connected, don't worry. Leave the motors disconnected for now. If your motors are already connected, don't bother trying to dismantle the motor coupling. The x-axis, which will be mounted directly to the table and run parallel to its surface, is identical to the y-axis, which will be mounted above the table on two riser stands. The z-axis is a smaller stage and motor. This will be mounted (or may have been mounted) directly on the y-axis. In case the Y-stage comes with the Z-stage already attached to it, make sure the Y-motor is not on the left (when positioned with the Z-stage motor on top). Although this is



Note the holes drilled in the carriage mounting plate to accomodate the Z-stage.

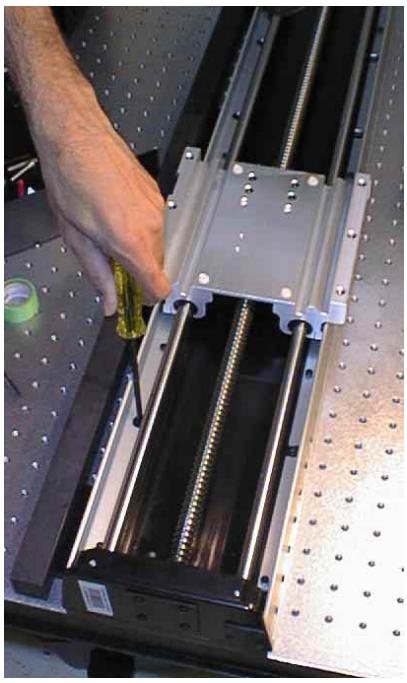
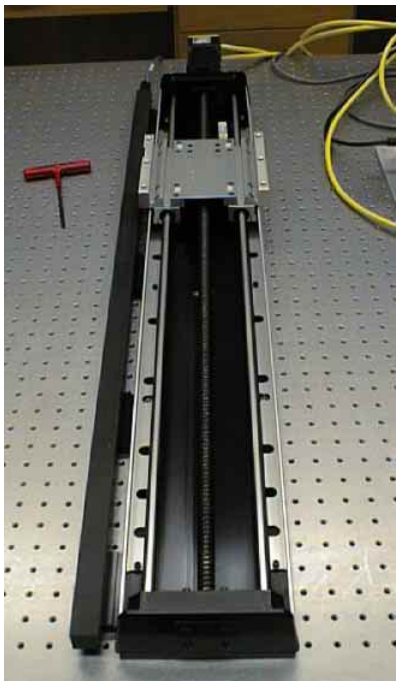
only a technicality, the software requires the Y-motor to be on the right side. Get out your M5 hex key, remove the Z-stage from the Y-stage, and reverse its orientation. If it's not already attached, you will need an adapter plate with holes drilled in the right places to attach the Z-stage to the Y-carriage later on. You have two options here: drill the holes yourself in the plate attached to the Y-carriage (See Figure) , or buy a small adapter plate from Western Technology or Parker. If you drill the holes yourself, drill them as counterbored through-holes for M5 screws.



Begin with the x-axis. With a labmate, heft the stage onto the table and position it in the middle of the table according to the diagram. To mount the stage, remove the protective metal cover of the stage by unscrewing the four small hex screws at each of the corners. You will often be faced with having a bunch of little loose parts, such as these screws, rolling around on the table. This is not advised since such parts seemingly gravitate towards the larger mounting holes of the breadboard. Once a screw has fallen inside the table, it can be difficult to recover it. We recommend having a small drawer or cup on hand to stash these small bits.

After removing the metal cover, line up the through-holes running along the edge of the backface of the stage with the mounting holes of the table. Find your box of 1/4"-20 mounting screws (pronounced

"quarter-twenties" in the biz), your hex wrench, and go at it. At the minimum, use six bolts to secure the stage. Take a look at the picture if you are unsure as to where the mounting screws are placed. The threads of the table will be stiff at first, so don't be alarmed at how much elbow grease it will take. Of course, take care not to cross-thread any of the bolts. Re-attach the stage cover.

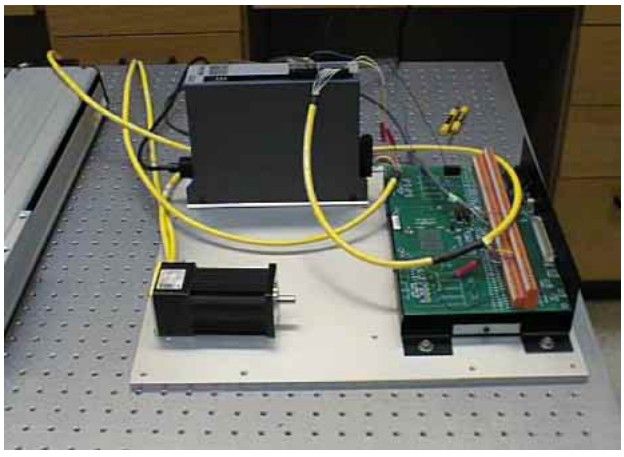



Fastening the X-Stage to the table.

If it isn't already beer hour for your lab, begin on the y-stage. First, it is necessary to mount the uprights. Attach the uprights to the table with 1/4"-20 bolts in the positions shown in the diagram. If you are absolutely positive that you have the uprights in the right position, go ahead and really crank down the bolts. For the system to function properly, the supports must be stiff as possible. Now, remove the metal cover from the y-stage and stash the tiny screws. Call a couple of lab mates over and lift the y-stage into position such that the mounting holes of the uprights are visible through the through-holes. While your friends continue to hold the stage up, grab eight 1/4"-20 bolts and tighten them up. Again, once all the bolts are in place, crank the screws down. Forget about putting the z-stage on the y-stage for now. It will be easier, and safer, to deal with later. Instead, unpack the z-stage and lay it, stage up, on the table.

It's now time to unpack the three TQ-10 amplifiers, ICM-1900 breakout box, and the DMC-1730 controller card. If you have received the servo mounting plate (a custom machined part), place it on the table and position the TQ-10 amplifiers as shown in the picture. Take the cover off the ICM-1900 breakout box for the wiring.

The mounting plate serves not only to organize the external electronics and provide a metric-to-English conversion (your table is English, or "imperial," and the mounting holes on the amplifiers are metric), but the servo plate also functions as a large heat sink for the amplifiers. Find your box of metric M5 screws, and secure the amplifiers and breakout box to the plate. You will probably need a washer to attach the ICM-1900.

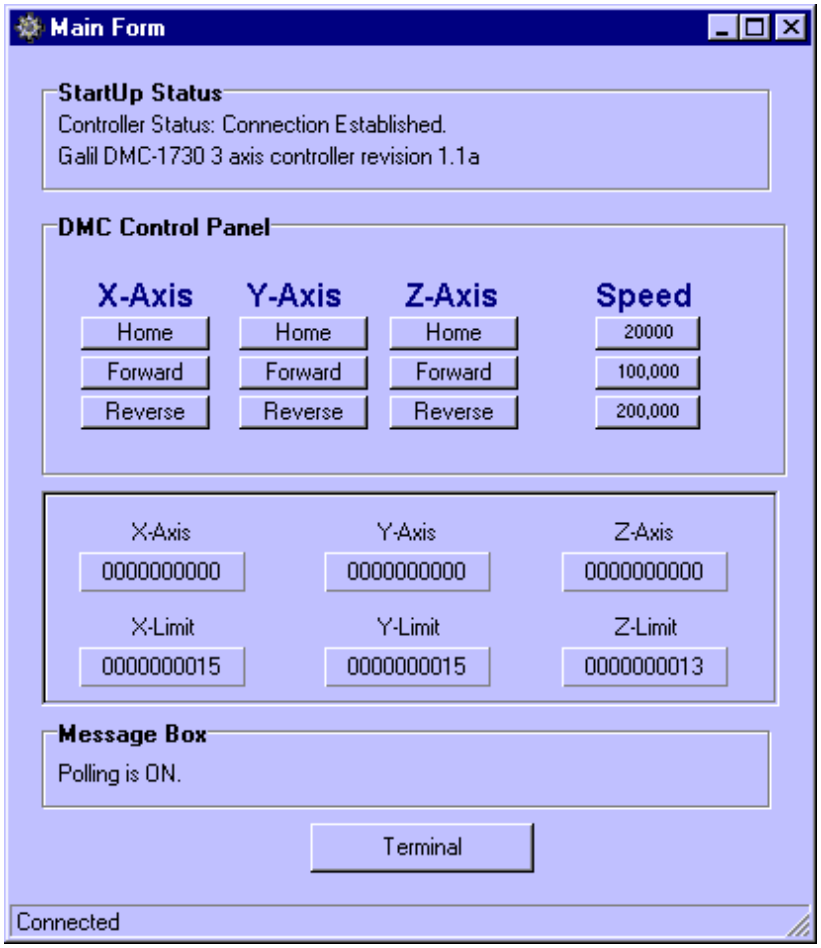


A single TQ-10 and the ICM-1900 breakout box on the servo plate.

Installation: Computer & Software

If you've got some time left in the day, or you are a graduate student and prefer to sleep in lab, go ahead and setup a table next to the arrayer. Place the computer on the table, such that the 100-pin cable supplied with the DMC-1730 controller card will reach from the slots on the back of the computer to the connector on the ICM-1900. If it's a brand new computer, run it for the first time and go through Windows setup before installing the controller and arrayer software. Unpack the controller card and take the cover off your computer. Hopefully, you have purchased a computer with a tower, or mini-tower, type of case. We found that the Gateway desktop models lacked the space required for the controller card. In other words, computer lid could not be put back on with the card installed. Of course, you may operate your machine without the cover, as one member of our lab is fond of doing, but this is not advised by the manufacturer. With luck, you will be able to re-cover the computer after installing the card. Typically, computers have two type of slots: PCI, and ISA. The DMC-1730 is an ISA card, and it doesn't matter which ISA slot (if you have multiple slots) you use for the card. Make sure the power is disconnected before installing the card. Avoid attaching any additional devices that need a PCI or ISA card, like network adapter, Jaz drive, SCSI drive, scanner etc. This is to avoid potential IRQ (interrupt request) conflicts. A Zip drive connected to the parallel port will be OK and useful for shuttling files and applications in the absence of a network connection.

Now is a good time to install the software that came with the DMC-1730. If Windows 95 behaves properly, it will detect the new device and bring up the **Update Device Driver Wizard**.Insert the Galil CD that came with the controller. Using the "Browse…" option to locate the "Install" folder on the CD. Within the Install folder, locate the "Dmc1700" folder. Click "OK." Windows will then ask for the file "Galil.VXD" Use the browse option again to locate this file within the above mentioned "Dmc1700" folder. After all of this craziness, you will find that there is an installation program on the CD which gives you several options. Most are password protected, but the only one that is handy is the "Windows Utilities and Programming Library." Go ahead and install this set of programs. This will put the Galil Registry program and Galil Terminal program on your computer. Choose the Restart computer option and reboot. Isn't Windows95 fun?



After running the jogger program, your screen should look like this.

Install the Stanford software according to the "READ ME" documents that accompany it. There are two programs: Jogger and ArrayMaker. Install the Jogger first.

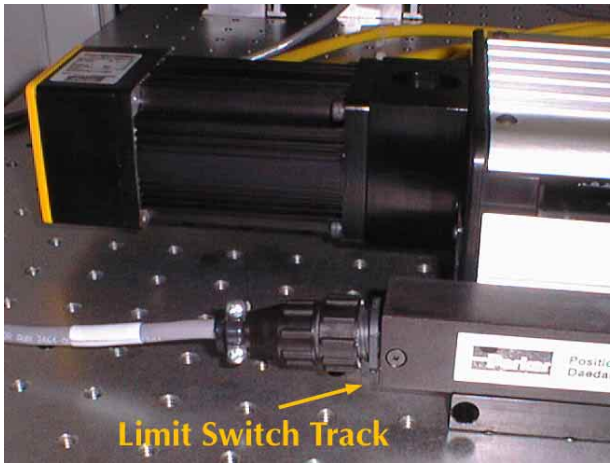
To verify that your installation of the card, Galil software, and Stanford software was successful, run the "Jogger" program. This little app is simply a diagnostic tool for checking connections and issuing commands to the card. Check that your screen matches our screen shot.

If the message reads "**Warning! No connection to the controller!**" then some component of the software did not install properly. Power down your system and check that the card is firmly installed in the ISA slot. Next, check that all software has been properly installed. Assuming you have successfully connected to the controller using the "Jogger" program, you can pat yourself on the back, crack open a beer, and go home knowing that you are well on your way to finishing the job.

Wiring the Motion Control System

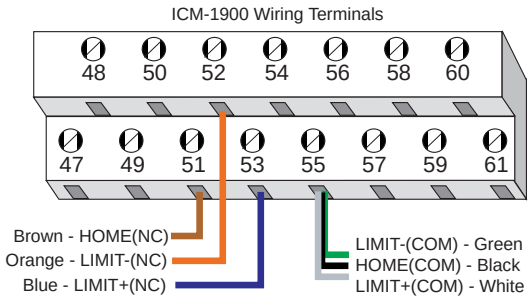
Truly, the only daunting task of putting the arrayer together is wading through the tedious task of wiring up the ICM-1900. For nearly the entire job, we employed the use of butt-connectors as an alternative to soldering. This has the advantage of being very fast, reliable, insulated, and non-toxic. Get out your vise grips (or connector crimping tool, if you have one), find that box of connectors, and get ready to rrrumble!

Turn off the computer, and make sure everything is unplugged. The first items to be wired in any motion control system are the limit switches. Limit switches prevent the stage from crashing into either side of the travel length by turning off the motors when the stage has passed a specific position. If the stage was allowed to crash, there is a substantial risk of damage to the ball screw, guide rails, motor, and motor coupling. Typically, a high speed crash at the end of the travel length will result in a shattered motor coupling. The sight and sound is not pretty. (The coupling is the spring-like device visible between the stage and the motor.)

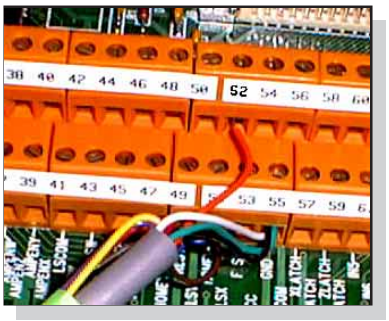


Let's wire up the x-axis limit switch first. The switches are located in the long black rectangular box ("limit switch track," or "LS-track") which rides outrigger to the rest of the stage. Do not attempt to dismantle the limit switch box yet. Hopefully, you will not need to do so at all. Supplied with your stage, you will find the limit switch connection wire. At one end, there is a round, multi-pin connector. This side attaches to the limit switch track. The other end of the cable sports a bunch of colored wires. Strip the following wires: Brown, Orange, Blue, White, Black, and Green. This leaves three wires leftover that we don't need. Fold these back and tape them to the insulation, or cut them off completely. Next, insert the wires into the appropriate terminals of the ICM-1900 according to the Limit Switch diagram:

X-Stage Limit Switch Wiring Diagram



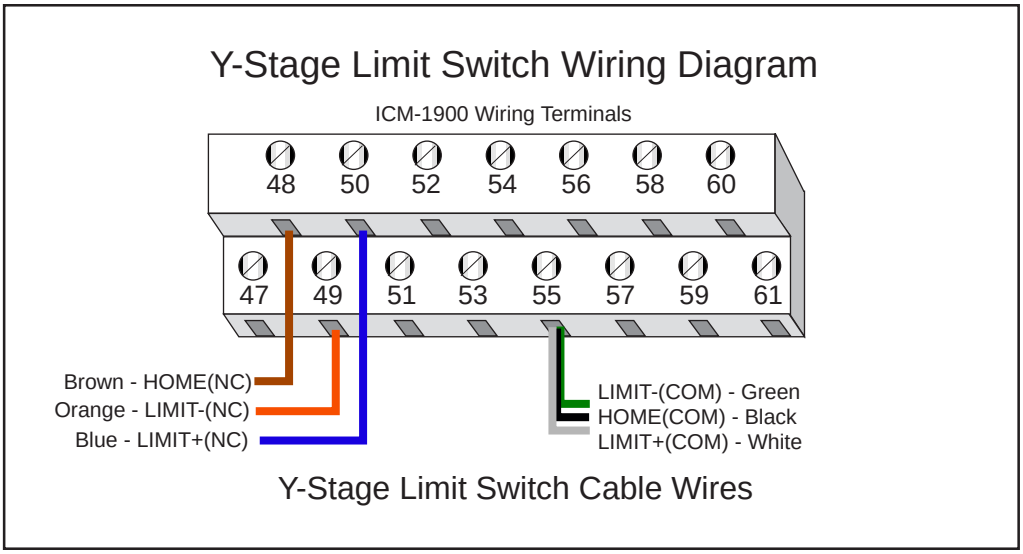
X-Stage Limit Switch Cable Wires

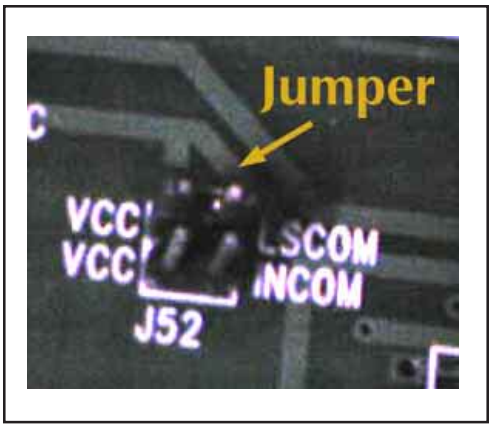


Forward Limit Switch Wiring for the X-Stage

The black, white, and green wires are the common ground wires for the switches. Because there are only a limited number of ground terminals on the ICM-1900, it is necessary to insert these bundled together into a single GND screw terminal (Do not use ground terminals that are labelled ISO-GND. These are opto-isolated terminals, which, for our case, will make them useless. If you're not sure, take your handy multi meter and attempt to measure a voltage from any VCC terminal and the GND in question. Note, the computer must be on and connected to the ICM1900. If you don't get 5 volts, the GND is not useable. The situation is corrected by the fact that recent versions of the ICM1900 sport a very handy block of GND terminals, which are perfectly useable, on the edge of the board. This is not part of the bright orange terminal blocks. Use these terminals if you have this situation. Shown in the figure is Revision D of the ICM 1900, which contains the extra block of terminals). If you find it difficult to insert the bundle, you can ease the burden by splicing wires together with the butt connectors. If you have never used these connectors, the procedure is straightforward. Insert the stripped end of one wire into the connector such that it slides into the internal, metal part of the connector. Take your vice grips, or crimping tool, and smash down that side of the connector. Test the connection by pulling on the wire. If you can pull it out, then you've missed. Try again with a new connector. Repeat for the other wire and other side of the connector.

Now, the terminal block should look similar to the picture. Repeat the process for the Y-Stage, according to the diagram:





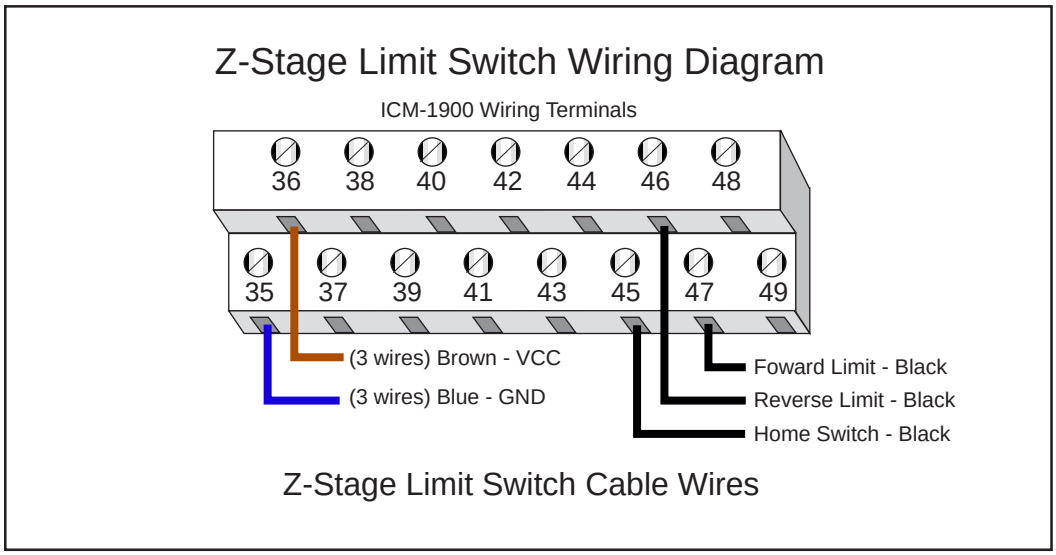
The limit switches need 5V of power to run. This can be supplied by the ICM-1900 (through the DMC-1730) by applying a jumper to the pins labeled "VCC" and "LSCOM" as shown in the picture. For those in the know, VCC stands for +5 Volts. If you don't have jumpers, you can solder the two pins together with a connecting wire. This will supply all of the limit switch terminals with the necessary voltage to operate the switches.

It's time to test your wiring job. First, plug in the computer and switch the system on. Run the Jogger program. There are three panels, one for each axis, which display the limit switch states. Grab the X-Stage carriage and move it to the middle of the travel length. It doesn't matter if a motor is attached or not,

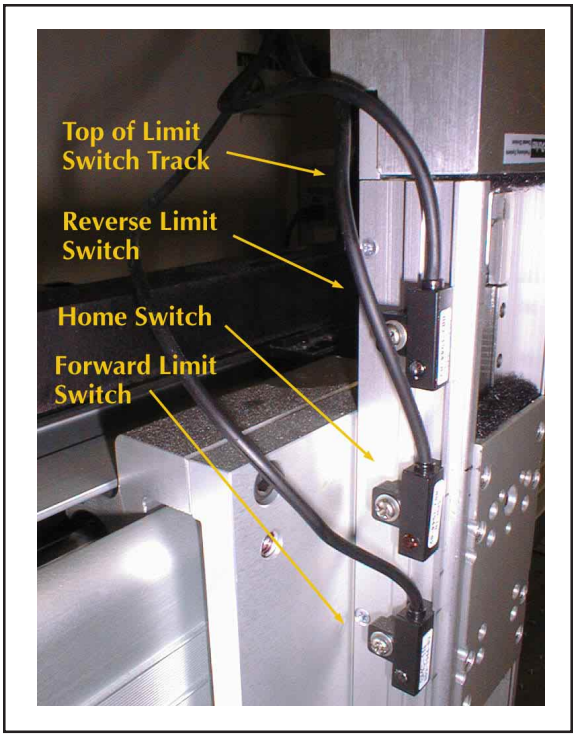
the carriage should move smoothly, although slowly. Now, pull the carriage towards the front of the table (away from the side with the motor). As you approach the end, watch the status numbers for the X-Stage on the computer screen. When the switch is thrown, the number shown in this panel will change from “15” to “7”. Now push the carriage to the other end of the travel length. Again, as you near the end, you will see a transition in the numbers. This time, there will be two transitions: one for the home switch, and one for the reverse limit switch. For the home switch, the numbers will change from “15” to “13” and for the reverse limit switch, the numbers will change from “15” to “11.” If you have witnessed these changes, then all the wires are correctly installed. Repeat these diagnostic checks for the Y-Stage. The number transitions are identical to the X-Stage.

troubleshooting: If the limit switch state panel reads anything else but “15” then this indicates that something is not connected properly. If the limit switch panels read “1” instead of “15,” this indicates that no power is reaching the switches. Double check your wiring. Check, with a multimeter, that +5V is registered between terminal 41 (LSCOM) and terminal 55 (GND) on the ICM-1900 board. Make sure you are not using one of the “ISO GND” terminals.

Having accomplished the correct wiring of the X and Y stages, go ahead and tackle the Z-stage. Turn off the computer first, thereby cutting power to the ICM-1900. The Z- stage uses hall effect switches. The switches are visible on the outside edge of the stage as three black oblong capsules sporting tiny red LED lights. Each sensor has a black cable with three wires. The brown wire is +5V, the black wire is the output, and the Blue wire is the ground. Because of the limited length of the limit switch cables, it will be necessary to lengthen these with additional wire. Again, the butt-connectors come in very handy here. Wire the limit switches as in the diagram. Note that the blue wires will need to be bundled together, as will the brown wires. Make sure you wire the switch at the bottom of the travel length (away from the motor) as the FORWARD limit switch, and the middle switch as the HOME. Mixing up these switches can have very bad consequences.



Now, when you flip the computer on, you will see some of the switches LED lights glowing faintly. This indicates that the switches are getting power. Test the switches by running the carriage up and down the travel length. On the Z-stage, you will need to turn the motor coupling to make the stage move. You should see the appropriate number transitions in the Jogger program. For the forward limit switch (away from the motor), the numbers will transition from “13” to “5,” and “13” to “15” for the home switch (middle), and “13” to “9” for the reverse limit switch. As an additional check, you can also watch the LED lights wink on and off as the stage pass through them. Cool, eh?

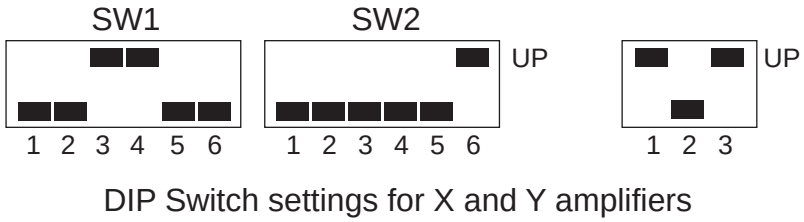


The limit switch positions for the X-Stage and Y-Stage should be at adequate positions when they come from the factory. The home switch should be very close to the reverse limit switch, and the forward limit switch and reverse switch should be very close to the limit of travel at either end of the travel length. If, for some reason, the switches are in the wrong place, one can easily open the LS track, and move the switches. Hopefully, you will be spared this inconvenience.

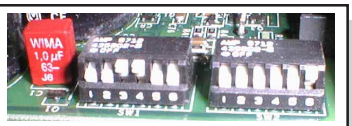
The Hall effect switches on the Z-stage are much easier to adjust. Simply loosen the bolt on each one, and slide the switch into its desired position.

Setting Up the Amplifiers

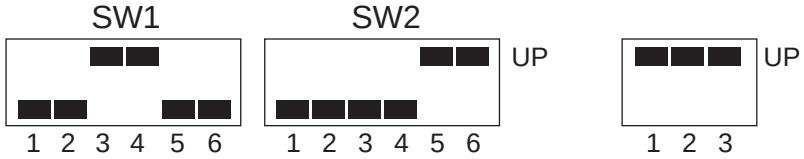
Label your amplifiers from left to right, X, Y, Z. Each amplifier has three sets of dip switches which must be correctly set for the type of motor used. The motors for the X and Y stages are identical, but the Z stage motor is slightly different. Two of the dip switch blocks are on the same side of the amplifier as the power cord socket. The other dip switch block, which only has three switches, is on the opposite side. Flip the switches on both the X and the Y amplifier so that they match the diagram:



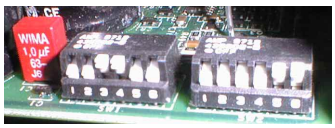
DIP Switch settings for X and Y amplifiers



X,Y: SW1 and SW2



DIP Switch settings for Z amplifiers



Z: SW1 and SW2

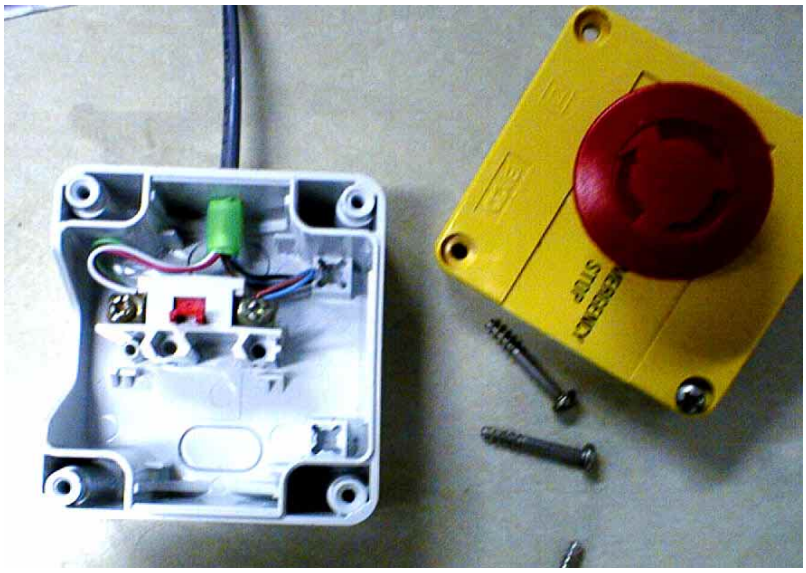
Now, proceed with the Z amplifier according to the diagram.

With each amplifier, three blocks of plug-in screw terminals are provided. Insert these into their slots, next to the numbers. The large terminal block goes on the side of the amplifier. It's probably best to leave the amplifiers unplugged until we are ready to test them. A word on power strips: it is advisable to keep the amplifiers on a separate power strip with a remote cut-off switch.

Wiring the Emergency Stop Button

One of the most important features of any motion control system is the emergency stop button. This allows the user to instantly stop the stages, should some aberrant behavior occur. Go ahead and wire this before progressing any further. Essentially, we will be using the "Enable" feature of the TQ-10 amplifiers. The way this works is that the motors can move only when the ENABLE IN and GND (ground) on the amplifier are connected. They are connected via the emergency stop button, which is normally closed. Hitting the button breaks the connection and immediately stops the motors. This is a good opportunity to use your multi-stranded wire. Cut yourself a five foot length from the spool. Pick three wires, note their colors, and wire them to the ENABLE terminals (terminal number 1) on each of the three amplifiers. Pick three more wires, and connect these to the ENABLE GND terminals (terminal number 2) on each of the three amplifiers.

Drill a hole in one of the three side panels in the bottom of the stop button and pass the multi-stranded wire through. Wind some tape around the wire inside the hole in the button so that the strain is not on the connections. The three 'ENABLE' wires are connected together to one terminal of the stop and the three 'ENABLE GND' to the other. Screw the top back on. The bottom may not be threaded, so you will need some wrist power to accomplish this. The switch may be fixed at any convenient location on the breadboard using Velcro or double sided stickies. Make sure it is accessible from the computer, where a typical user is likely to be working.



Inside the emergency stop switch.

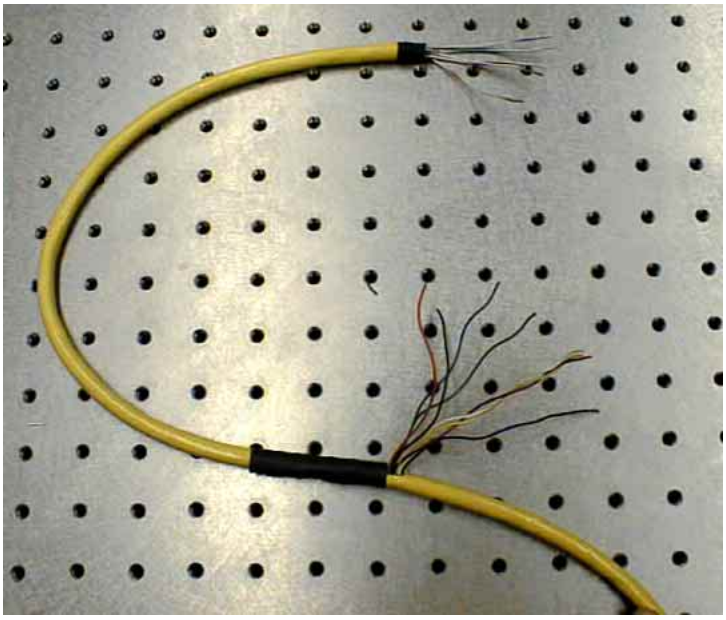
To test the cutoff switch, try the following: plug in the amplifiers, and turn on the power strip. The Power On LED on the face of each amplifier should be glowing a soothing green color. Hit the emergency stop button. Instantly, the LEDs should shift to a nasty red color. If this happens, then you have successfully wired this component. Twist the stop button so it pops back up, and the green colored lights will return.

Wiring the X-Stage Encoder

What is an encoder? The encoder measures rotational movement of the motor shaft, and relays a signal to the controller and amplifier. This allows the computer to control the position of the stage.

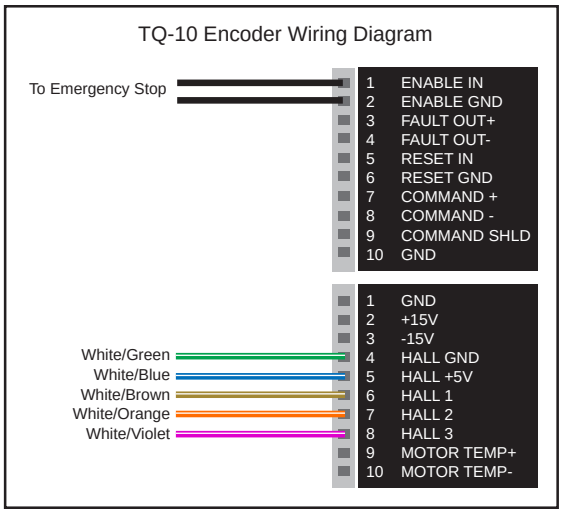
If your motors did not come attached to the stages, don't worry. Both the X and Y motors are identical. Pick one of the motors and put it on the table so that you have easy access to the wires. If your motors are attached to the stages, find the cables which stem from the X-stage motor.

You will notice that there are two yellow cables attached to each motor. Each cable contains a bundle of multi-colored wires. We are going to focus on the bundle which contains the greater amount of wires. Eight of these wires will be attached directly to the ICM-1900. The remaining five wires will go to the TQ-10 amplifier. You will notice that the amount of exposed wire prohibits simultaneously reaching both the TQ-10 terminals and the ICM-1900 terminals. There are two options. One is to



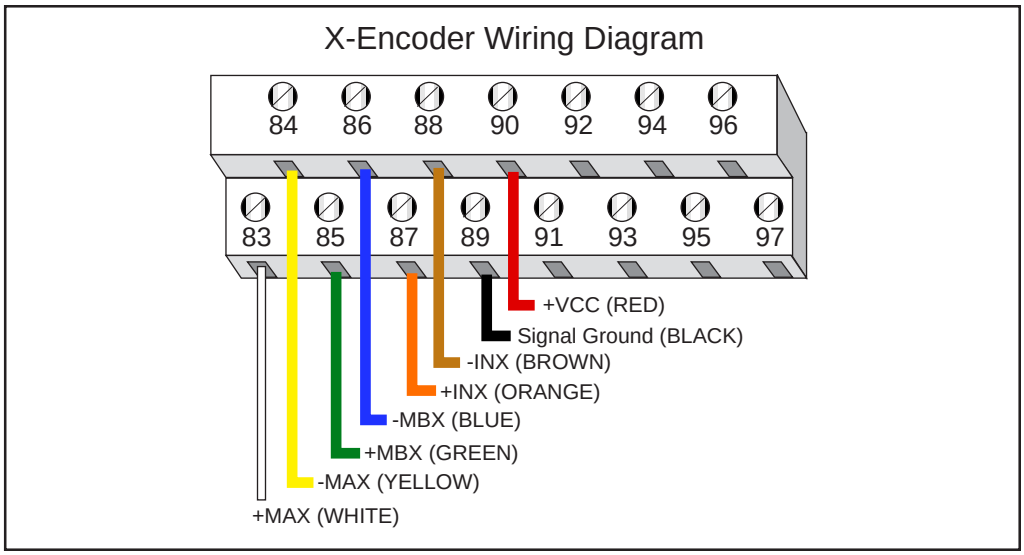
Option #2: Slice a hole in the cable shield and pull the necessary wires through.

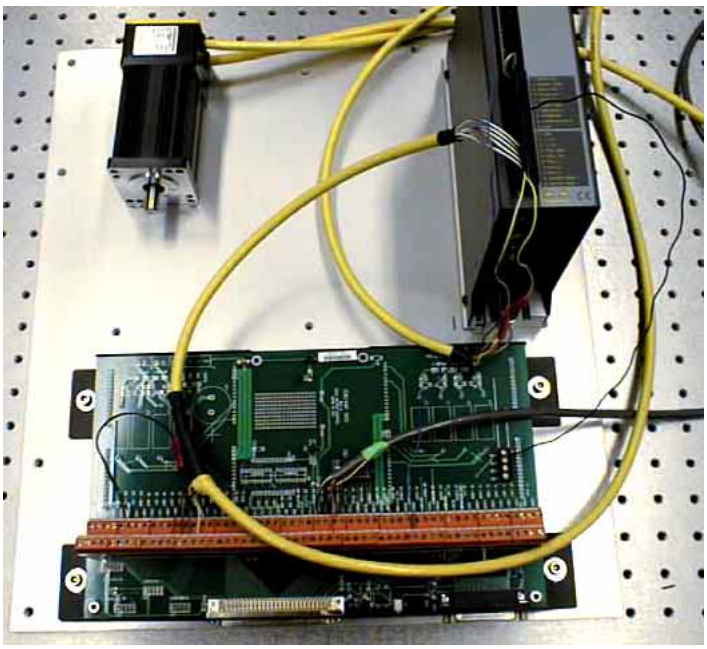
attach an additional length of wire. Here is another case where the multistranded wire comes in handy along with the butt connectors. Since the yellow cable is shielded, it is best to keep the wires which carry signals that are prone to interference closest to their destinations. Therefore, when you attach wire extenders, you should choose to extend the those that attach to the ICM-1900, and connect those that attach to the TQ-10 directly. Option #2 is to slice a hole in the side of the cable about 10 inches from the end and pull out only the bundle of twisted wires that is in the center. These are the wires that will attach to the ICM-1900. The rest will go to the TQ-10. This is easy if you twist the wire to slightly unwind the bundle.



Let's start with the TQ-10. Attach the five wires to terminals 4 through 8 as shown in the diagram.Then, attach the remaining eight wires to the ICM-1900 as shown in the diagram.

To test your wiring, and connect the power cord to the amplifier, turn on computer, and boot up the Jogger program. If your motors are connected to the stage, you should be able to nudge the carriage and see a corresponding response on the X-position panel. If your motors are not connected, then simply turn the motor shaft by hand, and you should see the result as changes in the position.





Troubleshooting: If you do not see any changes in the position panel for the X-stage, check the following. Is the TQ-10 powered up? (Green LEDs glowing?) Is the ICM-1900 properly connected to the computer? Are all the wires tightly connected in the terminals? If you used wire extenders, are all the connections tight? Check with a multimeter to verify that all connections are valid and that the ICM-1900 is powered up.

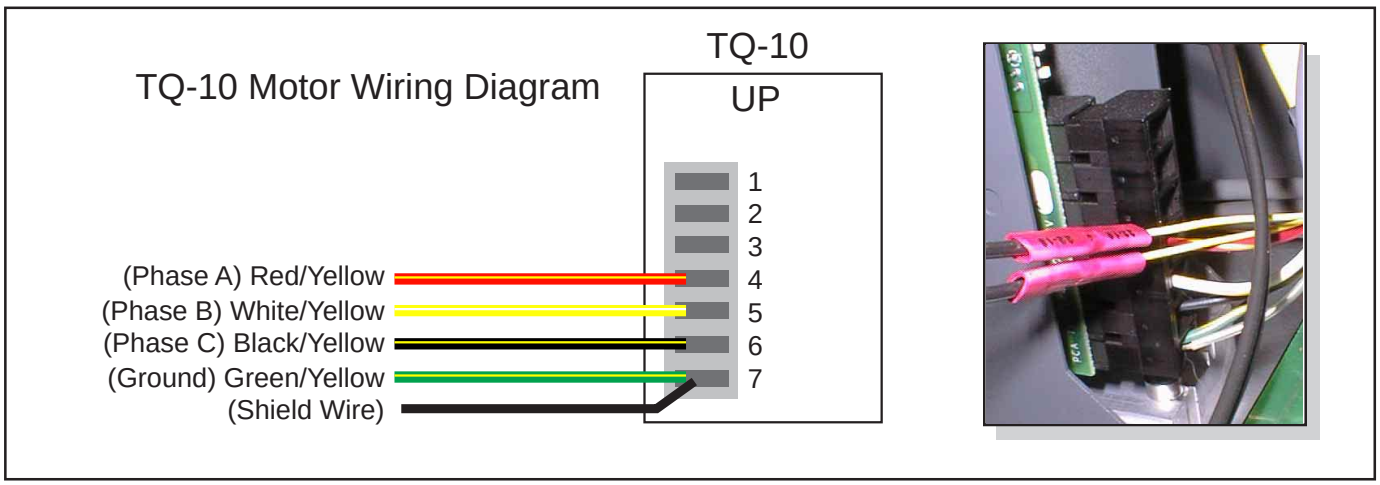
Assuming you are successful, hold off on wiring up the other two amplifiers. Power down the system, and unplug the amplifier. It's now time to wire the motor itself.

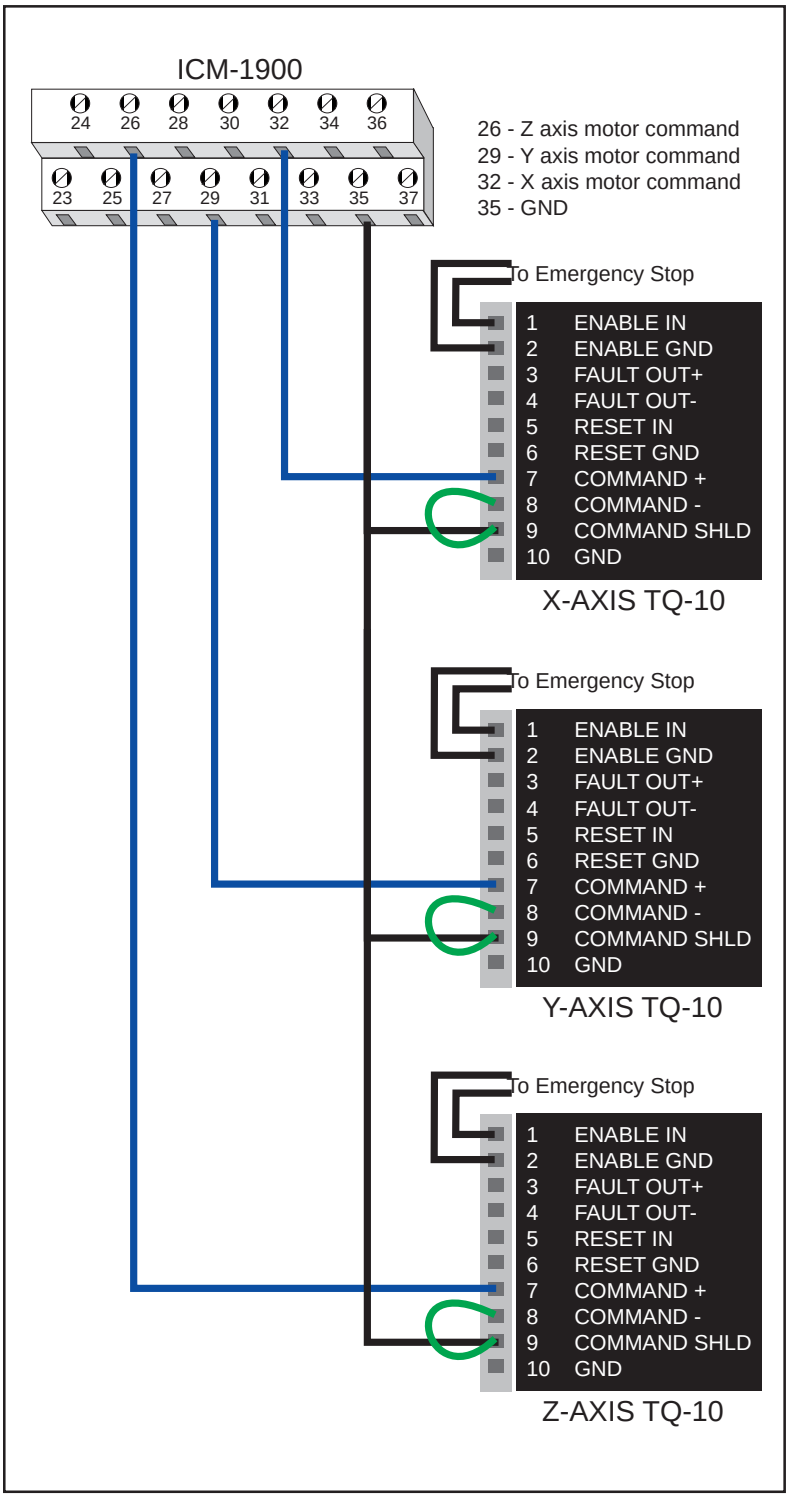
Wiring the Motors

This step of the procedure involves the other bundle of wire that was not used in the encoder attachment. There are six wires and a "shield sink." These wires will attach to the TQ-10 screw terminals on the side of the amplifier. These are the larger, heavy duty variety. (Opposite the side with the power cord socket.) Attach the wires as in the diagram and picture. Notice that you now have two left over solid yellow wires plus the shield sink. Connect the two yellow wires to terminals 9 and 10 on the top of the TQ-10. (Labeled 'Motor Temp+' and 'Motor Temp-') Again, you will need to extend these wires to reach. In the picture, you can see the two yellow wires attached to two black extenders via red butt connectors. The shield sink wire, which lacks insulation, should be wired to the bottom terminal on the side of the TQ-10, as in the diagram. (This is ground.)

Before we can test this wiring, we need to attach a few additional wires from the TQ-10 to the ICM-1900. For this job, the multistrand wire again is useful. Connect wires as shown in the diagram. Note that you must loop a small piece of wire from The Command- terminal (8) to the Command SHLD terminal (9). Another wire must then connect (9) to a GND terminal on the ICM-1900. ()

Now you are ready to test the X-Stage motor. Turn off the computer. Follow the following steps: If your motor is attached to the stage, make sure the carriage is in the middle of the travel length. For the purpose of this test, keep the emergency stop button within reach at all times. Now, plug in only the x-stage amplifier. If the stage begins to move, or if the motor shaft begins to turn, immediately unplug the amplifier or hit the emergency stop button. Any movement indicates that the wiring is improper or





incomplete.

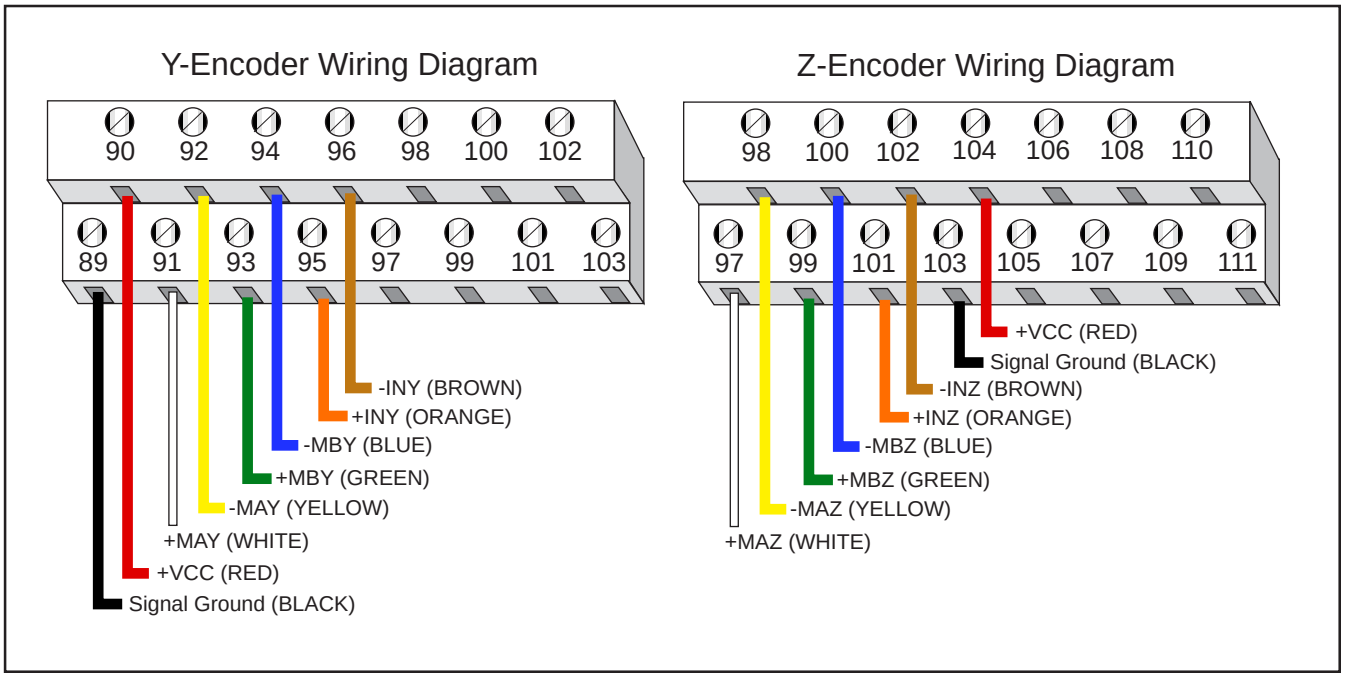
Assuming you have plugged in the amplifier without mishap, and the LED on the amplifier is glowing its soothing green color, then now is the time to try a directed movement. Turn on the computer and boot up the Jogger program. If the wiring was not properly completed, or if there exist loose connections, the stage may exhibit erratic, or out-of-control behavior. Thus, ***it is extremely important to keep the emergency stop button at hand***. Click the "forward" button on the X-stage panel. If your motor is attached, then the carriage should move smoothly forward a few inches. If your motor is unattached, then you should see the motor shaft spin several revolutions and come to a stop.

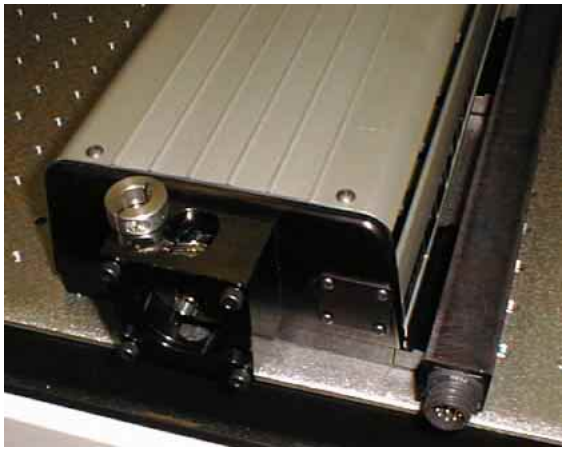
You should also be able to see that the computer successfully registers the position of the carriage. Assuming the above steps did not yield any catastrophic mishaps, go ahead and press the "reverse" button. The stage should return to the exact position from which it started. Or, if your motors are unattached, the shaft should rotate in the opposite direction for an equal number of revolutions.

If all this has gone well, congratulate yourself, and start in on repeating this process for the other two stages. Check the wiring diagram to make sure you are making the right connections.

Wiring diagrams for the Y and Z encoders .

Follow the diagram. Note that the X and Y encoders will need to share the +VCC and GND terminals on the ICM1900. You can accomplish this by bundling the wires together. Make sure the terminal screws are tight – you wouldn't want the controller to lose one of these connections during a serious print run. Remember, turn the power off before doing any wiring. Also, keep that emergency stop button handy.





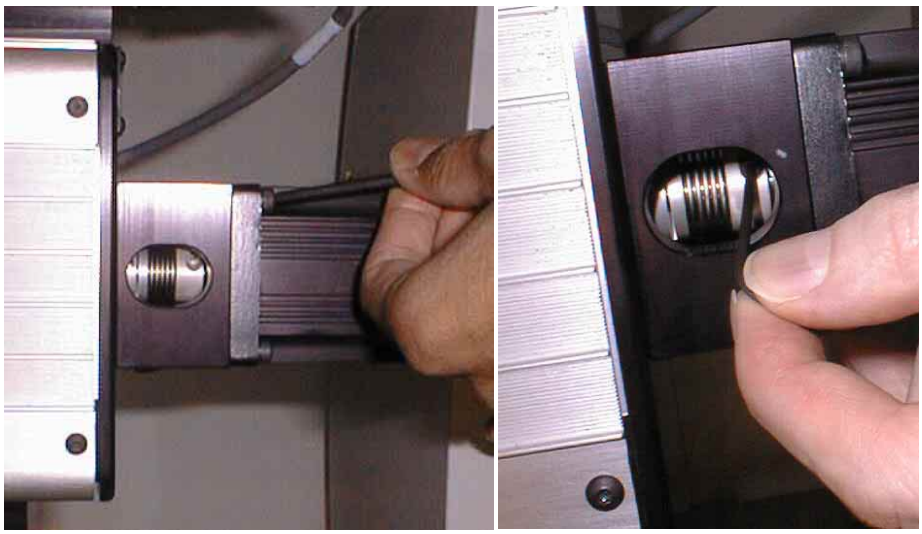
X-Stage without a motor. Note the heavy duty style coupler and collar.

Attaching the Motors

If your motors came from Western Tech unattached to the stages, then now is the time to connect them. The most important thing to consider is that the motor shaft be precisely aligned with the coupler. The coupler connects the motor shaft to the positioner shaft. These devices often look like coiled springs. Parker has been known to ship a variety of different couplers. The heavy duty variety features two collars, tightened by a screw. (See picture below)

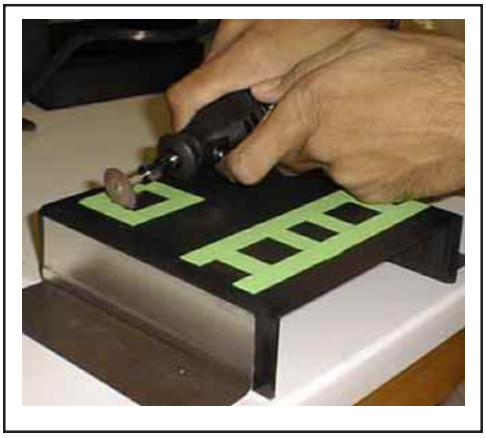
Before putting the motor on, remove the hex nut at the top of the coupler. ***Don't loose this screw!***

To mount the SM232 motor (X or Y stage) to the positioner, align the four mounting through holes with the tapped mounting holes on the stage. The motor shaft should fit into the coupler without deforming it in any way. (No resistance). If the motor shaft does not fit into the coupler smoothly, adjust the motor position until it does. Now, fix the motor with 1/4-20 mounting screws, as shown in the diagram.



Attaching the SM232 motor

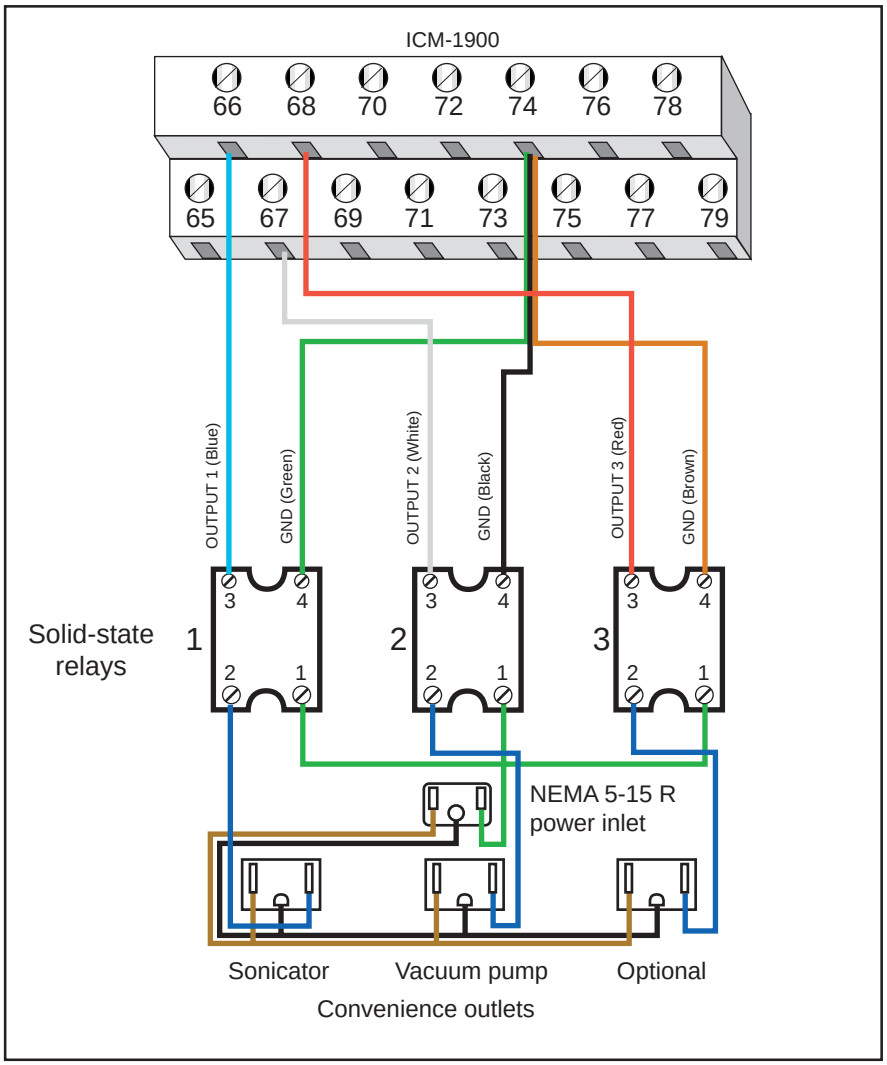
To tighten the coupler onto the motor shaft, find that hex nut and tighten it with a hex wrench. Make sure that this is very tight. (Don't strip it, though). If the coupler is loose, the positioner will slip during fast accelerations, resulting in non-repeatabilitity in the system.



Constructing the relay box

The arrayer software not only controls the stages by sending commands to the motors, but also controls the vacuum pump and the sonicator in concert with the stages, which forms an integral part of the arraying process. Since the controller can't communicate directly with these devices, the only option is to build a relay system. This uses solid state relays to turn on and turn off the pump and sonicator based on a small voltage signal from the controller. Basically, the device to be controlled is connected via one half of a solid-state relay to an AC power source. The relay is normally open, so there is no current flowing through the circuit. When a signal of 5 volts is sent through the other half of the relay by the controller, the circuit is closed and the device is now turned on.

To build the relay box, you will need the PacTec plastic enclosure or something similar from your local electronics store, one AC power inlet, 2 panel-mounting convenience outlets and of course the 2 solid-state relays. The inlet will be connected to a wall socket by a power cord and the 2 outlets are where you'll plug in the vacuum pump and the sonicator. In addition, you will need a few feet of the multi (six)-stranded wire, some heavy duty wire, solder, heat shrink, etc., and a good hand-held drilling/sawing tool. For the last, we recommend the Dremel, available in most hardware stores. You'll love using this one!



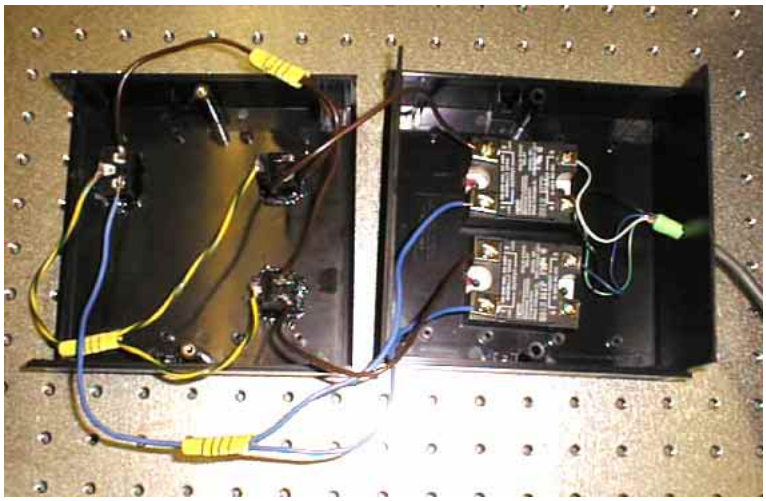
Relay Box Wiring Diagram. Note that this diagram shows a third optional relay. (For controlling another device or station)

Plan the layout of the relay box. The solid-state relays and all the connecting wires will be inside the box and the inlet and outlets will face out. If you are using the PacTec box, the best option is to have the inlet and 2 outlets on the flat top face of the box. The relays can be stuck to the bottom inside with double-sided sticky tabs.

Mark the outlines of the inlet and the outlets on the plastic, making note of how they will insert into the box. Don't make the outlines too

large, as they can become loose. Use the cutting discs on the Dremel to cut out the outline and make a tight fitting hole for the inlet and outlets. Exercise caution when using the Dremel; wear eye protection and firmly clamp or tape down the part being drilled. With luck, you will finish this part with all your fingers still intact. When the fit is snug, push down the inlet and outlets into their holes. For the inlet, you will probably have to remove the small plastic tab on top to ensure that the plug will fit. A dab of epoxy along the back edges will make the bond permanent. In addition to making these holes, also drill a small hole on a side towards the small terminals of the relays that will accommodate the multi-stranded wire.

When the epoxy has set, it's time to do the wiring. Lightly put on the clamps and screws on the relays, making note of the two different sizes. Use heavy-duty wire for connecting the inlet and the outlets according to the diagram. One convenient source of such wire is an unused heavy-duty power cord of the kind that is used on computers (and the amplifiers). You can strip the outer jacket, separate the three wires inside and use them in the relay box. The colours on the diagram are for illustrative purposes only; you can vary this if you want, as long as the actual wiring is done according to the diagram. Having a consistent colour will make it easier to troubleshoot however. You will need to connect three sets of three wires together and large butt connectors will make this easier. Connect the two grounds from the back of the outlets to the ground in the back of the inlet and do likewise for one of the lines. The best option for making secure connections to the inlet and outlets is to thread the wire through the holes in the back, twist it and solder it to the prong. Before attaching the wires to the inlet, pass a small length of heat shrink tubing over each wire and shrink it over the soldered prongs using the soldering iron. Before taking on these tasks, it might be wise to get used to soldering and using the heat shrink on bits of wire.



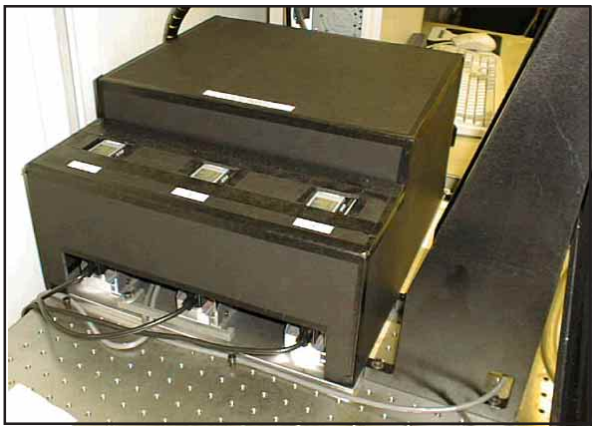
Connect the remaining load from the inlet to the relays and from the relays to each of the remaining loads on the outlets. It is important to make note of which relay gets connected to which outlet, i.e., they should be numbered as shown, as the devices and the terminals on the ICM-1900 are not interchangeable. Pass the multi-stranded wire though the small hole in the plastic enclosure and use tape to keep it from coming back out. Make the connections to the relays according to the diagram, making note of the colours. The completed relay box should look something like that shown in the picture. Test the connections using a multimeter on the terminals of the relays and the appropriate lines on the inlet and outlets. Close the box and put the screws in. The other ends of the green and black wires go together into a ground terminal on the ICM-1900 (# 74) and the blue and white wires go into the output terminals as labeled. Make sure to label the outlets on the outside of the box, so you'll plug in the vacuum pump and sonicator into the right places. Remember, these outlets are not interchangeable!

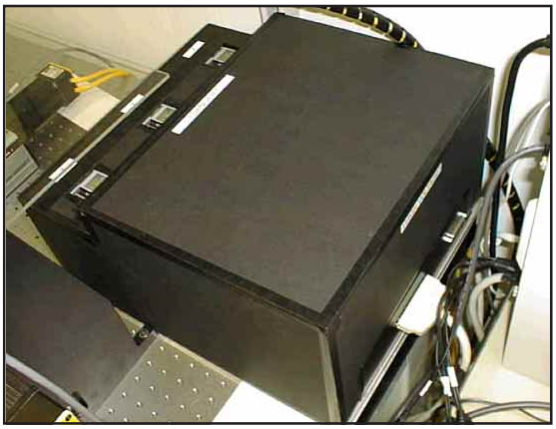
Congratulations! You have completed all of the difficult stuff. The second part of this guide is considerably more simple.

The MGuide Part II

After the completion of Part I, you should now have the software installed correctly, the limit switches active, and the stages moving. All of the tough stuff is finished. What remains is to integrate the various peripheral components. This section assumes you have ordered, or made yourself, the custom designed parts. Refer to our website for drawings and plans if you are not sure you have everything.

The servo mounting plate, amplifiers, breakout box, and associated cables, should be tucked safely behind the y-stage. Construct a box to protect the electronics from misguided fingers and over-zealous PI's. Secure the various cables using zip ties, or plastic cable wrap. Also, depending on your work area, it may be necessary to suspend the z-stage cable so that it doesn't drag on the x-stage. The other option is to fabricate a U-shaped guide for the wire that rests on top of the Y-stage.





***Foam-core box**. Constructed to protect the amplifiers and ICM-1900 from wandering fingers. Don't worry about the amplifiers getting too warm: the base acts as a huge heat sink.*

Mounting the slide platter

The slide platter consists of a large metal plate, with a pocket cut out at one corner. This is where the 96- or 384-well plate will reside during the actual printing process. It's extremely important to make sure that the printing plate does not shift around in this pocket. The best way of ensuring this is to place a plate holder (available from MJ Research) in the pocket and affix it using sticky pads at the bottom. You will need to cut slots in the sides of the plate holder to accommodate certain makes of 384-well printing plates. This will also ensure that the print plate is placed in the correct orientation every time. Several types of 384 well plates fit this holder, including the Genetix 384 sold by USA/ Scientific.

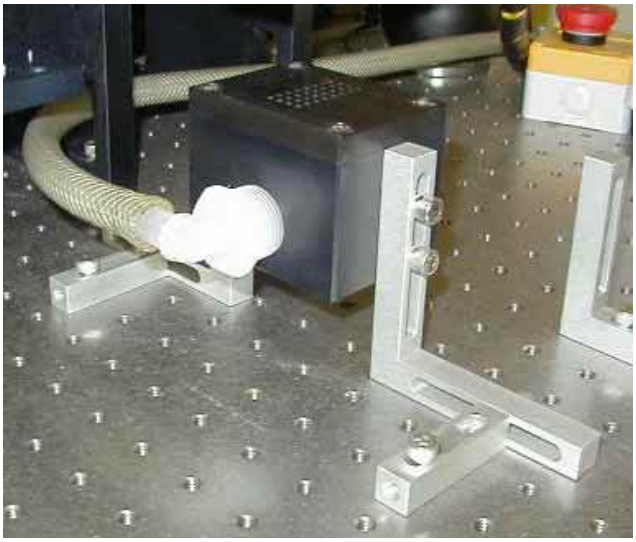
The MJ Research Plate Holder. Extra slots were cut to accomodate different 384 plates.

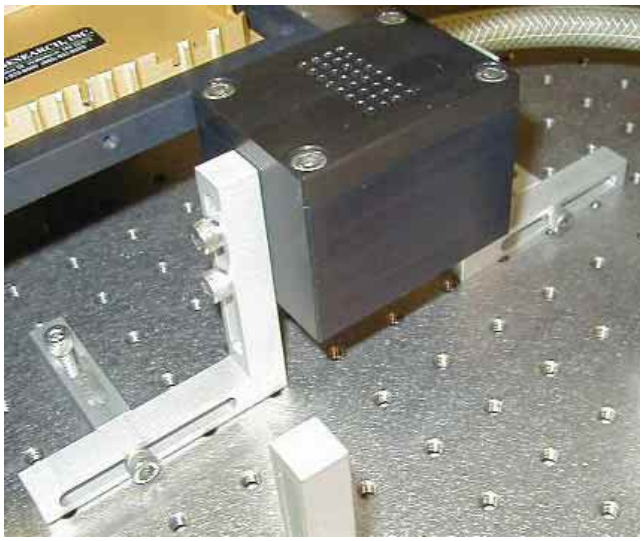
Notice the six counter-bored thru-holes on the face of the platter. Align these holes with the mounting holes one the x-stage carriage. Secure the platter onto the carriage using quarter-twenty mounting screws. The mounting threads on the carriage sport self-locking threads (painted red),

which will give a bit of resistance. Now, with the motors off, push the platter (and thus the carriage) down the travel length. Check that the platter successfully clears the upright supports for the y-stage. (It should be close.) You should also have, packed with the slide platter, a collection of small metal dowels. These will serve to align and separate the slides on the platter. Find an eager rotation student who would like to be a part of the action, and convince this person to fill all of the dowel holes on the platter with these pieces. The dowel holes should be slip fit, which means that you can easily take the dowels out anytime. This might be advantageous if you should get the desire to print on something other than the standard 1x3 microscope slide. Build an acrylic box to cover the printing platter during the print process. This will keep dust, fingers, hair, and other undesireable material off your precious slides. Typically, one can buy sheets of clear acrylic cut to size. Methylene chloride (borrowed from the peptide synthesis lab) can be used to glue the pieces together.

Putting together the dry station.

Among the custom pieces are the two halves of the dry station. Before attaching the dry station top to the base, insert a rubber O-ring in the groove on the bottom to ensure an airtight seal. Attach the top to the base with quarter-twenty mounting screws. To set up the dry station on the table, it is first necessary to align the mounting brackets. These are those L-shaped things with the slots cut out for mounting screws. Place them on the table as shown in the figure. If you placed them parallel to each other, you will now be able to attach the dry station with quarter twenty screws. The goal here is to align the top of the clean station with the top of the printing platter, and to align the dry station in the x-direction such that the printing tips, when present, will be able to dip into the dry station holes. To achieve this part of the alignment, we must first setup the z-stage. But, before you do that, finish the plumbing.





Dry Station Setup. Note how the brackets are positioned to allow maximum flexibility with regards to the alignment of the dry station. Also note that the dry station is positioned with only a few millimeteres of clearance away from the main platter.

***Vacuum Pump**. The GAST pump, shown in the top picture, sits under the table. The capacitor is taped securely to the table frame, highlighted in the white circle. The lower panel is a close up of the water trap, secured with zip-ties. Remember to keep the directionality correct. (arrow on top)*

The Vacuum Pump

Among the items you have ordered, please find the GAST vacuum pump. You should have also ordered a trap and a muffler. The trap is necessary to protect the pump from water damage. The muffler is a luxury item, although some would consider it a necessity. (If you want to draw a lot of curious eyes to the machine, leave off the muffler. The sound will be sure to attract and annoy.) Now, you will need to use some tubing adapters to attach the trap and the dry station to the pump via tygon tubing. Any good biochemistry stock room should have some stockpile of these sorts of adapters. If there isn't a central stockpile, check your local gel drying apparatus. (Or better yet, an apparatus in another department.) This is always a good place to find such vacuum tubing paraphernalia. Since your GAST pump will not be pulling significant vacuum, Tygon tubing will be fine. For our vacuum pump, we are using Tygon 3603 tubing. (ID 1/2" OD 3/4"). Put the trap close to the intake of the pump. Notice that your pump requires a tiny bit of wiring. You should have received a large capacitor with your pump. Find the wires with the red connectors and attach these to the capacitor. Now, sacrifice a spare power cable, and splice together with the two remaining wires of the pump. Test your wiring job by plugging the pump into a wall socket. You should be met with an alarmingly loud putter. Get used to it.

The Z-stage bracket and tip holder.

Attach the z-stage bracket to the Z-stage using M5 screws. Now, attach the tip holder bottom as shown in the figure. This will allow us to align the clean station. With the motors off, mover the y-stage carriage over to the dry station. Try to get the z-stage directly above the dry station. Now, lower the z-stage down to the dry station, by hand. Unlike the ball screws (x and y stage), the z-stage is a lead screw. This means that you will not be able to pull on the carriage to move it. Instead, you can turn the coupler with your fingers, which will result in z-stage movement. **Always** make **absolutely** sure those motors are off before you attempt to stick your fingers in there! Of course, you can use the jogger program for this, but it doesn't provide much flexibility as to the distance each stage travels per click of a button. To really determine whether your alignment is correct, you will need to insert a printing tip into the tip holder. Lower the z-stage far enough down so that the tip enters one of the dry station holes. If the tip does not align with the hole, loosen the dry station brackets (at the table) and adjust the dry station until you achieve proper alignment. Insert other tips, or move the one you are using to be sure that all the holes

are equally aligned. When you are sure that the alignment is correct, tighten down on the mounting screws to be sure that a casual knock will not displace the station.

The Sonicator

The sonicator is used to clean and rinse the printing tips between loads. All you really need to do is place the sonicator just to the right of the dry station and plug it into the relay circuit when that is completed. The thing to watch out for is that the dry station and sonicator need to be close enough to the print platter so that the Y-stage has enough travel to dip all 32-tips in the sonicator. At the same time, it cannot to be so close that the tip-holder (on the Z-stage) hits the edge of the sonicator when the tips are in the dry station. You will need to iteratively check the positioning by moving the Y-and Z-stage manually and via software. Once the sonicator and stage positions are set, it's useful to put in some 1/4-20 screws around the sonicator to ensure that it's firmly held in place and cannot be accidentally moved.

Use pins in the holder to properly align the dry station

At this point, you should have a completely functional arrayer. Refer to the ArrayMaker documentation and begin your first test prints.

Maintenance issues will mainly center around the printing tips, as these elements are the most fragile and subject to the most abuse. The ball screws, which drive the x and y stages, should be lubricated with Mobil HP grade grease after every few months of use. The lead screw on the Z stage will also require lubrication. SAE-10 machine oil is the recommended product.

Always remember that the arrayer is a powerful machine with minimal idiot-proofing. Be very careful and alert whenever using it. Keep loose hair, sleeves, jewelry, and other items clear. Never put yourself in the path of the stages while they are active. Make sure to kill the power before handling any part of the arrayer.