MTS

MTS **FSE MODULAR TRAINING**

256 Servovalve

July 7, 2016 Rev B

be certain.

256 3-Stage Servovalve

- A 3-Stage Servovalve is used in applications that require either high frequency, high oil flow, or both.
- A MTS model 256 3-stage servovalve can operate as high as 1500 L/min (400 Gal/Min). Frequency can exceed 100 Hz with a standard configuration and much higher with additional components.

256 3-Stage Valve Models

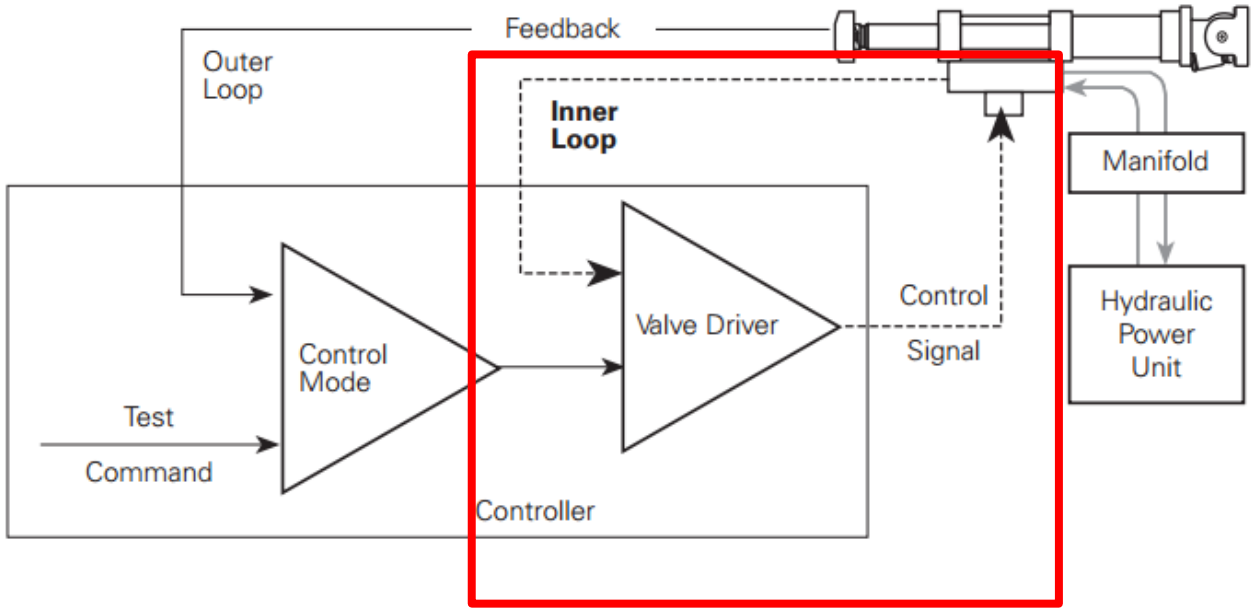
- The 256 3-Stage servovalve comes in several standard versions.
- The two numbers after the decimal represent the flow rating in gallons per minute.
- Example:
  - .04 = 40 GPM
  - .09 = 90 GPM

Model*	Rated Flow	
	L/min	GPM
256.04	150	40
256.09	340	90
256.18	680	180
256.25	950	250
256.40	1500	400

256 3-Stage Servovalve

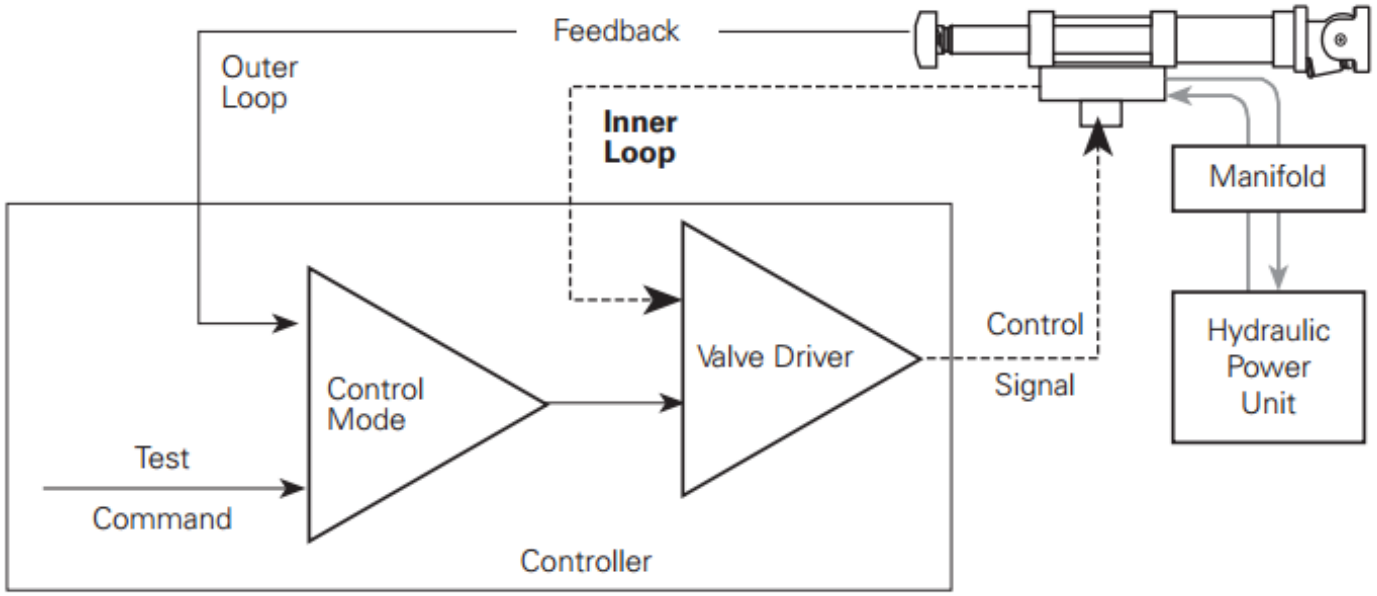
» A 3-stage servovalve operates as a closed loop system. By itself, without being coupled to a structural actuator manifold or load frame actuator manifold, it could be compared to a small displacement controlled hydraulic actuator.

- 3-Stage servovalves have inner loop command, inner loop feedback, and inner loop error



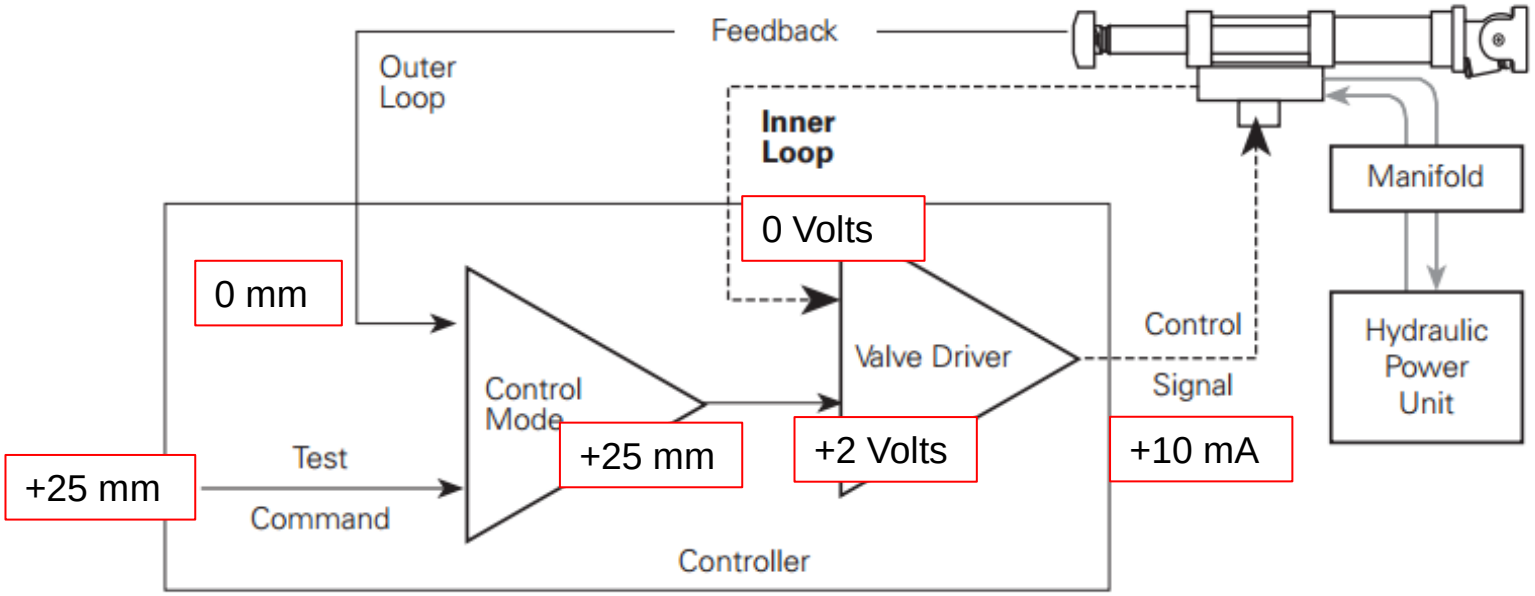
256 3-Stage Servovalve

- Inner loop is the name for the closed loop control circuit used with a 3-Stage servovalve. This uses a LVDT located on the servovalve for displacement feedback.
- This type of configuration is a closed loop control inside of a closed loop control.
  - The outer loop uses the force or displacement feedback from the load frame or actuator.
  - The inner loop uses the feedback from the 3-Stage servovalve LVDT.

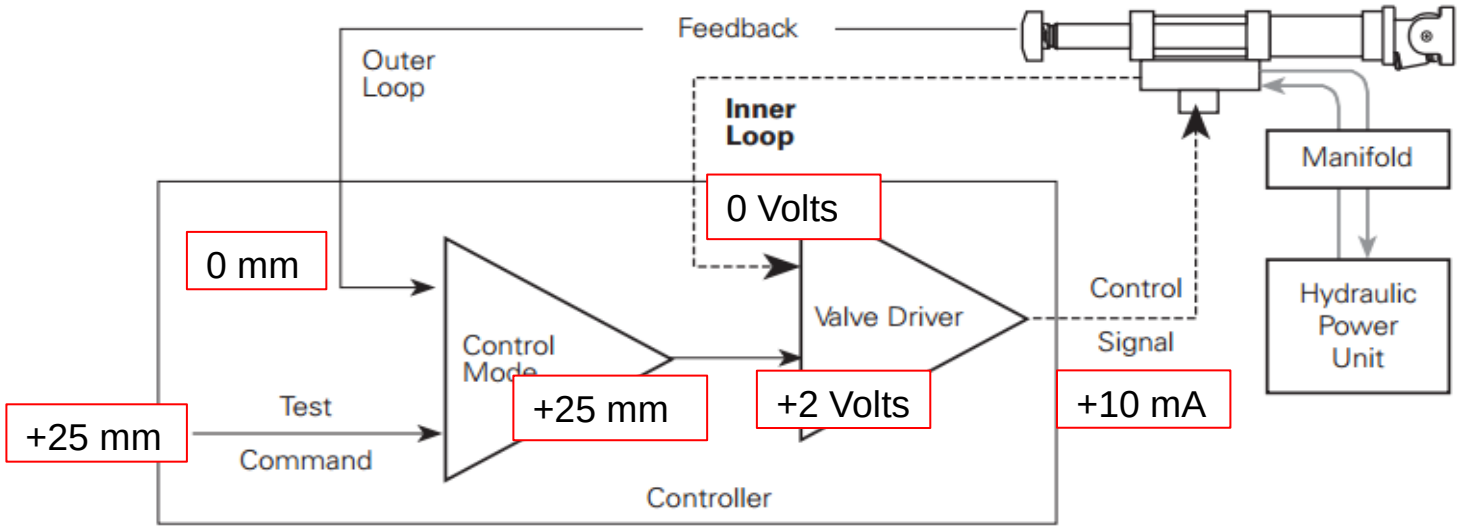


256 3-Stage Servovalve

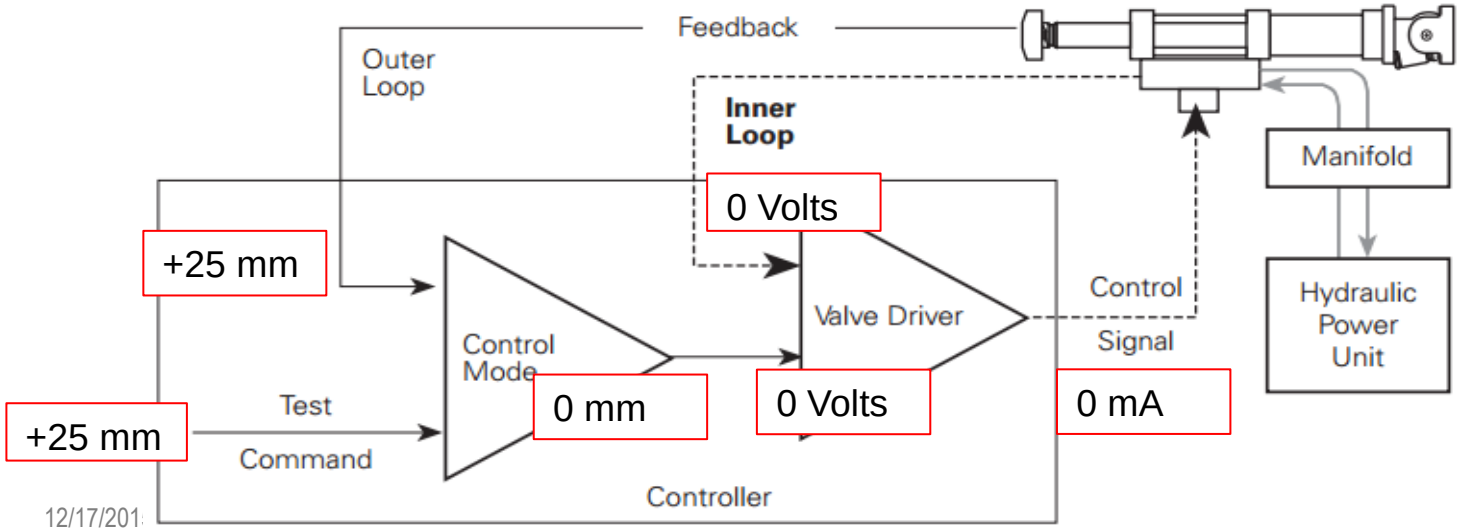
- The closed loop control works like any other with command, feedback, and error.
- The error from the outer loop which would normally be converted to current for the servovalve becomes the command for the inner loop.
- The inner loop then also computes error and that output is converted to current for the servovalve drive.



3-Stage Loop Signals



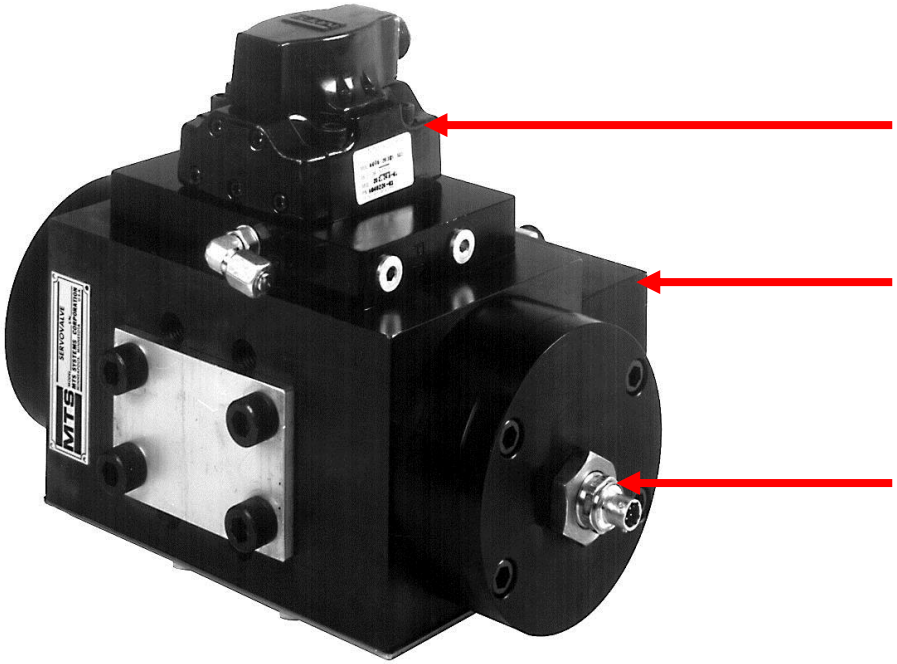
Instant command changes before actuator moves



After movement stops

256 3-Stage Servovalve Components

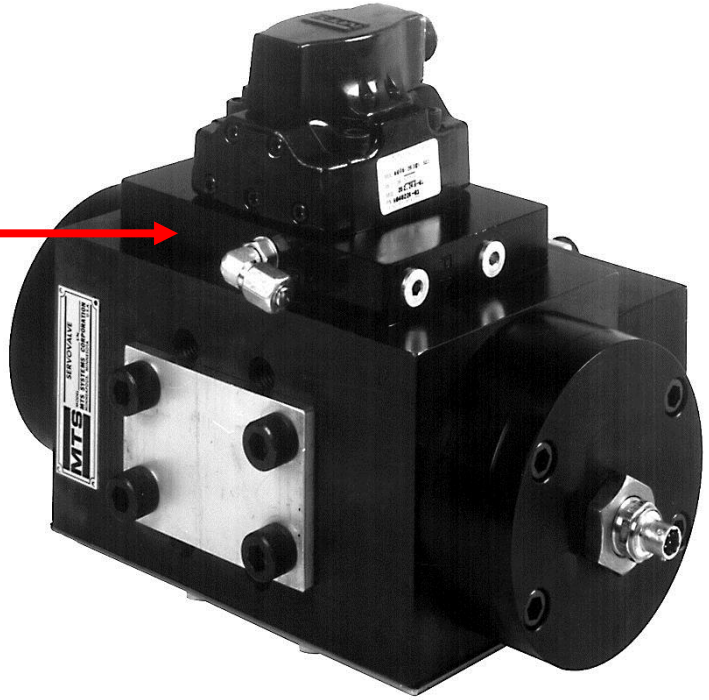
- A 3-stage valve is made up of a standard MTS 252 servovalve mounted to a 256 main stage valve.
  - The 252 valve is known as the pilot stage
- The 256 main stage contains a LVDT which is directly connected to the main stage servovalve spool for feedback.



256 3-Stage Servovalve Components

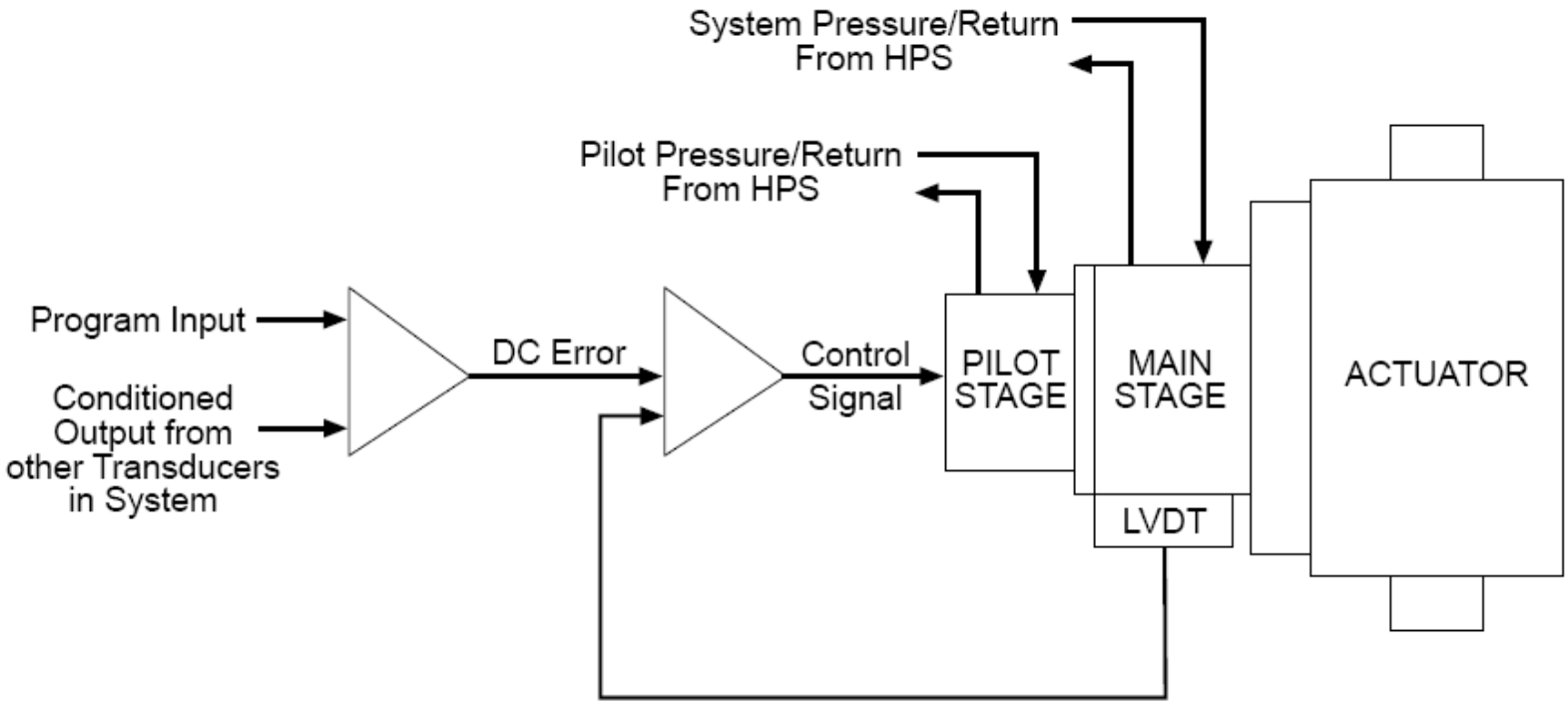
- The 252 pilot stage operates the same as any standard 252 servovalve
- The control pressure for the pilot servovalve is supplied from pilot pressure though a manifold block which is sandwiched between the pilot stage and main stage.
- This manifold has connections for pilot pressure and pilot return.
- Pilot pressure and pilot return are high pressure hoses.

Pilot Pressure Manifold



256 3-Stage Servovalve Components

» Pilot pressure is always present any time the HPU is on regardless of whether the HSM is on or off. Pilot pressure is sent to the pilot stage servovalve and also controls the spool movement of the main stage. The oil that goes to the actuator to move the piston does not come from pilot pressure.

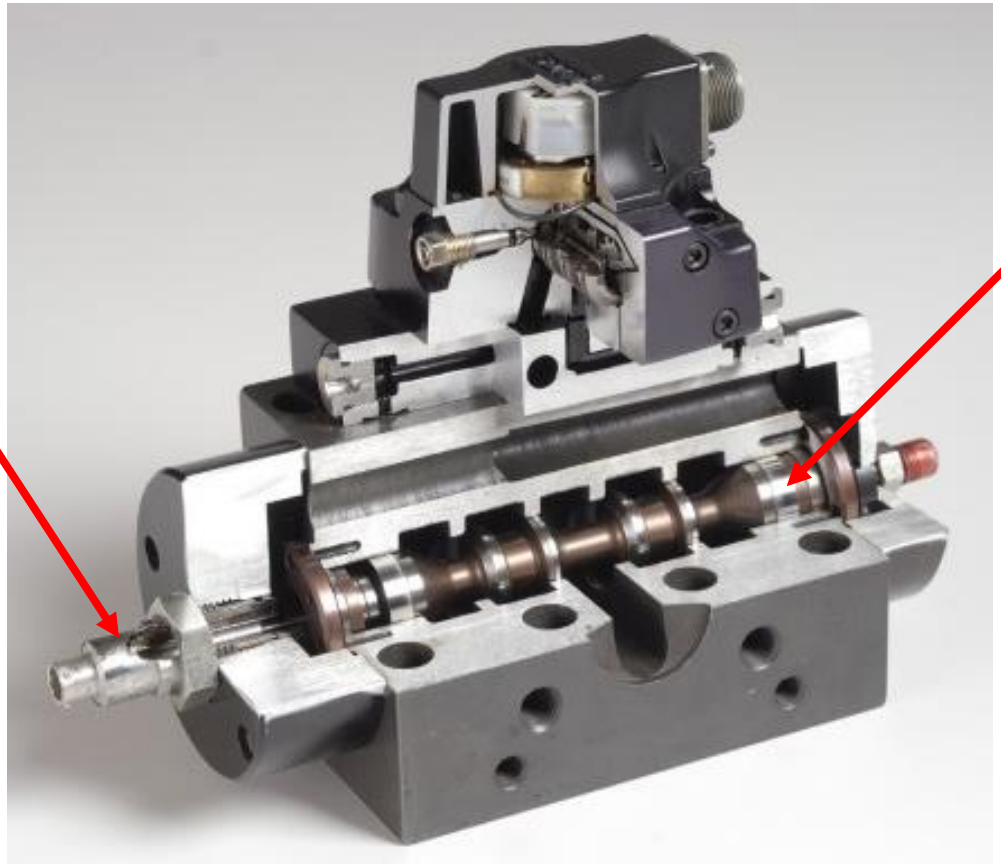


256 3-Stage Pilot Servovalve

- The pilot valve is typically a 4 port valve.
- The common pilot valve is a 252.21 4.0 L/min (1.0 gpm) servovalve.
  - Large 3-stage servovalves may use a 252.22 9.5 L/min (2.5 gpm) servovalve.
- Sometimes it is necessary to use a pilot valve smaller than 4.0 L/min (1.0 gpm).
  - Very small 3-stage valves may use these.
- A special class of 252 valve is used for the low flow application.
  - These valves are not common
- The 252.1X are valves with flow ratings less than 1 gpm
  - 252.11 = 0.125 gpm
  - 252.12 = 0.25 gpm
  - 252.13 = 0.5 gpm

256 Main Stage

- The primary main stage component is a spool which controls oil flow to the actuator.
- The spool is controlled by the pilot valve.
- The spool has an LVDT for feedback. This LVDT requires 10 kHz AC excitation.

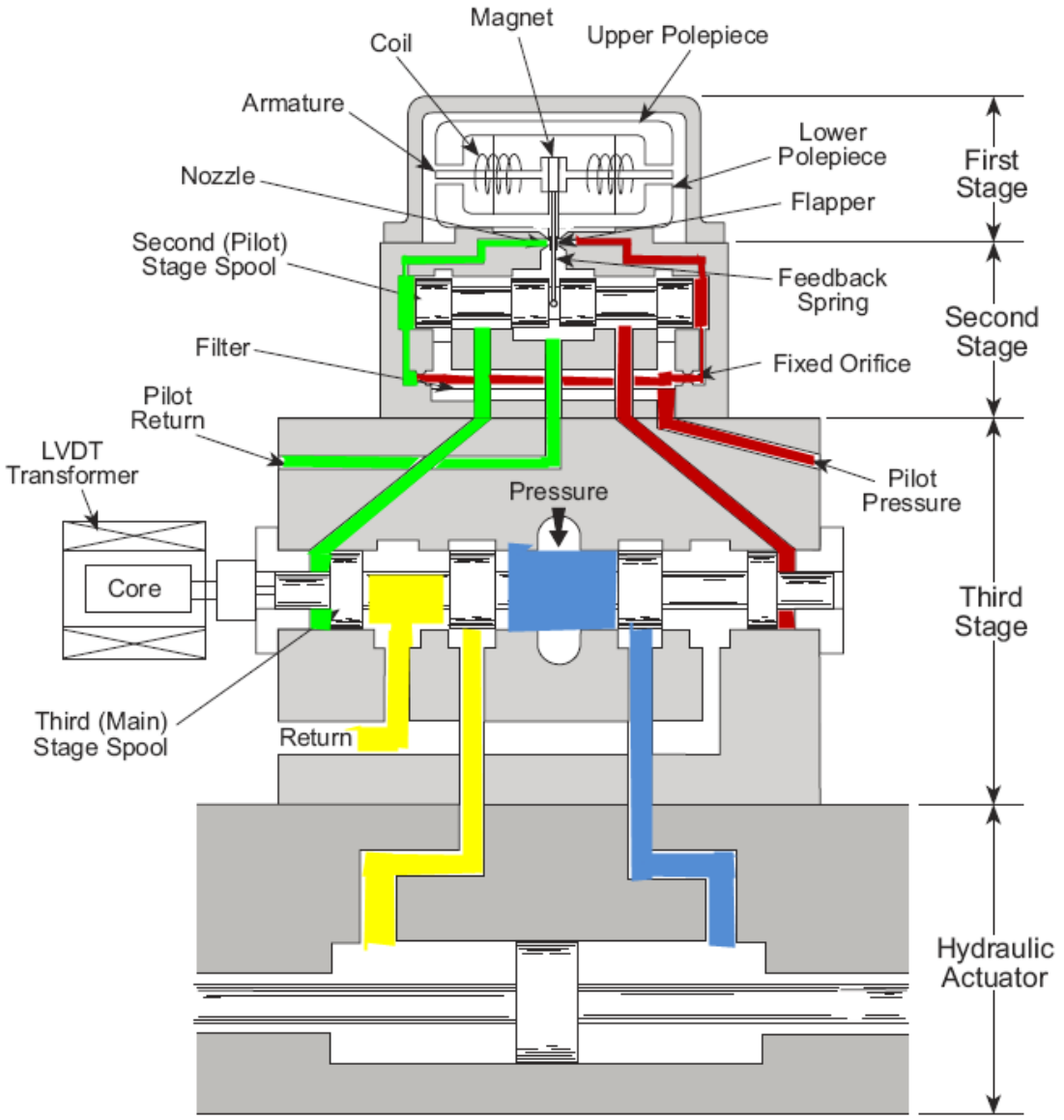


3-Stage Valve Oil Paths

- The illustration on the following page shows the oil paths of a 256 3-stage Servovalve
- Pilot pressure oil is supplied to the pilot valve (Red). The pilot valve spool moves based on command and connects pilot pressure (Red) to one of the oil ports and pilot return (Green) to the other.
- This oil is ported to the main stage spool which then causes the spool to move. When the main stage spool moves main pressure (Blue) is connected to either the C1 or C2 port and main return (Yellow) is connected to the other port.
- Main pressure and return are ported to the actuator. The actuator moves in relationship to the pressure and return applied to the piston of the actuator.

3-Stage Valve Oil Paths

- Pilot Pressure = Red
- Pilot Return = Green
- Main Pressure = Blue
- Main Return = Yellow

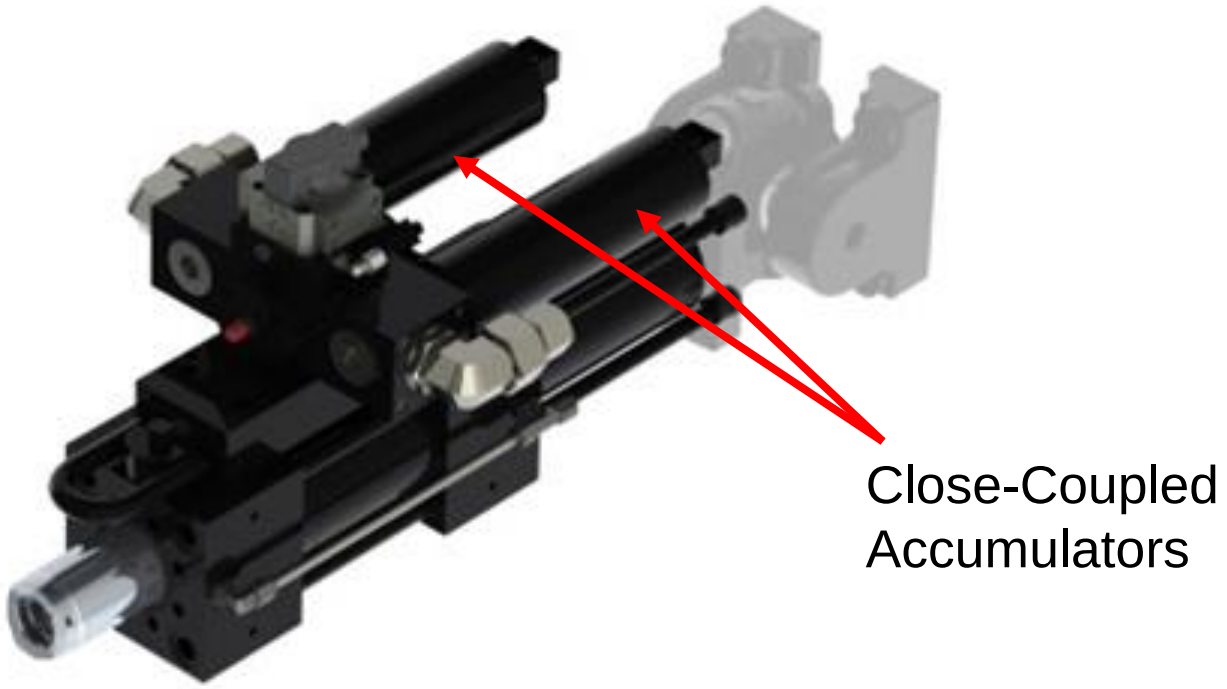


3-Stage Valve Oil Paths

- The illustration on the previous page shows main pressure is not required to move the pilot valve and main stage spool. The only oil requirement is that pilot pressure is present.
- Main pressure is controlled by the HSM on / off state. The 3-stage valve will function with only the HPU on and pilot pressure present with the HSM turned off.
- The main stage LVDT attached to the spool output can be monitored in this condition to verify if the main spool is moving.
- This technique is used during setup and troubleshooting. In this condition the 3-stage valve behaves like a small displacement control actuator.

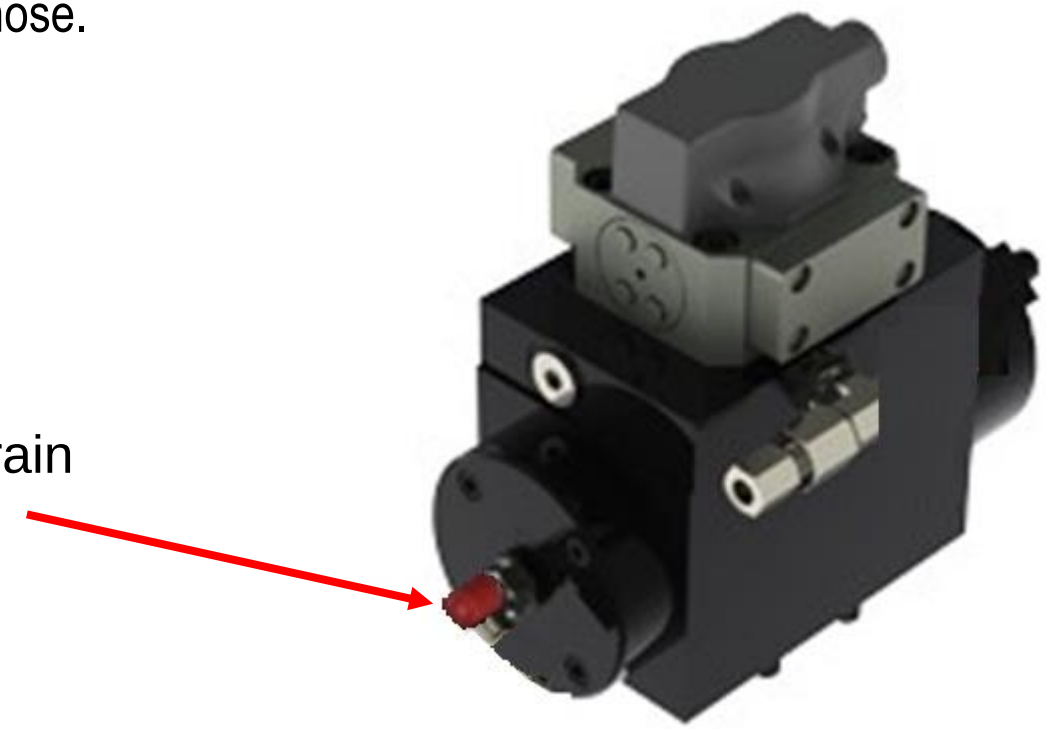
3-Stage Servovalve Manifold

» Many 3-Stage servovalves have accumulators directly attached to the servovalve manifold. These are known as close coupled accumulators. These accumulators are required because of the performance of a 3-stage valve.



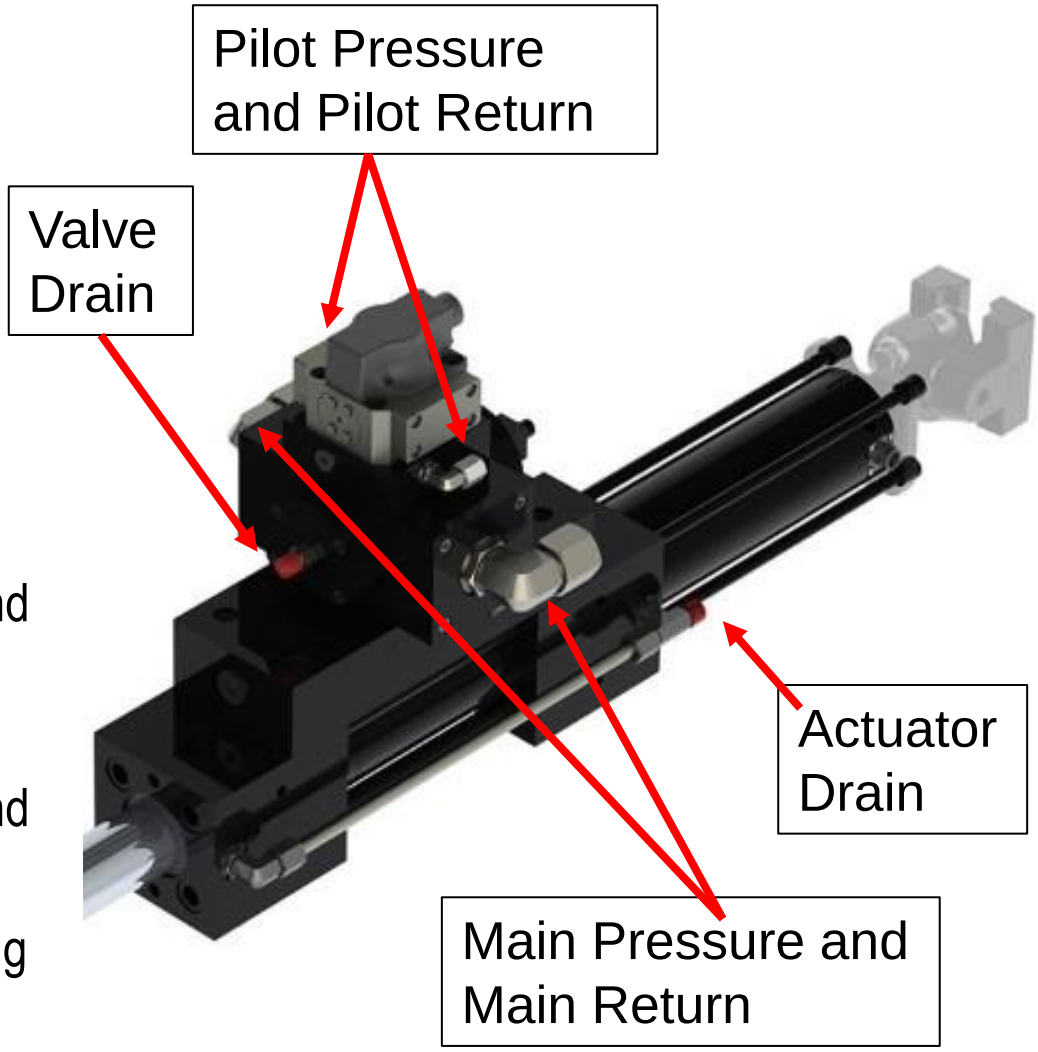
3-Stage Valve Drain

- In addition to pilot pressure and pilot return which supply oil to the pilot valve there is also a drain from main stage. This drain is located in the end cap opposite the LVDT. This drain needs to be connected in addition to the actuator drain. The drain connection arrives with a red cap installed on the fitting. This uses use a low pressure drain hose.



Installation – Hoses

- Main Pressure - P stamped into servovalve manifold
- Main Return - R stamped into servovalve manifold
- Actuator Drain – Red cap on drain connection at end cap
- Pilot Pressure – PP stamped into sandwich manifold between pilot and main stage.
- Pilot Return – PR stamped into sandwich manifold between pilot and main stage.
- Main stage drain – Red cap on fitting on main stage spool end cap



Installation - Cable Connections

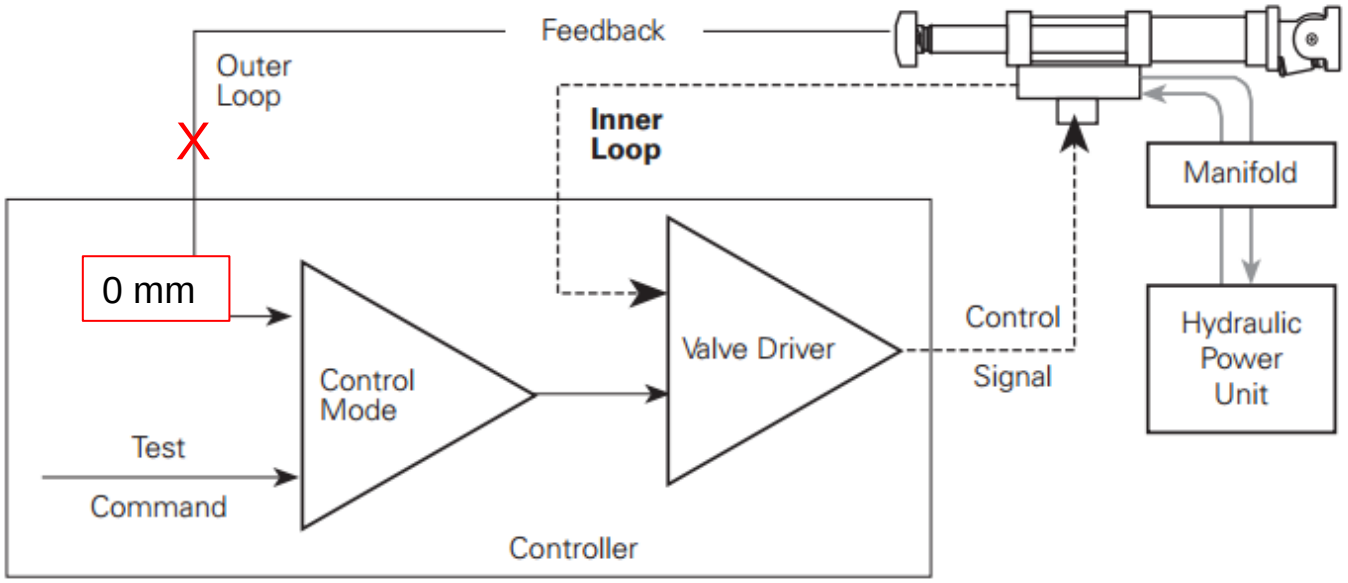
- The pilot valve uses the same cable connection as a 252 servovalve installation.
- The main stage LVDT connector is a 4 pin connector

3-Stage Valve Setup

- Once a 3-stage valve is hooked up hydraulically and electrically it will need to be setup and configured.
- The 3-stage valve behaves like a small displacement control actuator when there is no outer loop.
- To simulate this condition disconnect the electrical connector to the HSM to prevent the HSM from turning on main pressure.
- Put the controller into displacement control, disconnect the actuator LVDT cable, and set any displacement offset to zero so the displacement feedback is zero.
- When the HPU is energized pilot pressure will be present so the 3-stage valve will be active and functional.

3-Stage Valve Setup

- With the outer loop in displacement control and the LVDT disconnected you will see the following behavior.
  - Outer loop feedback = 0
  - Outer loop error = outer loop command (because feedback is held to zero)
  - Inner loop command = outer loop command
- In this configuration you can now operate the 3-stage valve as a displacement control actuator

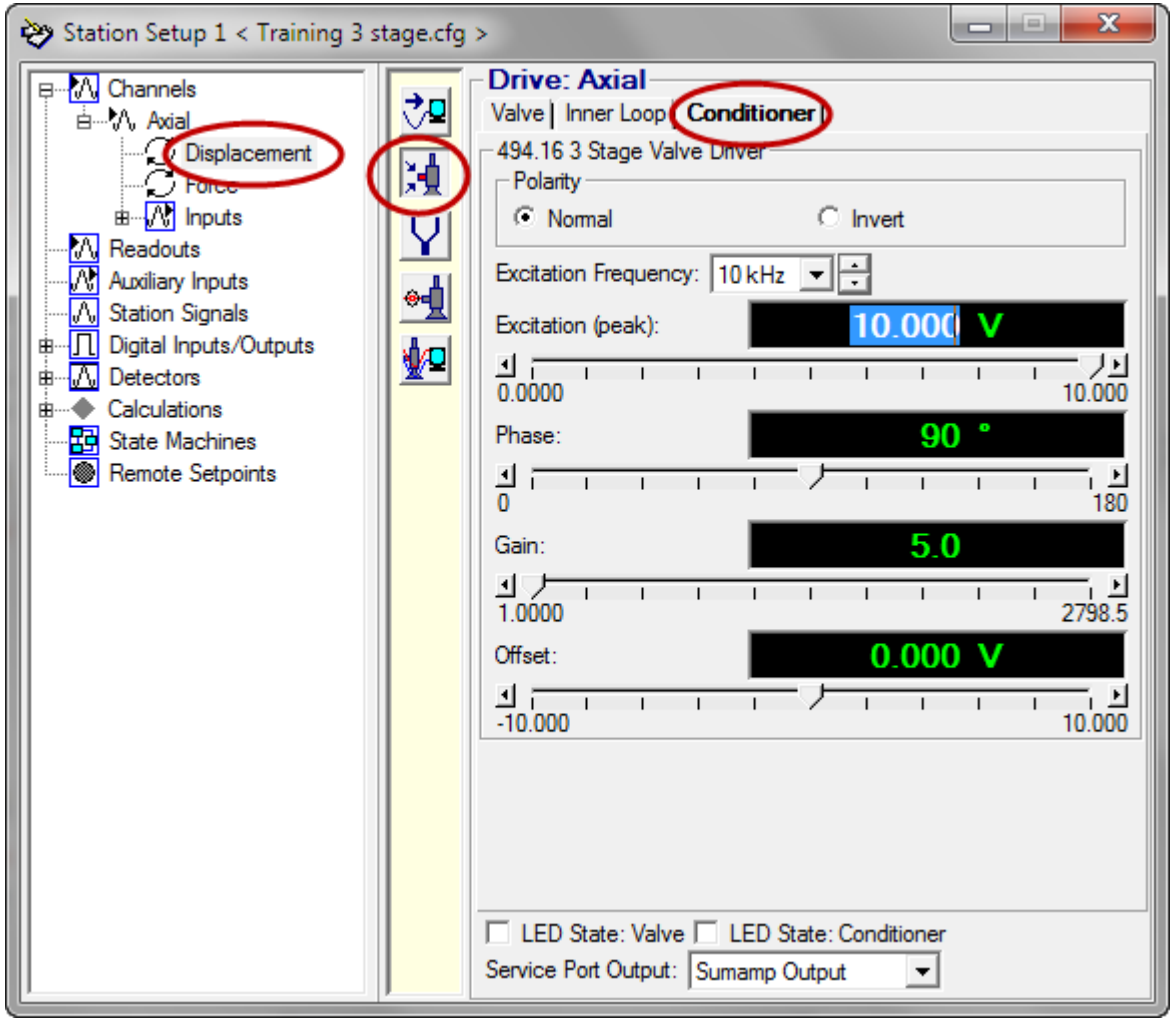


Setup Procedure

- **A complete setup procedure with screen captures that can be printed is at the end of this training material. For details or to follow along please print the procedure on the last 8 pages of this training.**
- All adjustments referenced are for 793 FlexTest software. If you are using a different controller use the appropriate product manual to locate the proper adjustment.
- Just like any actuator the first step is to establish control.
- To do that set preliminary values for the main stage spool LVDT
- The main stage spool adjustments are found on the “conditioner” tab of the 3 stage valve driver.

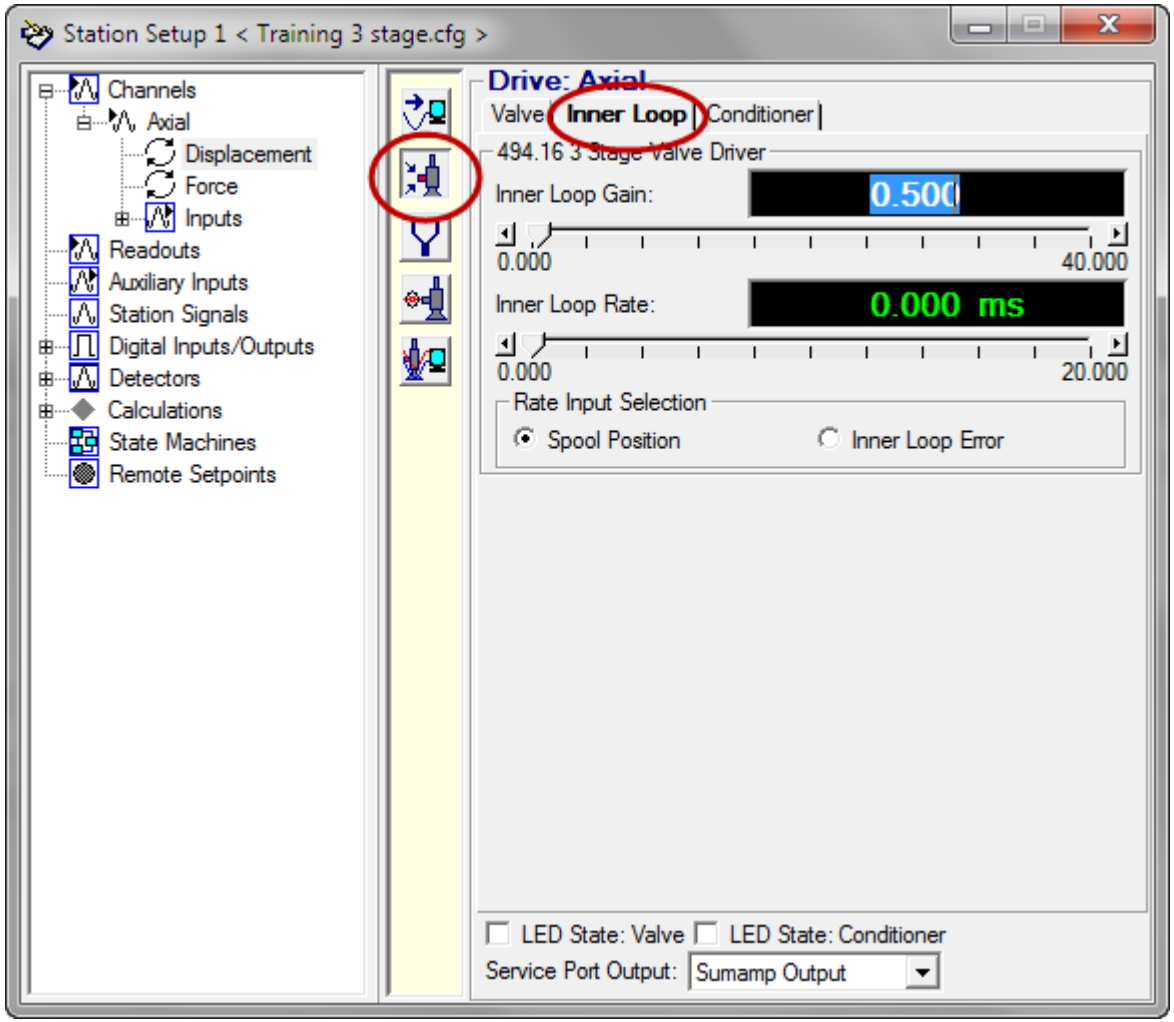
Setup Procedure

- Set the LVDT adjustments on the conditioner tab as follows:
- Excitation 10.000 Volts
- Gain 5.0



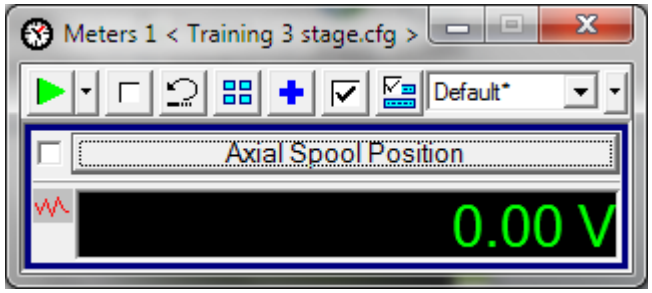
Setup Procedure

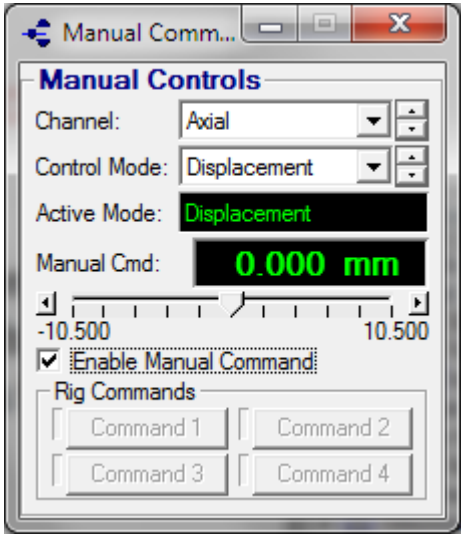
- Set the inner loop gain adjustments on the inner loop tab as follows:
- Gain 0.5
- Rate 0.0



Setup Procedure

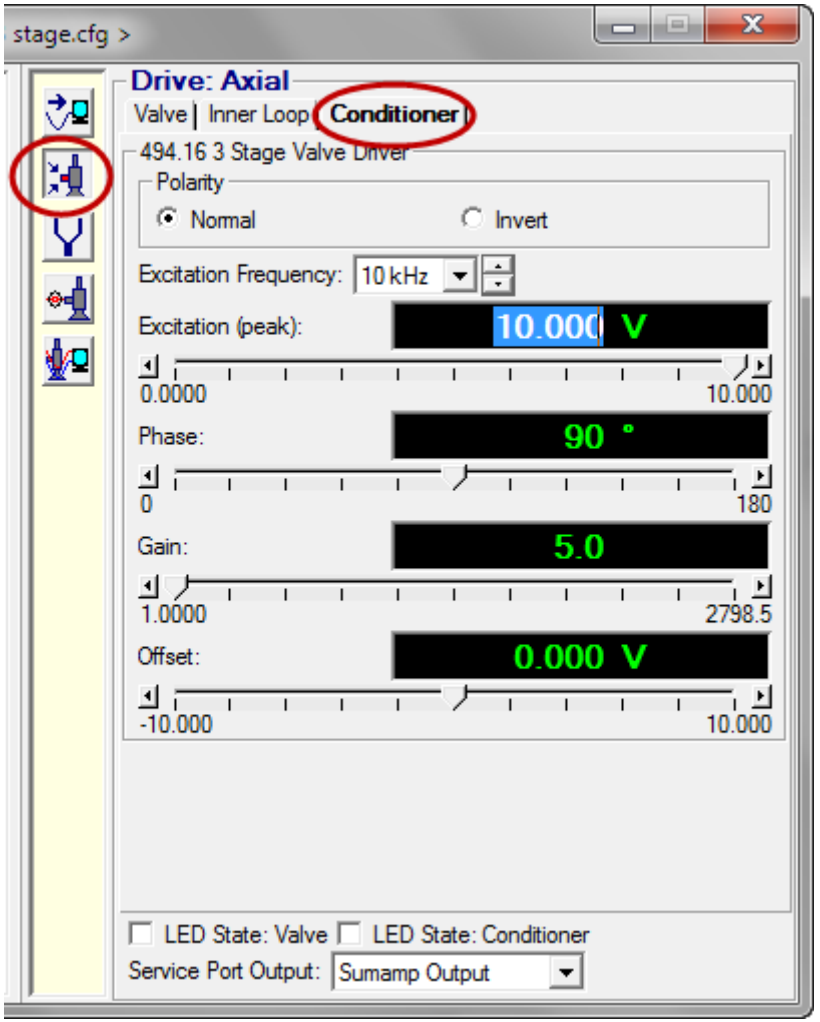
- The HSM cable should be electrically disconnected and the HPU on for these steps.
- Disconnect the LVDT cable or alternatively auto offset the displacement channel.
- Using a timed meter select spool position for the signal.
- Enable the manual command in displacement control and move the slider.
- If the spool position meter changes with the slider movement as you move it in both directions the polarity is correct.
- If the value in the meter remains constant and does not change or if it changes polarity but remains at a maximum value the polarity is incorrect.
  - Change the polarity on the “valve” tab





Setup Procedure

- Once the correct polarity has been established, the transducer gain needs to be adjusted.
- On the “Valve” tab change the polarity to the opposite non working position. This will drive the spool into the end cap. Do not use the polarity on the conditioner tab.
- Adjust the gain on the “Conditioner” tab for 8.00 volts spool position reading. Adjust the phase for the largest value on the meter. Readjust gain for 8.00 volts. This is not the final adjustment. The next steps will validate the LVDT is symmetrical.

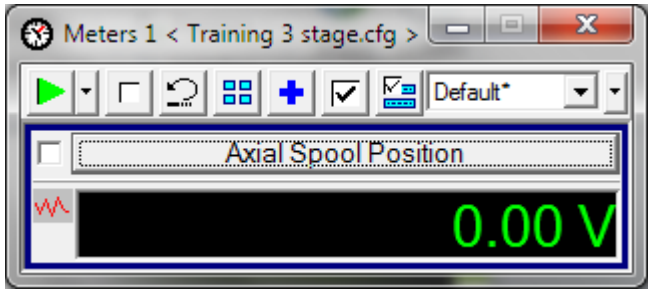


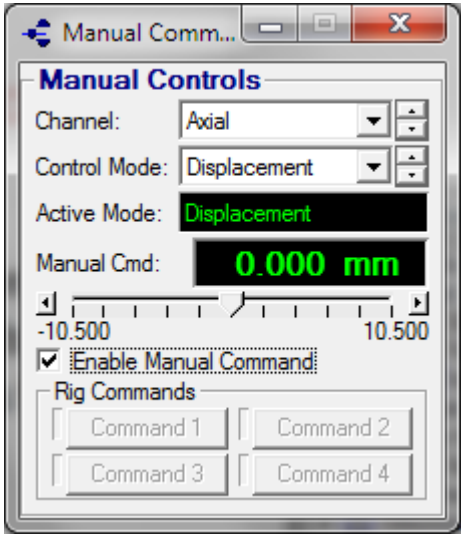
Setup Procedure

- Using the manual command move the slider to one end or the other until the polarity and value on the meter changes. This will be the opposite end cap. The spool position should be between 7.5 and 8.5 volts in the opposite polarity to what you started

- It may be necessary to significantly increase the displacement outer loop P gain to get the spool to move to the other end cap. Note the value before adjusting so it can be returned to the starting value.

- If the spool position is not between 7.5 and 8.5 volts, the LVDT must be physically adjusted. See the adjustment procedure later in the training.

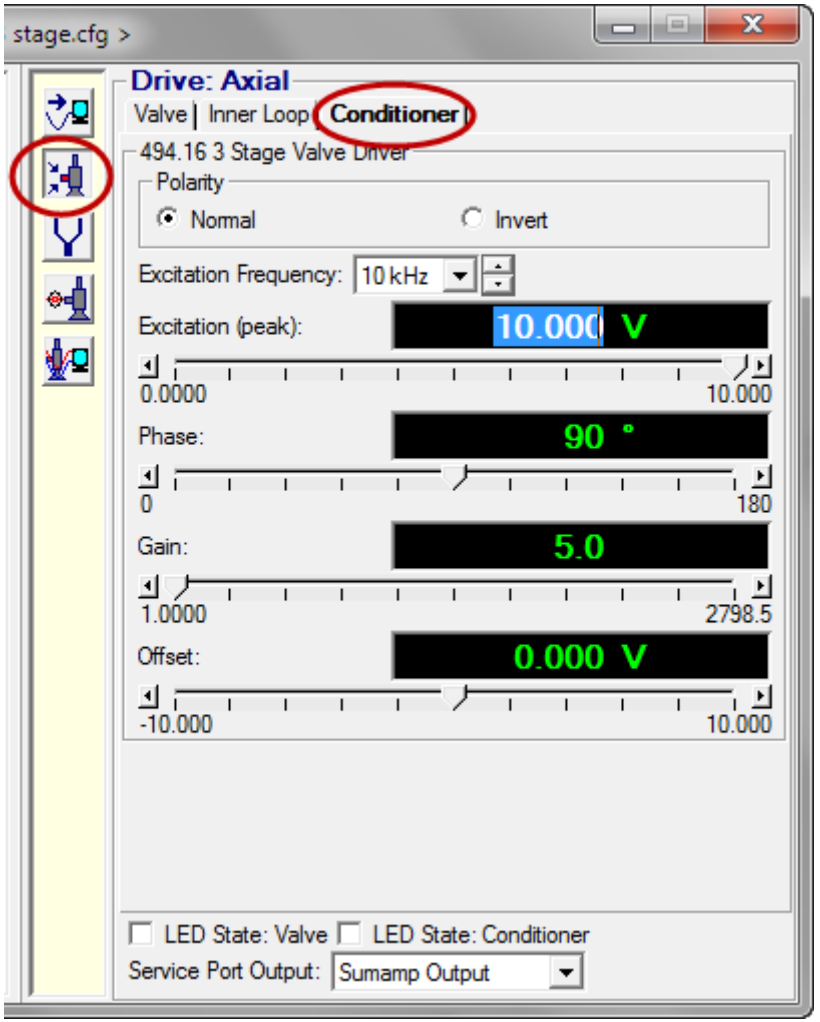




Setup Procedure

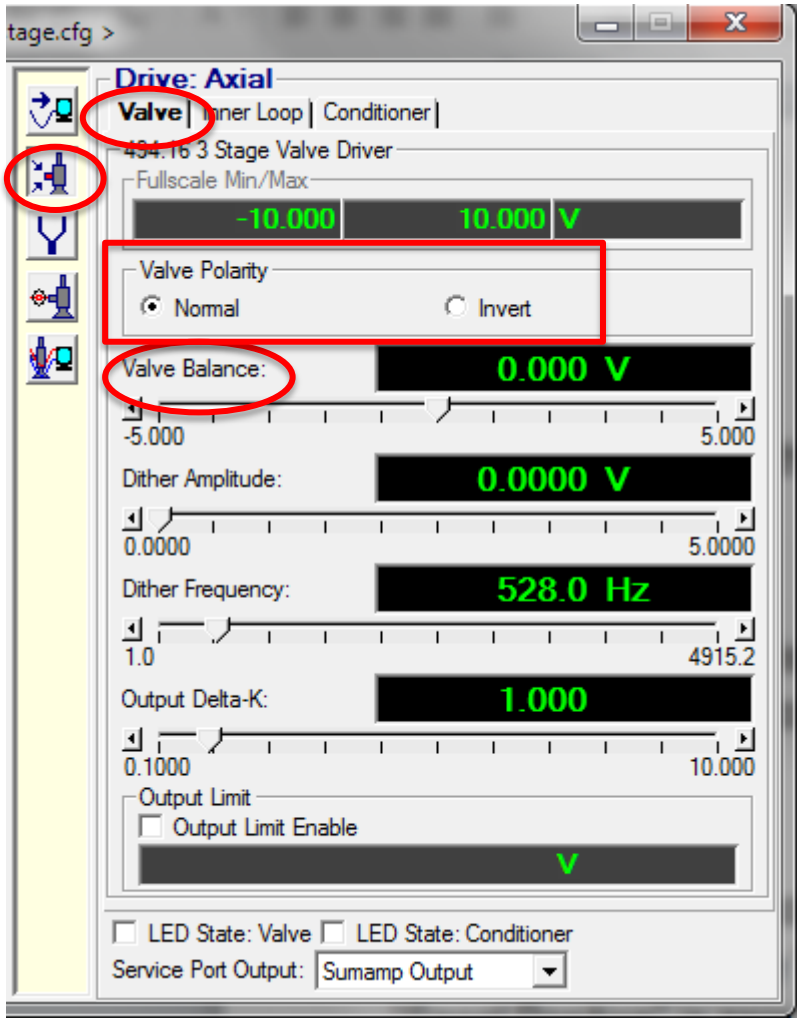
- Once the LVDT is properly centered, make the final conditioner gain adjustment with the spool in the end cap.

- Adjust the gain until spool position on the meter reads 10.000 volts.
  - High performance systems may have a lower full scale value when the spool is in the end cap.
  - A common value is 7.5 volts for simulation systems.
  - If you are not sure, adjust to 10.000 volts.



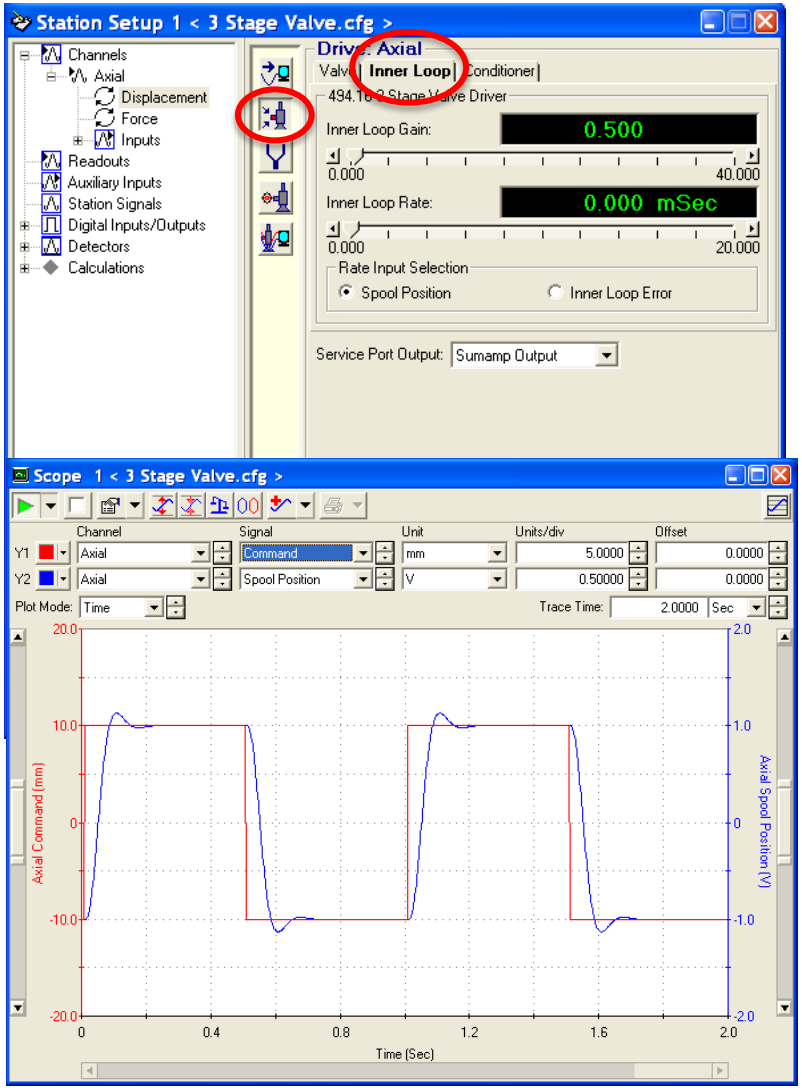
Setup Procedure

- Return the polarity on the “Valve” tab to the working position.
- Verify that the system is at zero error. If not zero use manual command to achieve zero error.
- While monitoring “Spool Position” on the meter adjust valve balance located on the “Valve” tab Until the “Spool Position” is zero.



Setup Procedure

- Set the scope for command and spool position. Set the function generator for a 1Hz square wave displacement control.
- Start the function generator and increase the amplitude until the spool position feedback is +/- 1 volt. You may have to increase displacement outer loop P gain to achieve +/- 1 volt.
- Increase the inner loop gain until there is 10% overshoot.
- Increase the inner loop rate until there is no overshoot.
- Stop the function generator.
- Inner loop gain remains at this setting and does not change when the outer loop is switched between force and displacement control.



Setup Procedure

- Use the manual command to adjust for zero error. Confirm the “Spool Position” is at zero. If not at zero, adjust the valve balance on the “valve” tab.
- Turn off the HSM.
- Re-connect the HSM and LVDT cables to re-enable the ‘Outer Loop’.
- Note the current value and temporarily reduce the Outer loop “I gain” to zero.
- Turn on Hydraulics to high pressure.
- If the actuator is in control check the actuator LVDT feedback polarity. Confirm it matches the desired feedback. If not, change 3 polarities. Actuator LVDT, valve conditioner, and valve.
  - Example: Actuator is in control. Using the manual command move the actuator to the full extension position. The polarity of the actuator when in this position is positive. Your customer wants extension to be negative to match compression negative. Turn off the hydraulics and change polarity in 3 places. Change the actuator LVDT polarity, the valve conditioner polarity, and the valve polarity.

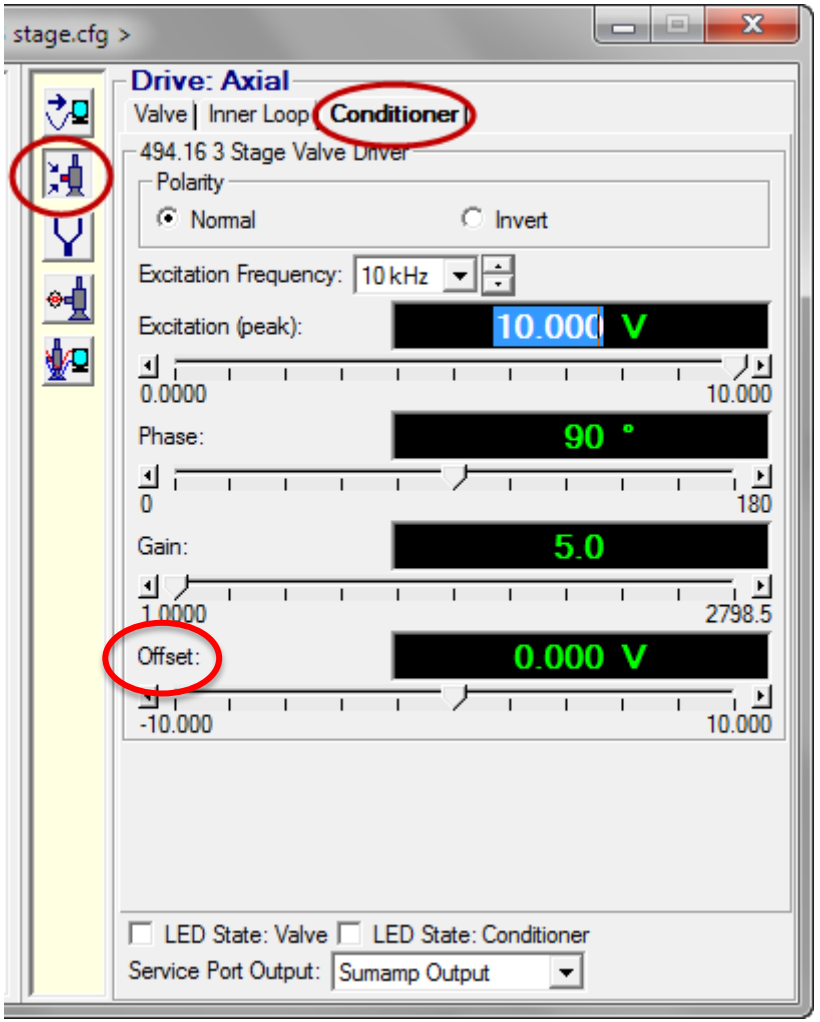
Setup Procedure

- If the actuator moves to one end cap and remains it is likely the polarity is incorrect. If the polarity of the actuator stroke feedback is correct then change BOTH the valve polarity and the conditioner polarity for the 3 stage valve setup. DO NOT change the actuator LVDT polarity.
  - Example: Extension is desired to be negative. The actuator fully extends and remains in the end cap. The actuator displacement feedback is negative. Turn off hydraulics and change both valve polarity and conditioner polarity.

- If the actuator moves to one end cap and remains and the actuator polarity is not correct change the actuator polarity only.
  - Example: Extension is desired to be negative. The actuator fully extends and remains in the end cap. The actuator displacement feedback is positive. Turn off hydraulics and change only the actuator LVDT polarity.

Setup Procedure

- After polarity is correct and actuator is in control turn on hydraulics and warm up system.
- Adjust manual command to a value of zero for position control.
- Monitor actuator displacement feedback on a meter and adjust the “Offset” on the “Conditioner” page of the 3 stage valve until the displacement feedback reads zero.
- Return the outer loop “I gain” to the setting noted earlier.

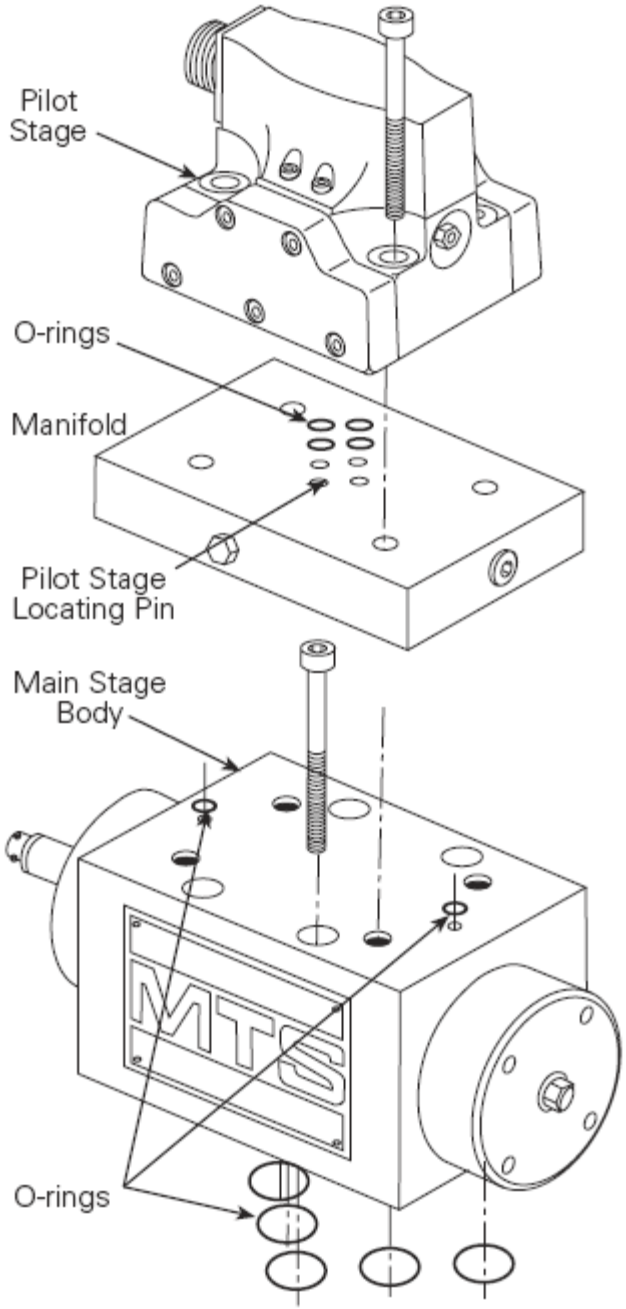


Setup Procedure

- The 3-stage valve is now setup and ready to continue installation.
- The next common step is to validate the tuning of the displacement control mode.
- For details, see the tuning module.

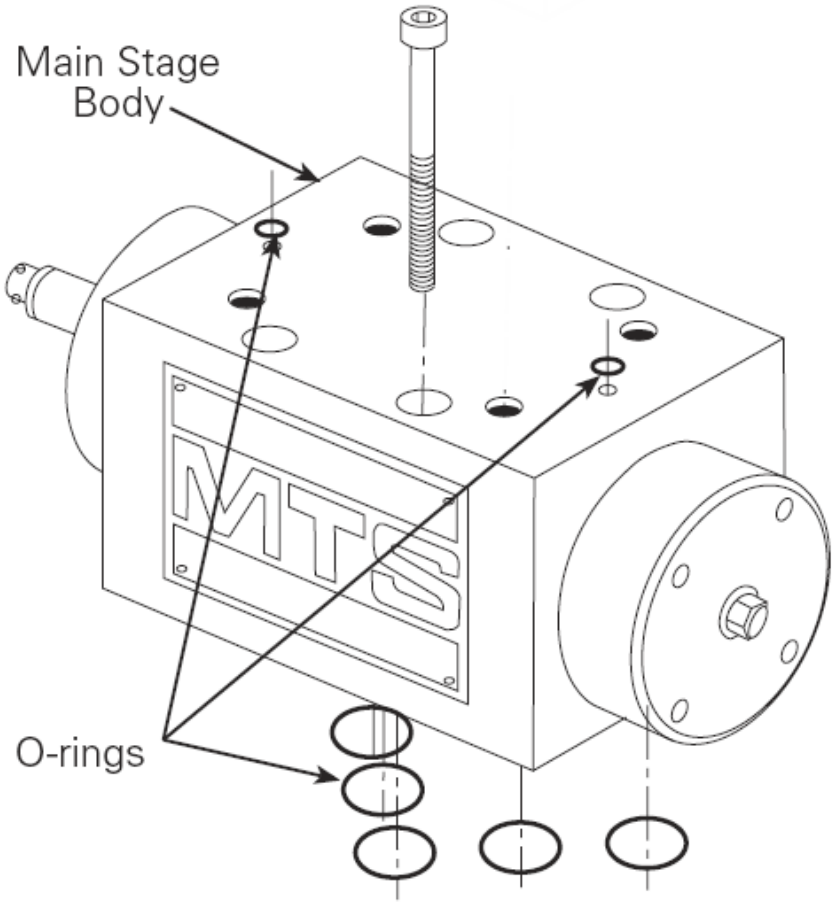
3-Stage Valve O-Rings

- There are 4 standard servovalve O-Rings under the 252 valve between the pilot valve and the manifold.
- 252 main port O-ring MTS P/N 010-010-510
  - .070X 90D BUNA-N .426ID
  - AS568A-013 90 Durometer
- There are 2 O-Rings under the manifold between the manifold and the main stage.
  - These are 90 Durometer O-Rings
- There are typically 5 O-Rings under the main stage between the main stage and the servovalve manifold.
  - These are 90 Durometer O-Rings



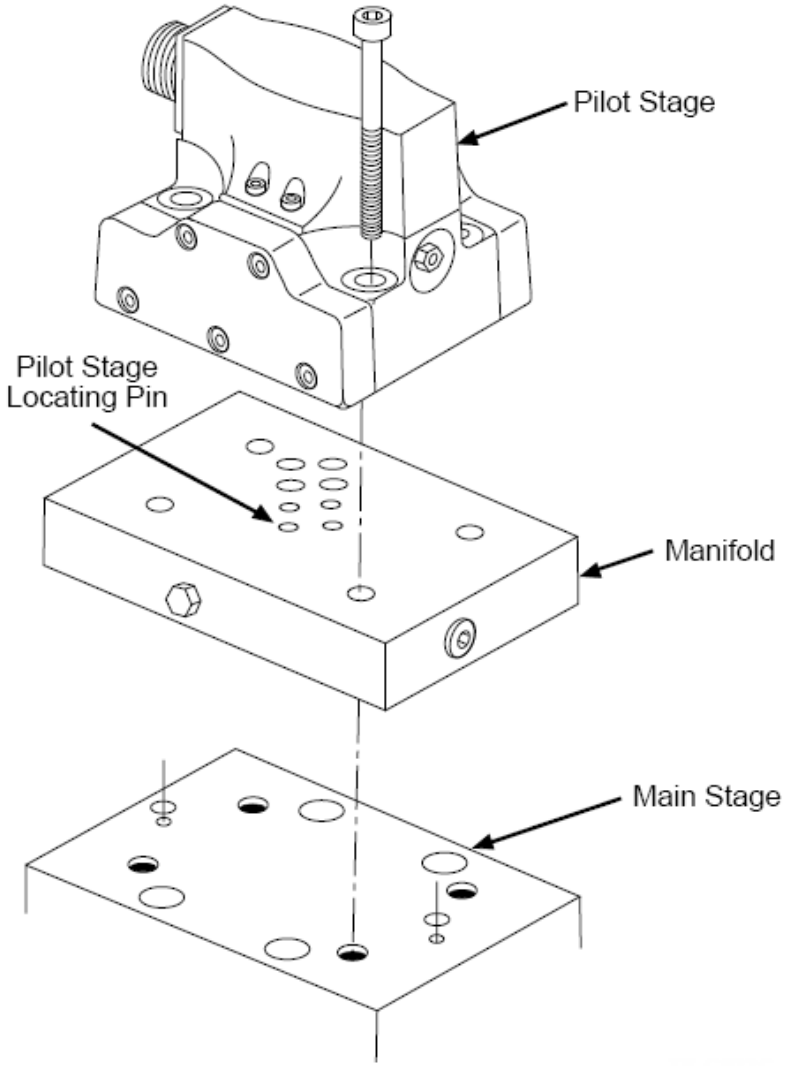
Valve Installation

- The 3 stage valve is mounted to the actuator in 2 steps.
- Lubricate the O-Rings with clean hydraulic fluid prior to installation.
- The first step is to install the main stage onto the servovalve manifold.
- Properly torque all fasteners.
- The torque chart is located near the end of the training material.



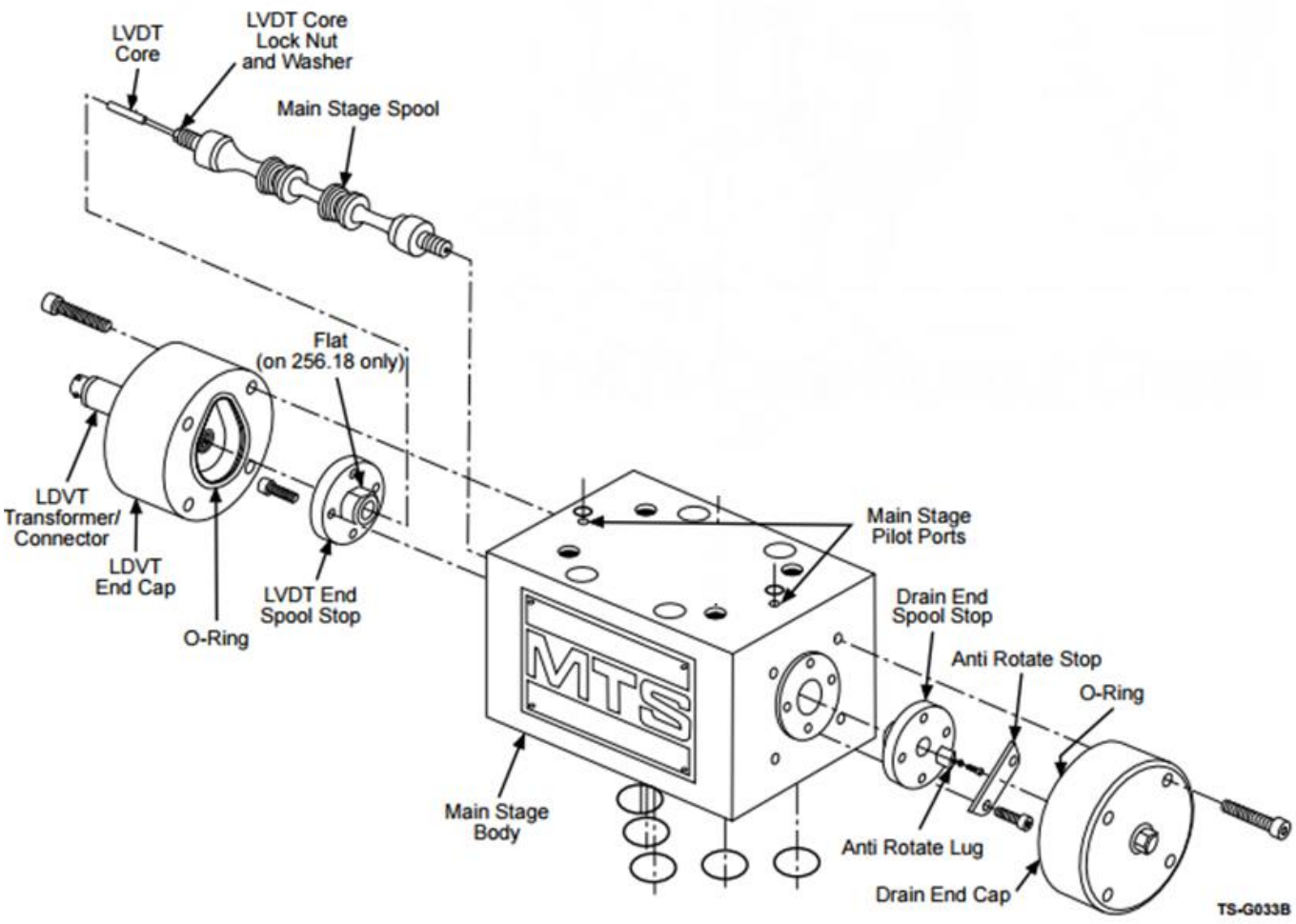
Valve Installation

- After the main stage servovalve is mounted to the servovalve manifold, the pilot pressure manifold and the pilot servovalve are mounted to the main stage.
- The bolts for the pilot valve pass through the pilot pressure manifold and are threaded into the main stage servovalve.
- Be sure to torque all fasteners.
- The torque chart is located near the end of the training material.



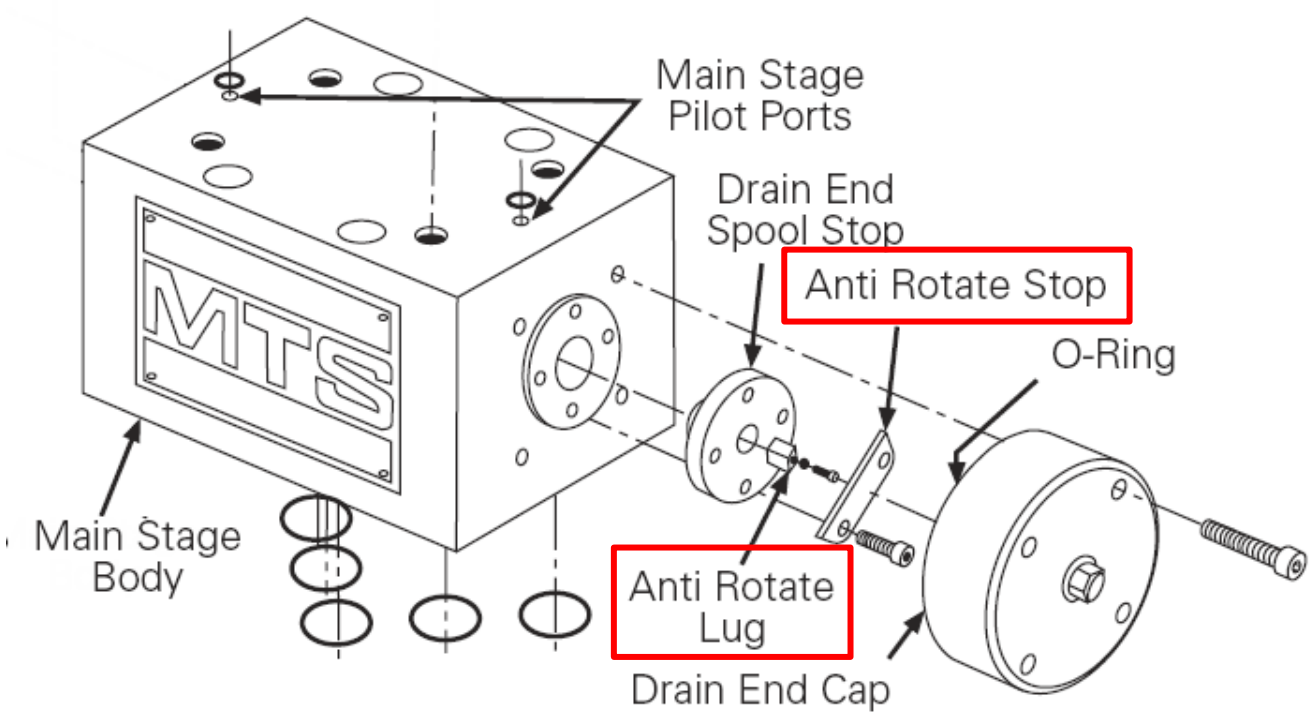
256 Valve Internal Components

» The 256 main stage components are shown below.



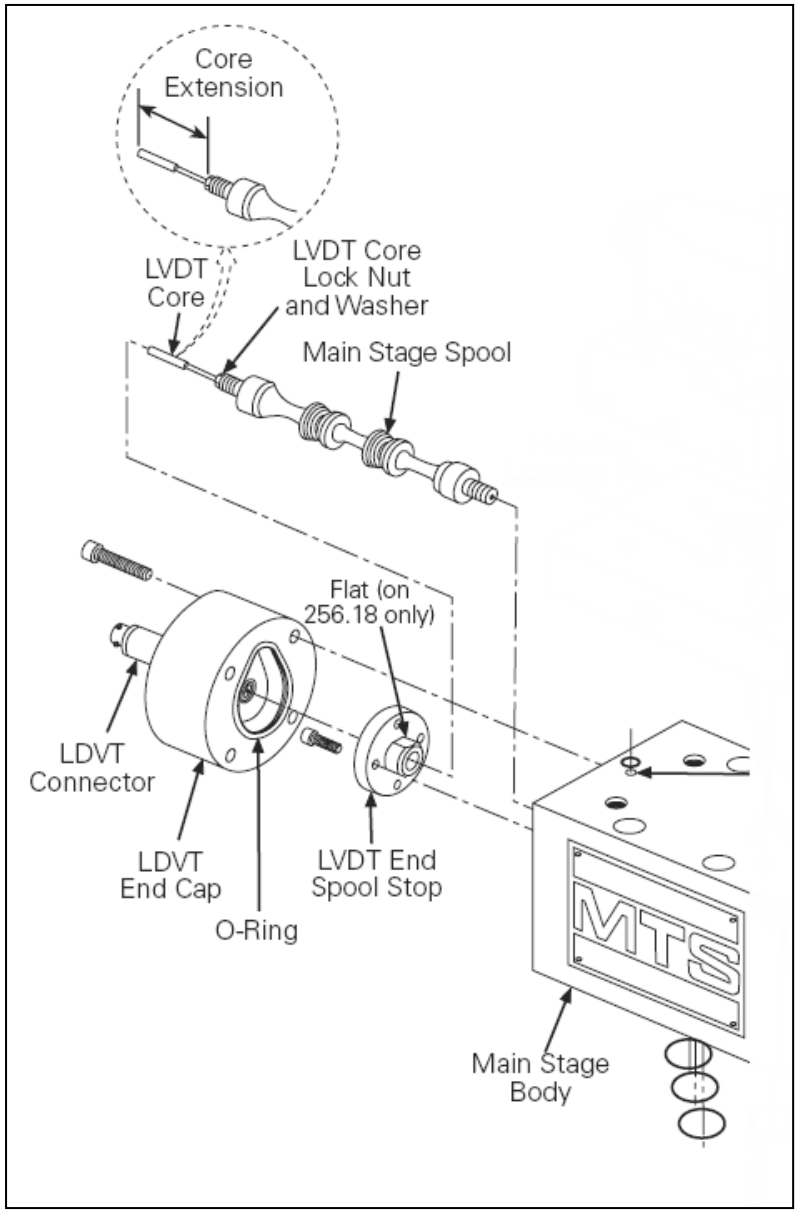
256 Valve Internal Components

» The end cap with the drain port has the anti rotate mechanism behind it. This keeps the spool from rotating. If the spool were to rotate it could cause the actuator to oscillate or rumble. The spool has a square anti rotate lug which rides against the anti rotate stop to prevent rotation. In early designed units the stop was manufactured from aluminum which often failed. The newer units the stop is made from steel.



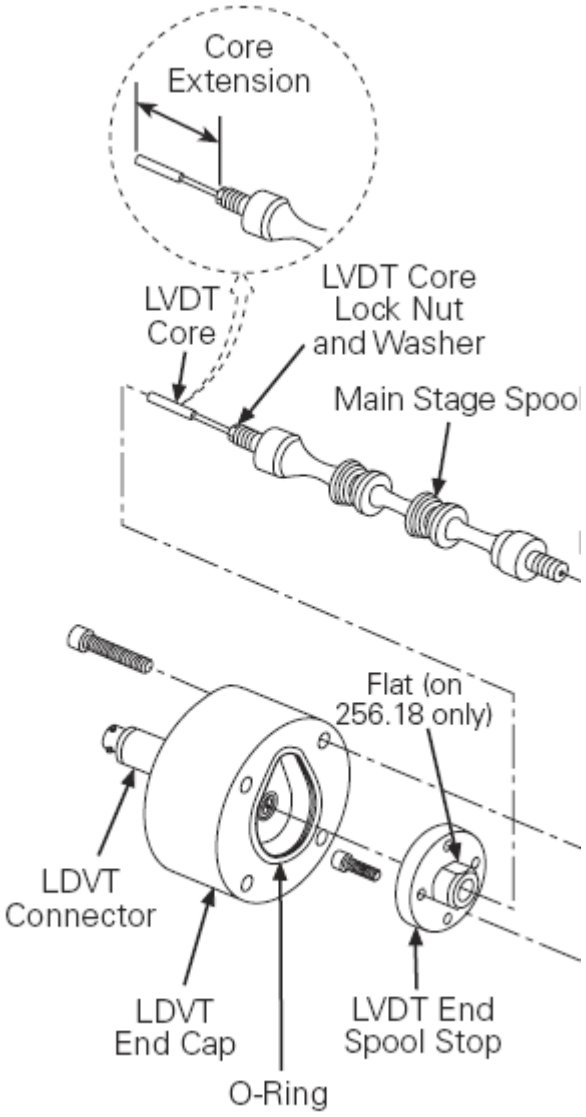
256 Valve Internal Components

- The end cap opposite the drain port has the LVDT.
- The coil is threaded into the end cap. The core is attached to the main stage spool.
- The main stage spool can be removed from the body by removing the spool stop.



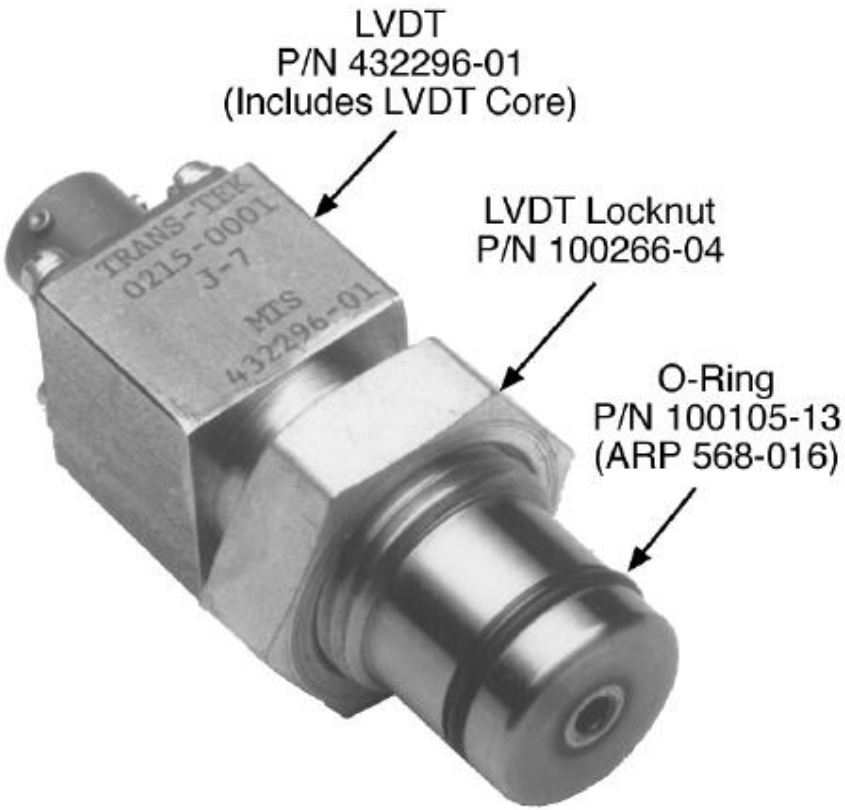
Main Stage LVDT Replacement

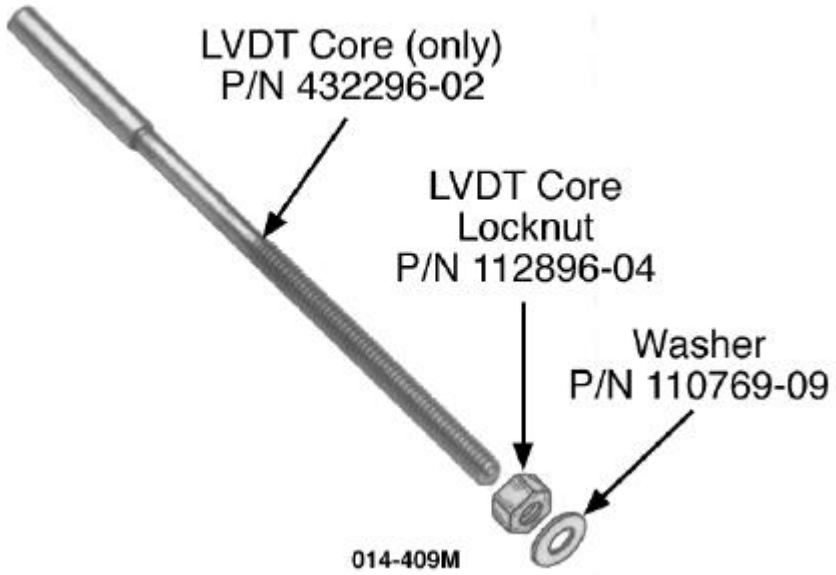
- The main stage LVDT is field replaceable.
- Turn off hydraulic pressure, ensure pressure is at zero, and use lock out / tag out procedures.
- Remove the LVDT end cap
- Next remove the LVDT spool stop and then carefully remove the spool and LVDT core from the main body.
- Loosen the lock nut on the core and unscrew the core from the spool.



Main Stage LVDT Replacement

- Loosen the locknut on the LVDT coil and unscrew from the end cap.
- Count the number of threads as you unscrew the old core and use the same count for the new one.





Main Stage LVDT Replacement

» When reassembling the new core to the spool the core needs to be adjusted to the proper length. The chart below shows the length of the core from the end of the spool to the end of the core.

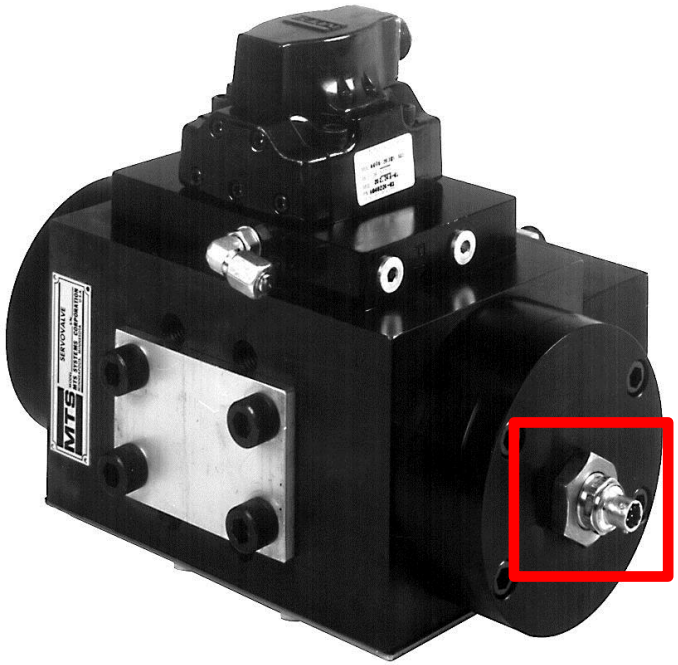
Model Number	Core Extension*†
256.04	35.5 mm (1.4 in)
256.09	35.5 mm (1.4 in)
256.18	35.5 mm (1.4 in)
256.25	40.6 mm (1.6 in)
256.40	40.6 mm (1.6 in)

* Core extension is the length the core extends from the end of the spool to the outer end of the core.

† The linear range is ±6.35 mm (0.25 in).

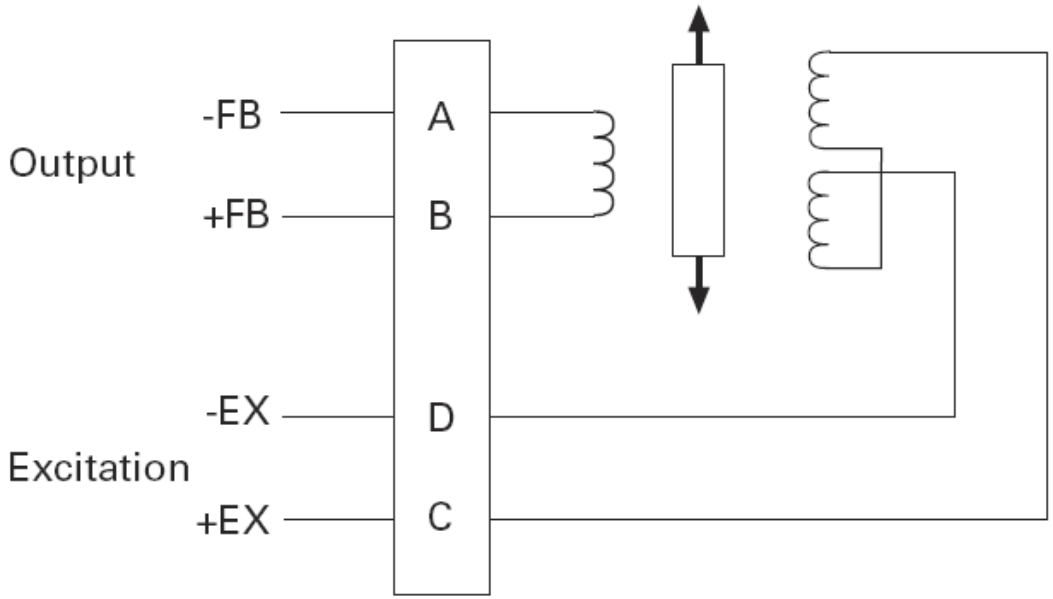
LVDT Centering

- After LVDT replacement or if the LVDT has become off center it must be adjusted.
- Centering of the LVDT is performed by turning the LVDT coil either into or out of the valve body. When the LVDT is correctly positioned secure its position by tightening the LVDT Lock Nut.
- The LVDT should have an equal output but opposite polarity in each end cap.
- Use the polarity on the “Valve” tab to generate an out of control condition to drive the spool into the end cap
- Use the manual command to drive to the other endcap



Main Stage LVDT Connector

» The LVDT main stage connector pinout is shown below.



256 Valve Torque Chart

» Use the torque in the chart below for fasteners on a 256 servovalve

Socket Head Screw Torque Values*

Socket Head Screws (Quantity)	Servovalve Models				
	256.04	256.09	256.18	256.25	256.40
Spool Stop (8)	3.95 N·m (35 lbf·ft)	3.95 N·m (35 lbf·ft)	3.95 N·m (35 lbf·ft)	12.20 N·m (108lbf·in)	12.20 N·m (108lbf·in)
Drain End Cap (4)	12.20 N·m (108lbf·in)	12.20 N·m (108lbf·in)	12.20 N·m (108lbf·in)	47.45 N·m (35 lbf·ft)	47.45 N·m (35 lbf·ft)
LVDT End Cap (4)	12.20 N·m (108lbf·in)	12.20 N·m (108lbf·in)	12.20 N·m (108lbf·in)	47.45 N·m (35 lbf·ft)	47.45 N·m (35 lbf·ft)
Main Stage Mounting† (4)	47.45 N·m (35 lbf·ft)	47.45 N·m (35 lbf·ft)	47.45 N·m (35 lbf·ft)	12.20 N·m (108lbf·in)	12.20 N·m (108lbf·in)
Pilot Stage Mounting (4)	24.40 N·m (18 lbf·ft)	24.40 N·m (18 lbf·ft)	24.40 N·m (18 lbf·ft)	24.40 N·m (18 lbf·ft)	24.40 N·m (18 lbf·ft)

* Tighten all screws in sequence. Tighten one, then the one opposite it, then the ones in between until all are tightened to the specified torque.

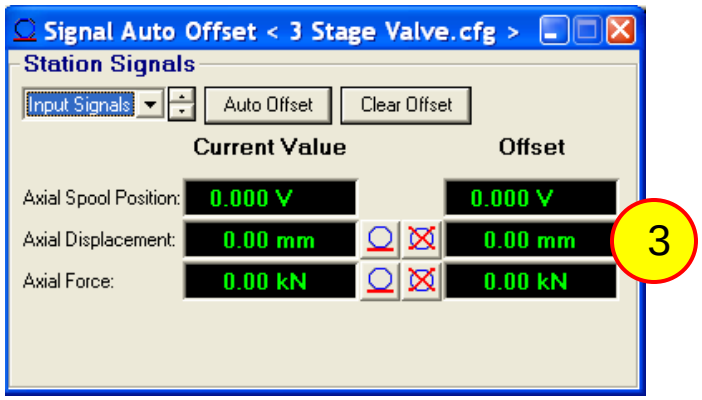
† The 256.04 has 3 main stage mounting socket head screws

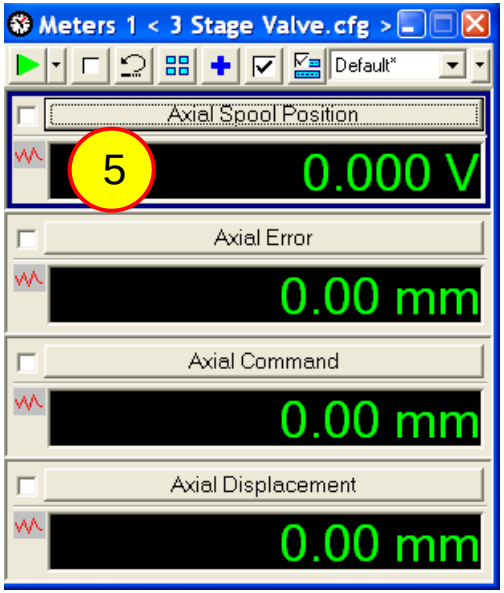
Model 256.XX 3-Stage Valve Set Up

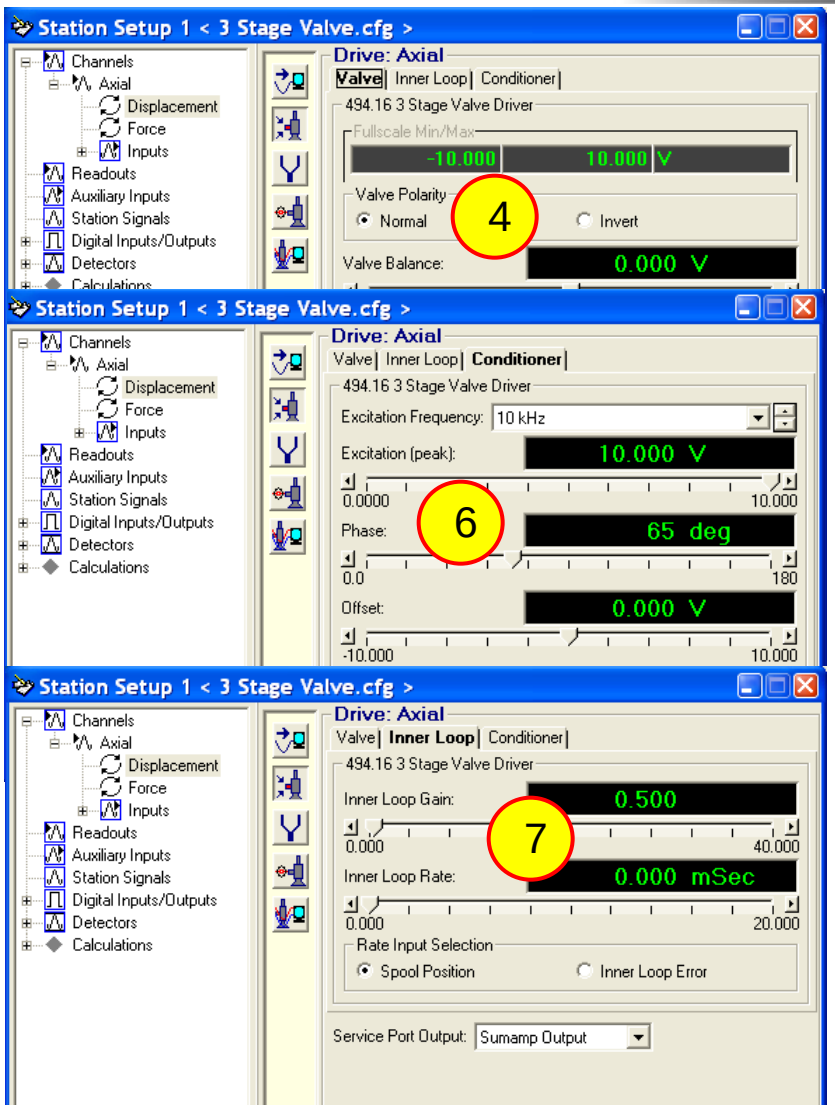
1. Isolate the Inner Loop by disconnecting the cable going to the “HSM” connector (J28). Ensure pilot pressure is on and both valve and oil have been warmed up.
2. Ensure that the Channel is in displacement control.
3. Since in most situations, the actuator is not in its center of travel, note the value of the **“Offset”** for the displacement transducer. Do an **‘Auto Offset’** for the displacement transducer. An alternative method is to disconnect the actuator LVDT cable. The purpose of this step is to create ‘Zero’ Error for the displacement control mode.
4. On the **“Station Setup”** window, locate the **“3-Stage Valve Adjustment”** window. Select the **“Valve”** Tab & change the ‘Valve Polarity’ to cause the 256 Valve to go out-of-phase.
5. Setup a 793 ‘Timed’ meter to read ’Spool Position’.
6. These next 2 steps are for preliminary adjustments→ On the **“Conditioner”** Tab, adjust ‘Excitation’ for 10.00 volts. Adjust conditioner ‘Gain’ for a ‘Spool Position’ reading of 8.000 volts. Adjust ‘Phase’ for a maximum reading. Readjust ‘Gain’ until the meter reads 8.000 volts.
7. On the **“Inner Loop”** Tab, adjust the ‘IL Gain’ for 0.5 & ‘IL Rate’ for 0.0.

SEE FIGURES ON NEXT PAGE

Model 256.XX 3-Stage Valve Set Up





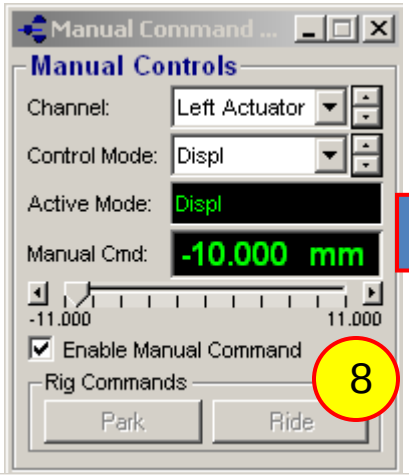


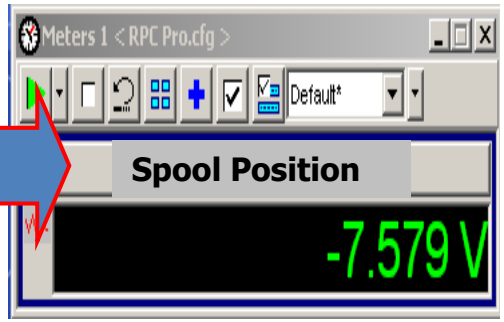
Model 256.XX 3-Stage Valve Set Up

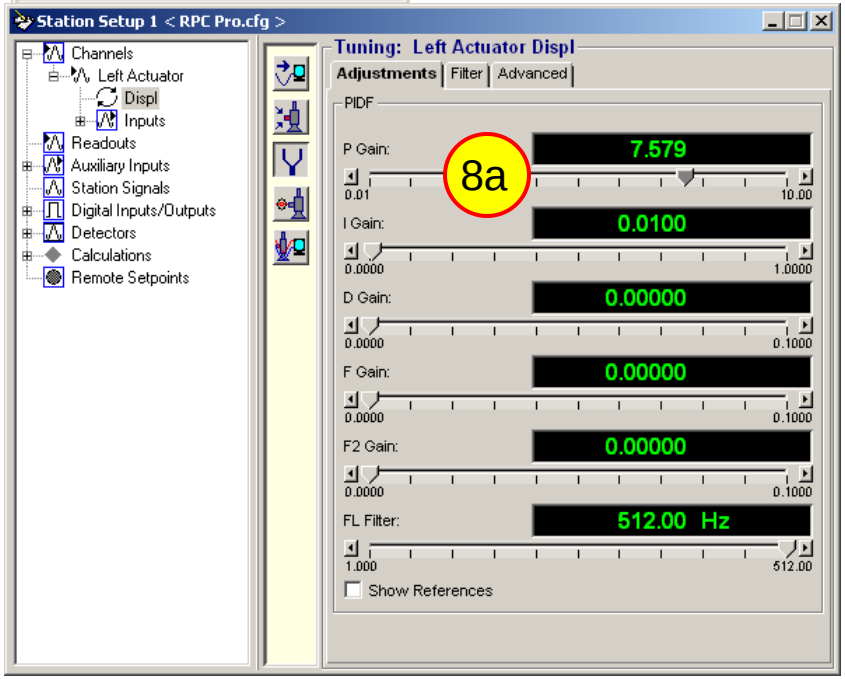
8. Using the “Manual Command” adjust for a maximum value to cause the Valve spool to move to its other end cap. You may need to increase the ‘Outer Loop’ “P” Gain to achieve this adjustment. Be sure to note the value of the “P” Gain before adjusting same.
9. You will notice that the “Spool Position” meter will change ‘polarity’ once the Inner Loop Spool moves.
10. Note the “Spool Position” meter value. It should be within 0.5 volts of the initial reading before the polarity changed (7.5 to 8.5 volts). If not, the valve LVDT coil will need adjustment.
11. Once you have verified that the Valve LVDT output is symmetrical, then adjust “IL Conditioner Gain” to the appropriate value for the system. This value can be between 7.5 to 10.0 volts.
12. Return the “IL Valve Polarity” on the “Valve” Tab of the ‘Channel Drive’ in ‘Station Setup’ to the correct position for Inner Loop control. Return the Outer loop “P” gain to the value noted in step 8 prior to adjustment.
13. Verify that the system is still at zero error. If not zero error use manual command to achieve zero error. While monitoring “Spool Position” adjust valve balance located on the “Valve” tab Until the “Spool Position” is zero.

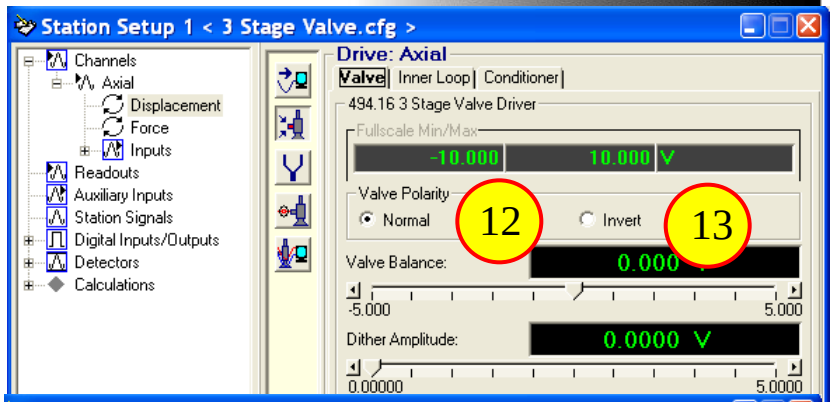
SEE FIGURES ON NEXT PAGE

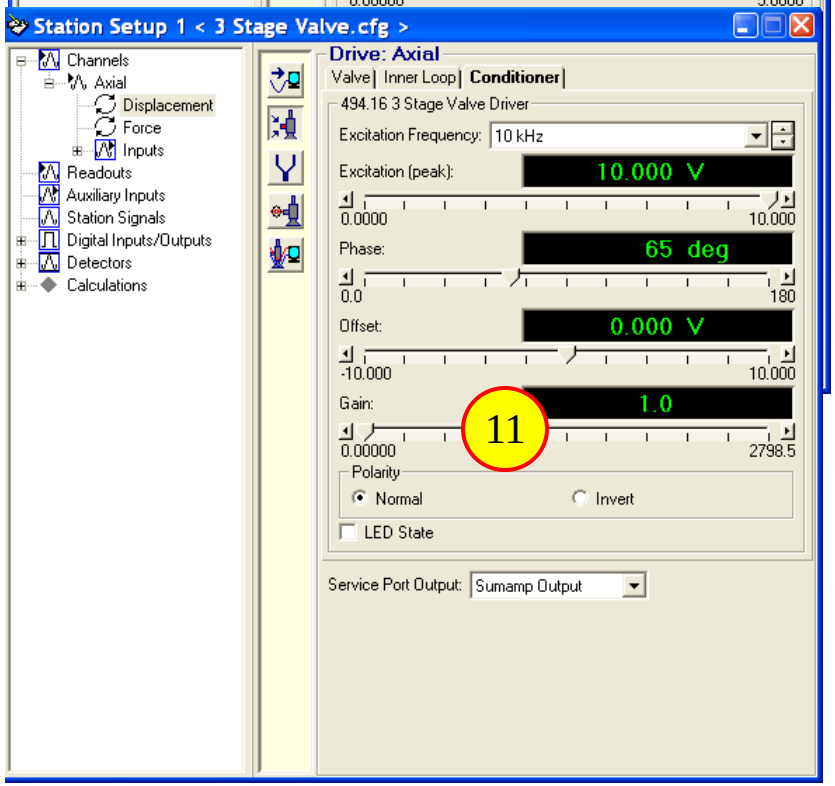
Model 256.XX 3-Stage Valve Set Up









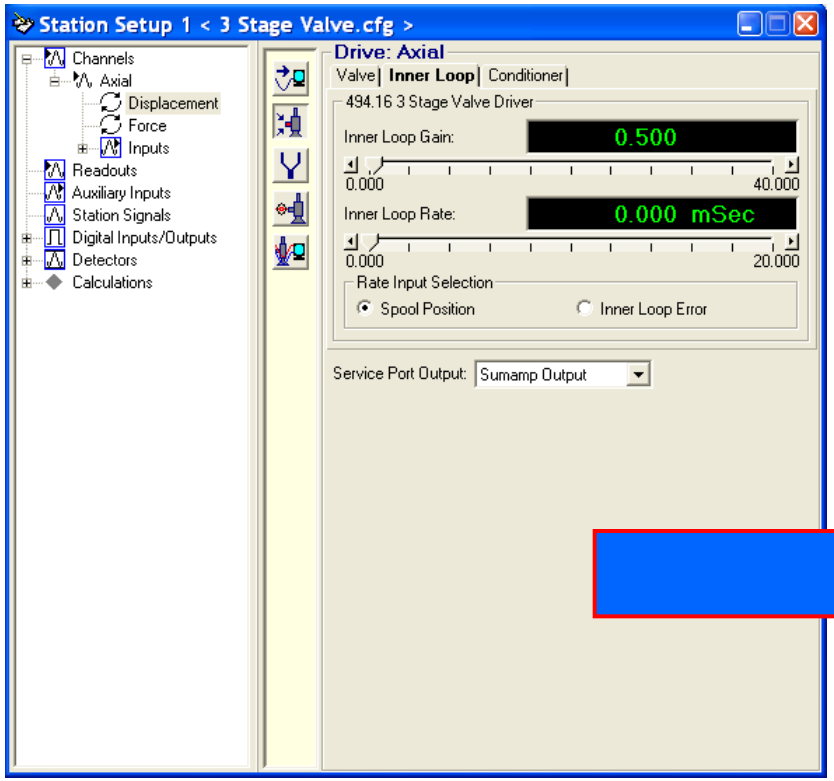


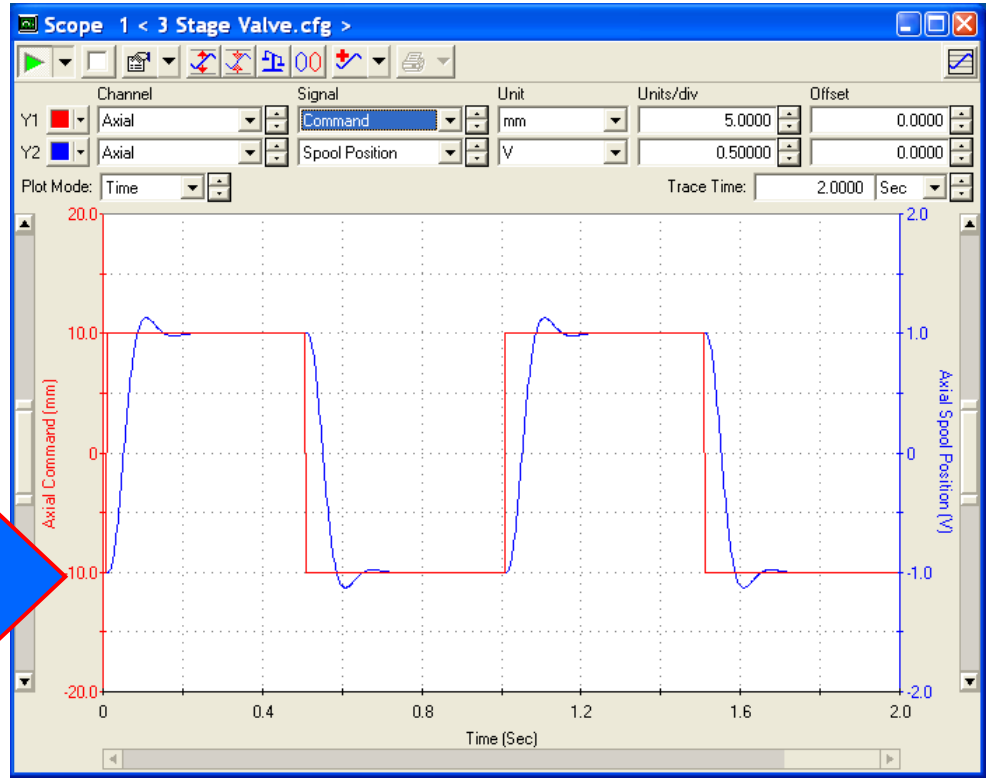
Model 256.XX 3-Stage Valve Set Up

14. Select “Spool Position” and “Command” for display on the 793 Scope.
15. Program the 793 Function Generator for a 1 HZ ‘Square Wave’ with a “Target Setpoint” of 0.0 mm/inches and a “Target Amplitude” which will generate 1.0 volts of feedback on the “Spool Position”.
16. Adjust the “IL P Gain” on the “Servo” Tab of the ‘Channel Drive’ section of ‘Station Setup’ for ≈10% **Overshoot** on the “Spool Position” waveform.
17. Next, adjust the “IL Rate” on the “Servo” Tab of the ‘Channel Drive’ section of ‘Station Setup’ for **No Overshoot** on the “Spool Position” waveform.
18. Stop the function generator. Use the manual command to adjust for zero error. Confirm the “Spool Position” is at zero. This step checks that the inner loop balance is still in tolerance. If not at zero, follow step #13.
19. Return the Displacement “Auto Offset” to the original value recorded in Step #3.

SEE FIGURES ON NEXT PAGE

Model 256.XX 3-Stage Valve Set Up





Model 256.XX 3-Stage Valve Set Up

20. Re-connect the cable going to J28X of the Controller to re-enable the ‘Outer Loop’.
21. Note the current value and Temporarily reduce the Outer loop “I gain” to zero.
22. Turn on Hydraulics to high pressure.
23. Adjust manual command to a value of zero for position control.
24. Monitor displacement feedback and adjust the “Offset” on the “Conditioner” page of the 3 stage valve until the displacement feedback reads zero.
25. Return the outer loop “I gain” to the setting noted in step #21.

SEE FIGURES ON NEXT PAGE

Model 256.XX 3-Stage Valve Set Up