

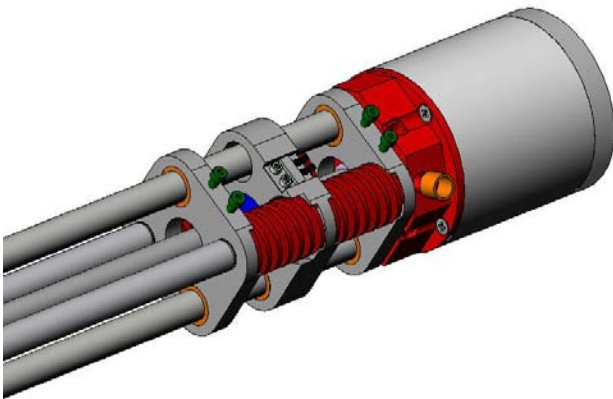
- Step 900: QC: Check all the hole sizes for all of the actuator parts using plug gages.
- Step 1000: Put O-rings on the bushings. (8 for each actuator)
- Step 1110: Assemble Carriage Outside Asm (**CarriageOutsideAsm movie**). Secure one bushing on each side of the 002-400-P-1023 piece between 2 002-400-P-1076 washers with #2-56 X 0.25 bolts.
2 assemblies needed for each actuator
- Step 1120: Assemble Carriage Nut Asm (**CarriageNutAsm movie**). Secure one bushing on each side of the 002-400-P-1025 piece with one 002-400-P-1076 washers with #2-56 X 0.3125 bolts.
1 assembly needed for each actuator
- Step 1130: Ballscrew Front Asm (**Ballscrew Front Asm movie**). Secure one bushing on each side of the 002-400-P-1026 piece with two 002-400-P-1076 washers with #2-56 X 0.25 bolts.
1 assembly needed for each actuator
- Step 1140: Assemble the correct plunger assembly for the desired actuator configuration. **DO NOT GLUE THE PLUNGER YET!**
- Step 1200: Glue 7" 3/8 Shafts into Motor Block using Hysol 9433. Make sure to shoot a bunch out of the mixer nozzle to ensure good mixing first.
(MotorBlockAsm movie)
- Step 1300: Put the angular contact bearings into the Motor Block, and put the bearing holder on. Make sure to have the bearings make a diamond with their markings to get the correct orientation. Secure with 4 #6-32 X 1/2 flat head socket cap screws with Loctite 262. Tighten the screws evenly and tight. The bearing holder piece will visibly deflect.
- **(MotorBlockAsm movie) MAKE SURE THE 3/8 SHAFTS MAKE CONTACT WITH THE BEARING HOLDER!**
- Step 1400: Put the Nut Rider over the ball screw and secure with 4 M3 0.5 X 8 socket head cap screws with Loctite 262. Try to not get ball screw grease on the screws. Tighten evenly, then crank down hard (but do not ruin the threads!). Press

in 4 Springs on each side of the CarriageNutAsm. Press The Carriage Outside Assemblies on the other side of the springs (**Ball Screw With Carriage movie**)

- Step 1500: Put the Motor Block Assembly and the Ball Screw with Carriage together so the ball screw goes through the motor block. Make sure you're not missing anything.
- Step 1650: Put on the spacer, magnet, bearing, and nut. Tighten down hard with 10mm and 14mm wrenches. But do not bend the ball screw!! Bending the ball screw will lead to a fluttery actuator. Do not use a large lever arm when tightening. Put on the nut squishy retaining piece and set screw. (**MotorBlockWithMotorAsm movie**)
- Step 1700: Put the motor back together using the original 4 long screws. (**MotorBlockWithMotorAsm movie**)
- Step 1700: QC: Put an external retaining ring on a 0.352 precision shaft. Compare the outside diameter of the external rings to those on the plunger shafts to make sure they are the same. (Groove should be 0.352 +- 0.002).
- Step 1800: Position (but don't glue) the Ballscrew Front Asm to the ends of the Motor block shafts. Insert the appropriate Plunger for the actuator configuration desired. Mount the Clamp Assemblies to the top and bottom of the Carriage and squeeze the springs. **DO NOT OVERSQUEEZE THE SPRINGS!** Insert the retaining rings and remove the clamps.
- (**SEA with Motor movie**)
- Step 1810: Remove the top of the Plunger and (**only after the retaining rings are in place and the clamps removed**) glue it back at the end of the plunger shafts. (this is to ensure that there is no twist on the bearing from shafts at different heights).
- Step 1900: Put together the force encoder strip using 8 #2-56 X 3/16 socket cap screws. Make sure to put the encoder all the way on the front edge and so you can read U.S. digital when looking down. Look at the sizes of the circles halves and make sure they are about the same. Do not touch or scratch it. Tighten the screws evenly but not all the way or the encoder will deform a little. Probably use low strength Loctite...(Encoder5.75inAsm movie)
- Step 1910: Put together the position encoder head using two #3-48 X 1/2 socket cap screws Probably should low strength Loctite everything.(**encoder position encoder assembly** movie)
- Step 1920: Put together the force encoder strip holder to the carriage using 4 #4-40 X 1/2 Socket Cap Screws. Loctite.

- Step 2200: Put together the position encoder strip using 8 #2-56 X 3/16 socket cap screws. Make sure to put the encoder all the way on the front edge and so you can read U.S. digital when looking down. Look at the sizes of the circles halves and make sure they are about the same. Do not touch or scratch it. Tighten the screws evenly but not all the way or the encoder will deform a little. Probably use low strength Loctite...
- Step 2300: Mount the position encoder head using two #3-48 X 1/2 socket cap screws and two #4-40 X 1/4 flat head button head screws. Probably should low strength Loctite everything.
- Step 2400: Mount the position encoder strip holder to the carriage using 2 #10-32 X 1/2 Socket Cap Screws. Loctite.

Step 1: Insert and Fit Bushings



- Press Bronze Bushings into each bushing bore on the Carriage Ends and Nut Rider but NOT the End Block
- With the Guide Rails inserted into the Motor Block, test fit the Carriage End by sliding it down the Guide Rails until it rests against the Motor Block.. If it doesn't slide all the way to the Motor Block without

resistance then ream the Carriage End's bushings to .3750". Repeat the test fit procedure and continue to ream in .001" increments until the Carriage End easily slides up against the Motor Block. Note that you should not have to REAM above .3770 if the parts have been machined correctly.

- Test fit Nut Rider in the same manner as above. This time, you should be sliding both the Carriage End AND the Nut Rider toward the Motor Block. Again ream in .001" increments. You should not have to ream above .3770 unless there is a machining problem.
- Test fit the second Carriage End in the same manner as above. This time, you should be sliding the Carriage End, Nut Rider, and new Carriage End toward the Motor Block. Again ream in .001" increments. You should not have to ream above .3770 unless there is a machining problem. Once reaming is complete, you should be able to slide all three carriage pieces up and down the guide rails with little resistance.
- Place the End Block at the end of the Guide Rails. Recall there are NO BUSHINGS in the End Block at this point. You should be able to easily slide the three carriage pieces back and forth between the Motor Block and End Block. Ream the Carriage End closest to the End Block in .001" increments until you can easily slide between the Motor Block and End Block. If the parts were machined properly this step should not require any reaming.
- Insert the Plunger Rails thru the three carriage pieces and slide back and forth between the Motor Block and End Block. Again, ream as required to make the parts slide easily.
- Insert bushings into the End Block and re-assemble the End Block. At this point, you may need shaft collars to hold the Plunger Rails and Guide Rails in place while sliding back and forth. Don't be surprised if the fit is suddenly very tight. You will need to ream the End Block Bushings until the hole assembly slides easily from end to end. You may need to ream these bushing all the way out to .385" to get the appropriate sliding fit.

Step 2: Press in Angular Contact Bearings

- Press Fit the first angular contact ball bearing into the Motor Block housing, applying pressure to the OUTER RACE ONLY. A 5/8" or 13mm socket drive should work well. If the press fit is extremely tight you may want to heat the Motor Block with a torch to ease the press fit.
 - Note that orientation of the first bearing should be such that the bearing COULD be pressed in via the inner race. In this configuration the bearings will tolerate the greatest amount of misalignment of the ballscrew..
- Press fit the second bearing by applying pressure to the OUTER RACE ONLY.
 - Note that the orientation should be opposite the first bearing. Thus if you pushed on the inner race the while inserting the bearing it would separate. Again, this allows for the greatest misalignment.

- Install the Bearing Retaining Plate using equal torque on each of the four screws.

Step 3: Glue Guide Rails into Motor Block bores

- Mount the Motor Block to the Assembly Jig and insert the two Guide Rails.
- Slide the three carriage pieces onto the Guide Rails.
- Mount the End Block to the Assembly Jig.
- Pull the Guide Rails out of the Motor Block to allow enough room to apply E30CL two-part epoxy to both the Motor Block bore AND the Guide Rails.
- Apply a moderate amount of glue to the contact surfaces
- Slide the Guide Rail into the Motor Block using a twisting action to evenly spread the glue
- Slide the three carriage pieces as close to the Motor Block as possible without touching the glue joint.
- Allow to dry for 12 hours before continuing with the assembly process.

Step 4: Assemble Ball Screw into Motor Block and add Spacer, Magnet, Ball Bearing and ¼-20 Nut.

- Apply Loctite 262 (permanent thread lock) to the ball nut threads and screw the Nut Rider piece onto the ball nut (which should already be mounted on the ballscrew).
- Insert the ballscrew through the Carriage End such that it is loosely hanging off the ballscrew.
- Insert Guide Rails through the Carriage End and Nut Rider bushings and continue to assemble along that direction until the ball screw journal passes through the angular contact bearings in the Motor Block. Note that the journal should be a slip fit with the angular contract bearings.
- Add the spacer that goes between the angular contact bearings and the magnet. This should be a very loose slip fit.
- Test fit the Magnet (No Loctite) to make sure that it fits easily over the ball screw journal. If it doesn't slide easily then you should check the journal and magnet core for burrs etc.
- Apply a few drops of Loctite 680 to the outside of the journal near the threads. Apply a few drops to .188 shaft and spread around on the magnet core.
- Slide the magnet over the ball screw journal
- Slide the ball bearing over the end of the journal.
- Add the ¼-20 low profile nut to the threads on the ballscrew and tighten snugly. This is critical step because it draws the ball screw snugly against the inner races of the angular contact bearings, spacer, magnet core and inner race of the rear ball bearing.
- Allow this to dry for 30 minutes before handling any further.

Step 5: Glue Carriage End to Plunger Rails

- Add the other Carriage End to the outboard portion of the ballscrew, sliding its bushings over the Guide Rails.
- Slide the Plunger Rails through the open bores on the Carriage Ends making sure to add the compression springs as you do this.
- Apply Loctite E30CL to the end of each Plunger Rail (after it has been assembled through the Carriage End closest to the Motor Block.)
- Add the retaining rings to the end of the Plunger Rails.
- Pull the plunger rails (while spinning) until the springs is snug between the Carriage End and Nut Rider. The spinning insures that the glue is spread evenly. Be sure the spring has seated correctly in its counter bore seat.
- Set assembly aside for 24 hours to allow the glue to dry.

Step 6: Compress springs and Glue the second Carriage End to the Plunger Rails.

- Add retaining ring clips to the Plunger Rails, sliding them near the groove where they will soon be seated.
- Mix up a small batch of Loctite E30CL
- Plug motor into the electronics Box
- Apply a jumper on the PID board such that the Force Pot input is Grounded. This is important because the Force Pot has not been added to the actuator yet and the “floating” signal can cause problems with compressing the springs.
- Use a DVM to measure V_{out} on the PID board. Turn the trim potentiometer until this signal is + 0.5 Volts. The will gently drive the carriage toward the motor block.
- Flip the Kill Switch to enable the motor. After the motor has seated against the Motor Block, turn the Trim Pot CCW to increase the V_{out} to +10 Volts. At this point the springs closest to the Motor Block should be fully compressed.
- Slide the other two springs up against the Nut Rider and slide the Carriage End away from the Nut Rider. This will expose the area around the retaining ring grooves.
- Apply Loctite E30CL to the portion of the Plunger Rail where the Carriage End will be seated.
- Slide the Carriage End back towards the Nut Rider. Make sure that the springs are seated in there counter bore seats.
- Slide the retaining rings toward the Ball Nut until they are seated in there grooves.
- Slowly turn the Trim Pot Counter CW to release the compression of the springs.
- Allow to dry for 24 hours before continuing with assembly.

Step 7: Glue End Block and Plunger End

- Dry fit Plunger End and End Block and make sure that carriage slides freely from end to end.

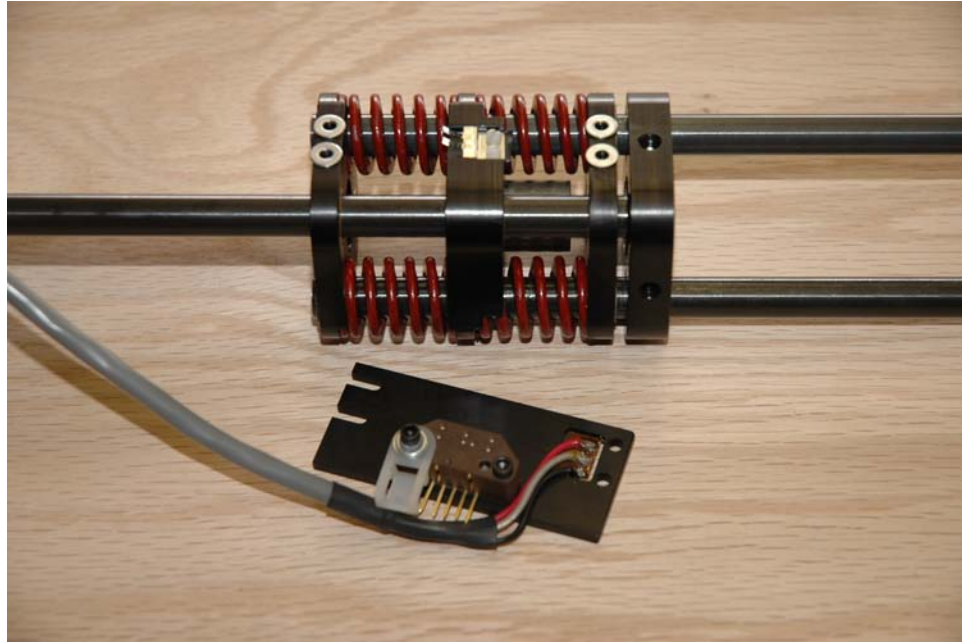
- Apply Loctite E30CL to End Block bores and Guide Rail ends.
- Slide End Block into place and use Encoder Mount Strip to locate it.
- Apply Loctite E30CL to Plunger End bores and Plunger Rail ends.
- Slide the Plunger End into place
- Allow to dry for 24 hours before continuing with assembly.
- Slide Ballscrew Support Bearing over end journal and add retaining clip.

Step 8: Assemble Sensors

- Cut the Force Pot wire to the correct length, such that the stripped portion of the wires reaches beyond the End Block by about 1”.
- Glue the Resistive Element to the Sensory Array Mount and solder the leads to the solder pads. It is easiest to thread the stripped wire thru the hole on the solder pads and bend it over on the other side to hold it in place. Solder from the topside.



- Apply #4-40 washers to each Carriage End to act as a spacer for the Force Pot.
- Mount the Force Encoder Head to the Sensory Array Mount using #4-40x.75” on one side and #4-40x.88” on the other. The .88” screw should be mounted using 2 flat washers and 1 lock washer and 1 cable mount anchor.



- Finally, mount the Sensory Array to the Carriage Ends using #4-40x.38" Button Head screws with 1 flat washer and 1 lock washer. The Button Heads are critical to avoid interference with the Encoder Strip Mount.
- Next, glue the Encoder Strip to the Encoder Strip Mount using Loctite instant adhesive #410. The Encoder Strip should overhand the Mount by .30". This is critical for proper alignment.



- Fasten the Encoder Mount Strip to the Actuator using #10-32x1.0" socket head cap screws and 1 lock washer on each. Note that one of these screws also holds a Cable Anchor.



Step 8: Test

- Fully retract the actuator and add 2 piece shaft collars to the Guide Rails to the clamp the carriage in place.
- Set the trim pot on the PID boards so that the Trimmed Force is 0.0Volts.
- Apply a 500mV step command to the actuator and view the step response on the Scope 200mV/div X 10ms/div. Tune the P & D gains until a desirable affect is found. I have been using P = 298 Ohms and D=1750 Ohms to get 25Hz Bandwidth.
- Record scope images of the 500mV step response, 0 Phase Shift point using Sinusoidal input of 500mV PP, and 90 Phase Shift using Sinusoidal input of 500mV PP. Each test should be conducted using 200mV/div X 10ms/div settings on both channels on the scope. Save these images in a folder named after the particular job in the Actuator Folder.

