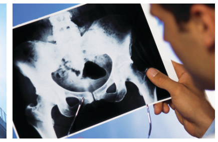
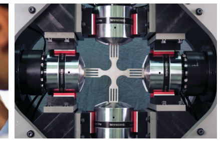
MTS®



be certain.

MTS Series 793 Tuning and Calibration

100-147-134 E

Copyright information

Trademark information

Proprietary information

Software validation and verification

MTS software is developed using established quality practices in accordance with the requirements detailed in the ISO 9001 standards. Because MTS-authored software is delivered in binary format, it is not user accessible. This software will not change over time. Many releases are written to be backwards compatible, creating another form of verification.

The status and validity of MTS's operating software is also checked during system verification and routine calibration of MTS hardware. These controlled calibration processes compare the final test results after statistical analysis against the predicted response of the calibration standards. With these established methods, MTS assures its customers that MTS products meet MTS's exacting quality standards when initially installed and will continue to perform as intended over time.

Publication information

Manual Part Number	Publication Date	MTS 793 Software Release
100-147-134 A	June 2006	Version 4.0A or later
100-147-134 B	October 2006	Version 4.0B or later
100-147-134 C	January 2008	Version 5.0B or later
100-147-134 D	September 2008	Version 5.1A or later
100-147-134 E	August 2009	Version 5.2A or later

Contents

Chapter 2 Tuning Procedures 47

Chapter 3 Calibration Procedures 121

Index 213

Technical Support

How to Get Technical Support

Start with your manuals

The manuals supplied by MTS provide most of the information you need to use and maintain your equipment. If your equipment includes MTS software, look for online help and README files that contain additional product information.

If you cannot find answers to your technical questions from these sources, you can use the internet, e-mail, telephone, or fax to contact MTS for assistance.

Technical support methods

MTS provides a full range of support services after your system is installed. If you have any questions about a system or product, contact MTS in one of the following ways.

MTS web site
www.mts.com

The MTS web site gives you access to our technical support staff by means of a Technical Support link:

www.mts.com > Contact MTS > Service & Technical Support

E-mail

techsupport@mts.com

Telephone

MTS Call Center 800-328-2255

Weekdays 7:00 A.M. to 5:00 P.M., Central Time

Fax

952-937-4515

Please include “Technical Support” in the subject line.

Before You Contact MTS

MTS can help you more efficiently if you have the following information available when you contact us for support.

Know your site number and system number

The site number contains your company number and identifies your equipment type (material testing, simulation, and so forth). The number is usually written on a label on your MTS equipment before the system leaves MTS. If you do not have or do not know your MTS site number, contact your MTS sales engineer.

Example site number: 571167

When you have more than one MTS system, the system job number identifies which system you are calling about. You can find your job number in the papers sent to you when you ordered your system.

Example system number: US1.42460

Know information from prior technical assistance

If you have contacted MTS about this problem before, we can recall your file. You will need to tell us the:

- MTS notification number
- Name of the person who helped you

Identify the problem

Describe the problem you are experiencing and know the answers to the following questions:

- How long and how often has the problem been occurring?
- Can you reproduce the problem?
- Were any hardware or software changes made to the system before the problem started?
- What are the model numbers of the suspect equipment?
- What model controller are you using (if applicable)?
- What test configuration are you using?

Know relevant computer information

If you are experiencing a computer problem, have the following information available:

- Manufacturer's name and model number
- Operating software type and service patch information
- Amount of system memory
- Amount of free space on the hard drive in which the application resides
- Current status of hard-drive fragmentation
- Connection status to a corporate network

Know relevant software information

For software application problems, have the following information available:

- The software application's name, version number, build number, and if available, software patch number. This information is displayed briefly when you launch the application, and can typically be found in the "About" selection in the "Help" menu.
- It is also helpful if the names of other non-MTS applications that are running on your computer, such as anti-virus software, screen savers, keyboard enhancers, print spoolers, and so forth are known and available.

If You Contact MTS by Phone

Your call will be registered by a Call Center agent if you are calling within the United States or Canada. Before connecting you with a technical support specialist, the agent will ask you for your site number, name, company, company address, and the phone number where you can normally be reached.

If you are calling about an issue that has already been assigned a notification number, please provide that number. You will be assigned a unique notification number about any new issue.

Identify system type

To assist the Call Center agent with connecting you to the most qualified technical support specialist available, identify your system as one of the following types:

- Electromechanical materials test system
- Hydromechanical materials test system
- Vehicle test system
- Vehicle component test system
- Aero test system

Be prepared to troubleshoot

Prepare yourself for troubleshooting while on the phone:

- Call from a telephone when you are close to the system so that you can try implementing suggestions made over the phone.
- Have the original operating and application software media available.
- If you are not familiar with all aspects of the equipment operation, have an experienced user nearby to assist you.

Write down relevant information

Prepare yourself in case we need to call you back:

- Remember to ask for the notification number.
- Record the name of the person who helped you.
- Write down any specific instructions to be followed, such as data recording or performance monitoring.

After you call

MTS logs and tracks all calls to ensure that you receive assistance and that action is taken regarding your problem or request. If you have questions about the status of your problem or have additional information to report, please contact MTS again and provide your original notification number.

Problem Submittal Form in MTS Manuals

Use the Problem Submittal Form to communicate problems you are experiencing with your MTS software, hardware, manuals, or service which have not been resolved to your satisfaction through the technical support process. This form includes check boxes that allow you to indicate the urgency of your problem and your expectation of an acceptable response time. We guarantee a timely response—your feedback is important to us.

The Problem Submittal Form can be accessed:

- In the back of many MTS manuals (postage paid form to be mailed to MTS)
- www.mts.com > Contact Us > Problem Submittal Form (electronic form to be e-mailed to MTS)

Preface

Before You Begin

Safety first!

Before you attempt to use your MTS product or system, read and understand the *Safety* manual and any other safety information provided with your system. Improper installation, operation, or maintenance of MTS equipment in your test facility can result in hazardous conditions that can cause severe personal injury or death and damage to your equipment and specimen. Again, read and understand the safety information provided with your system before you continue. It is very important that you remain aware of hazards that apply to your system.

Other MTS manuals

In addition to this manual, you may receive additional MTS manuals in paper or electronic form.

If you have purchased a test system, it may include an MTS System Documentation CD. This CD contains an electronic copy of the MTS manuals that pertain to your test system, including hydraulic and mechanical component manuals, assembly drawings and parts lists, and operation and preventive maintenance manuals. Controller and application software manuals are typically included on the software CD distribution disc(s).

Conventions

Documentation Conventions

The following paragraphs describe some of the conventions that are used in your MTS manuals.

Hazard conventions

As necessary, hazard notices may be embedded in this manual. These notices contain safety information that is specific to the task to be performed. Hazard notices immediately precede the step or procedure that may lead to an associated hazard. Read all hazard notices carefully and follow the directions that are given. Three different levels of hazard notices may appear in your manuals. Following are examples of all three levels.

Note *For general safety information, see the safety information provided with your system.*

DANGER

Danger notices indicate the presence of a hazard with a high level of risk which, if ignored, *will* result in death, severe personal injury, or substantial property damage.

WARNING

Warning notices indicate the presence of a hazard with a medium level of risk which, if ignored, *can* result in death, severe personal injury, or substantial property damage.

CAUTION

Caution notices indicate the presence of a hazard with a low level of risk which, if ignored, *could* cause moderate or minor personal injury, equipment damage, or endanger test integrity.

Notes

Notes provide additional information about operating your system or highlight easily overlooked items. For example:

Note *Resources that are put back on the hardware lists show up at the end of the list.*

Special terms

The first occurrence of special terms is shown in *italics*.

Illustrations

Illustrations appear in this manual to clarify text. It is important for you to be aware that these illustrations are examples only and do not necessarily represent your actual system configuration, test application, or software.

Electronic manual conventions

This manual is available as an electronic document in the Portable Document File (PDF) format. It can be viewed on any computer that has Adobe Acrobat Reader installed.

Hypertext links

The electronic document has many hypertext links displayed in a blue font. All blue words in the body text, along with all contents entries and index page numbers, are hypertext links. When you click a hypertext link, the application jumps to the corresponding topic.

Chapter 1

Introduction

This manual describes how to perform servovalve adjustments, tune, and calibrate all MTS 793 Controllers.

Note *TestStar IIs, TestStar II AP, and FlexTest II CTM Controllers are not equipped with this manual. The equivalent information is located in the associated service manual (PDF) on the 793 Installation CD.*

This chapter describes how individual tuning and calibration controls work in general—that is, their principals of operation.

Where to find control descriptions for specific controller models

For a description of *specific* tuning and calibration controls (as displayed in the MTS 793 control software user interface) for FlexTest IIm, automated FlexTest SE, FlexTest GT, and TestStar IIm Controllers, see the *MTS 793 Control Software* manual.

For a description of the specific tuning and calibration controls displayed on the front panel of stand-alone FlexTest SE Controllers, see the *FlexTest SE Users* manual.

Contents

About Tuning

Tuning is adjusting your test system so that its servo loop responds accurately to its command signal. When you tune, you are setting the response and stability of the servo control loop. Proper tuning improves the performance of your test system just like setting the timing on an automobile improves its performance.

It is not necessary for you to always have every control mode of every control channel perfectly tuned. Tune whenever necessary to whatever extent needed to have your test system behave the way you want it to.

The controller system software includes several tuning controls. You do not need to use all of the controls to properly tune your system. *In fact, most testing can be accomplished with just the proportional gain adjustment*. The other adjustments introduce a signal to the command to compensate for specific situations.

Note *Throughout this chapter the terms gain, rate, and reset represent proportional gain, rate derivative, and reset integration respectively.*

Control loop elements

The control loop of your test system basically has three elements:

- The command, which is really demanding, "I want you do this."
- The feedback, which is responding, "I'm actually doing this at the present time."
- The error, which is complaining, "You two are out of agreement by this much."

Summing junction

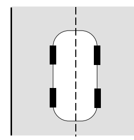
This means that Error = Command - Feedback. This is the summing junction. You want to get the summing junction to drive the error to zero, and to do it smoothly and efficiently.

Consequences of a large degree of error

While precise tuning is not usually necessary, inaccurate tuning increases the error and phase lag between the command and the feedback. If the error is large, it can reduce control accuracy and repeatability, and prevent the full program command from being applied to the specimen.

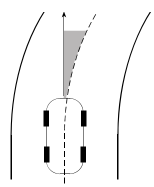
How the Tuning Controls Work

To understand how tuning works, consider the analogy of taking a car on the highway. The dashed line down the middle of the road is where the driver wants to be—so this is the command.



This is an automated system that tells the driver if the car is following the command and, if not, how far it is off and in what direction. As the car moves, the road begins to curve. The driver does not respond immediately, so the command (the desired path) and the feedback (the actual path) are starting to differ.

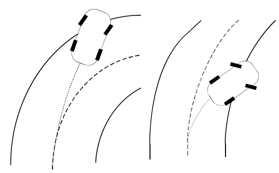
This difference (command minus feedback) is error. It is indicated by the shaded triangle.



Note that error increases the longer the driver waits to correct it, that is, the larger the difference between the desired path and the actual path.The driver turns the steering wheel to adjust the car's path. But there is a problem.

Note *Assume the error detector is set to a value that represents the width of the road. If the response is too slow or too quick, the error detector can stop the program before you go off the road.*

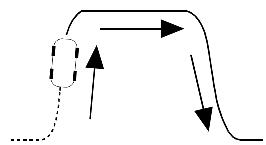
If you turn the steering wheel too little, and the car responds too slowly. If you turn the steering wheel too much, the car overresponds. So the objective for a good driver is to turn the wheels just right. If so, the car accurately follows the line, the passengers have a smooth ride.



The test waveform

We want our servo loop to work just like the skilled driver, that is, to turn the steering wheel just the right amount.

Now imagine the road transformed into the square wave shown in the diagram, which is one type of test waveform. We want our test (the car) to follow the desired command (the road) in all respects. That means the test system should exert the precise force (or displacement or strain) that we want on the specimen.



The only problem is that different types of materials—from the softest to the hardest—exhibit different reactions to the force or displacement or strain. Just as we would tune a car differently for racing than we would for a weekly drive to the store, the tuning differs too. A system properly tuned for a soft specimen will go unstable if you install a very hard specimen.

The ultimate goal

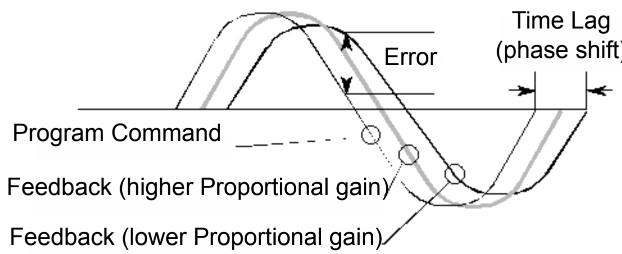
Get the error signal to be as small as possible at all times (without compensators), because:

- The error signal tells the servovalve to open.
- The larger the error signal, the more the servovalve opens.
- Therefore, if the error is zero, the servovalve is closed. This means the servo loop is "satisfied" and all is well.

Remember: If the error is as close to zero as possible (actually maintaining zero is impossible), it indicates that the system is closely following the command.

Getting there

- Start with the command.
- Add the feedback—it lags the command.
- Adjust to get the error and phase shift as low as possible.

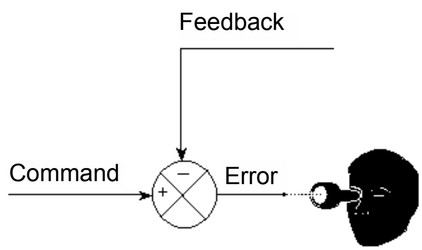


Proportional (P) Gain

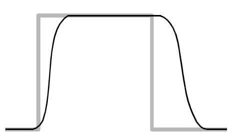
Proportional gain is the primary and coarsest control of the system. It is similar to a radio’s volume control in that it amplifies the error signal by an appropriate amount to control the system. In its most generic sense, the term proportional gain means that the change in power output is proportional to the error.

Remember that for our car, the amount of steering (amplitude) is proportional to how much we want to correct, and how fast. This is proportional gain. Our formula is now:

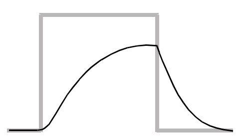
Error = Gain x (Command - Feedback)



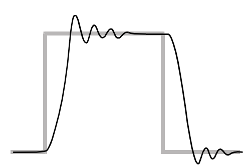
Proportional gain looks at the Error side of the summing junction.



The shaded square wave represents the test command. The solid waveform shows an idealized feedback signal.



This waveform shows a sluggish (low gain) feedback signal.

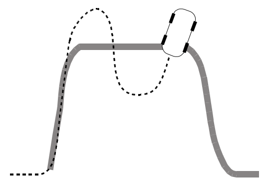


This waveform shows an unstable (high gain) feedback signal.

Note *Proportional gain is not speed (how far your push down on the gas pedal), it is how fast you turn the steering wheel. So proportional gain in the servo loop is acceleration. The “speed” of the system is controlled by the size of the hydraulic components.*

At first, it may seem desirable to make proportional gain as large as possible. After all, we want the system to react quickly and positively. One sign of a system with insufficient proportional gain is that it is sluggish.

There is only one problem with having proportional gain higher than necessary: it is very difficult to keep the car on the road. It flies off, we overcontrol trying to correct it, and the cycle continues. A servo loop can do that too; it is said to be ringing. It is unstable. There is nothing subtle about an unstable loop—you will hear it. If the test fixture is large enough, you will feel it too.



So as a general rule, the gain should be as high as possible without causing the loop to go unstable. General principles to remember are:

- With a given error signal, increasing the gain increases the input to the servovalve.
- Increasing the input to the servovalve opens it more.
- Opening the servovalve more moves the oil faster into the actuator.
- Moving oil faster makes the loop respond quicker, reducing the error faster.

More about Proportional gain

Proportional gain is used for all tuning situations. It introduces a control factor that is proportional to the error signal. Proportional gain increases system response by boosting the effect of the error signal on the servovalve.

Keep in mind:

- As proportional gain increases, the error decreases and the feedback signal tracks the command signal more closely.
- Higher gain settings increase the speed of the system response.
- Too much proportional gain can cause the system to become unstable, while too little proportional gain can cause the system to become sluggish.
- Gain settings for different control modes may vary greatly. For example, the gain for force may be as low as 1 while the gain for strain may be as high as 10,000.

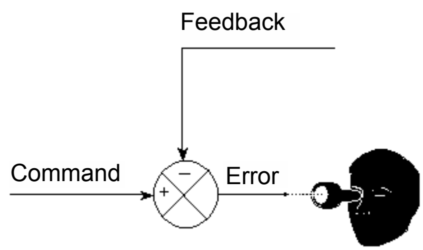
Integral (I) Gain

Integral gain generates increased gain over longer time spans (including steady state). Integral gain is sometimes called Reset gain.

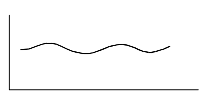
To return to the car analogy: The race is over. You’ve won and the trip home is an easy one. You’re driving on a straight highway so you are not being as attentive as when you were racing.

The car drifts off of its desired path. The problem is that this happens so slowly that you don’t realize it. You need something to boost your attention.

That’s what integral gain is, or why it is sometimes called Reset Integration. It is the integral of the error signal, that is, it is essentially the error signal multiplied by time. This means that even a small error signal eventually will become conspicuous.

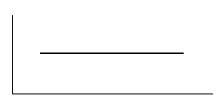


Intergral (Reset) gain looks at the error side of the summing junction. It is the integral of the error, indicating the size of the error over time.



too much integral gain

An error signal made unstable by too much integral gain.



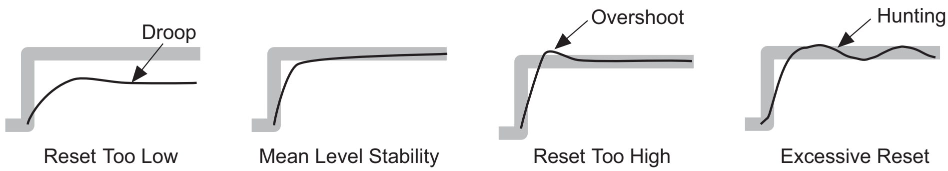
dc stability

An error signal that is stabilized by correct gain.

More about Integral gain (I)

Integral gain introduces “an integral of the error signal” that gradually, over time, boosts the low-frequency response of the servovalve command.

Integral gain increases system response during static or low-frequency operation and maintains the mean level at high-frequency operation. It can offset a DC or steady-state error, such as that caused by valve imbalance.



A ramp and hold waveform illustrate different levels of reset. The I Gain adjustment determines how much time it takes to improve the mean level accuracy.

Integral gain:

- Improves mean level response during dynamic operation
- Corrects feedback droop caused by the spring characteristic of the servovalve in static and very low-frequency test programs
- Minimizes the amount of time the system needs to recover from transitions or transients

Keep in mind:

- Higher integral gain settings increase system response.
- Too much integral gain can cause a slow oscillation (hunting).
- You may want to use the max/min display to monitor the mean level, reset the display, and check it again.

Integrator limit

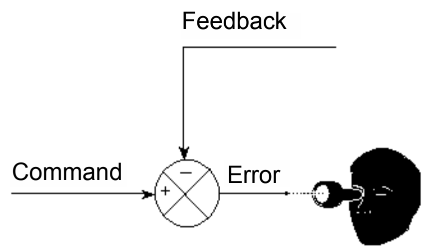
The Integrator Limit control allows you to set the maximum integrator value as a percentage of full-scale output.

Derivative (D) Gain

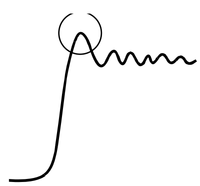
Derivative gain is an adjustment you may or may not need. Another name for derivative gain is Rate gain.

Get back into the car and back on the race track. Only now you are going really fast and the curves are electrifying. But it is a race, so you are actually accelerating while in the short straightaways.

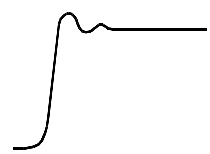
In your attempt to accelerate, you press the gas pedal all the way to the floor—and hold it there. But now you are going too fast to safely round a curve, so you slam on the brakes just as you enter the curve, then release them. The brakes stabilize the trip by restraining the driving action at the time that the car is changing direction. Consider this: you barely need brakes if going slowly down a wide, level street. Brakes become more essential the faster you go and the quicker you change direction. Derivative gain is the same concept. It stabilizes the system by reducing the error signal when its rate of change is the greatest. This reduces overshoot and ringing at high proportional gain settings.



Derivative gain looks at the feedback side of the summing junction. It is the derivative of that signal, indicating how fast the feedback is changing.



Here is a signal with a high degree of proportional gain. Derivative gain has not been applied yet. Notice how noisy the signal is.



The same high gain signal after derivative gain has been applied. The derivative gain tends to damp out the ringing.

So, derivative gain indicates the change in acceleration in the error signal. Or, in an equation:

Derivative Gain = Gain x (Command - Feedback)'

(The ' symbol in the equation above means “first derivative.”)

Do you need derivative gain?

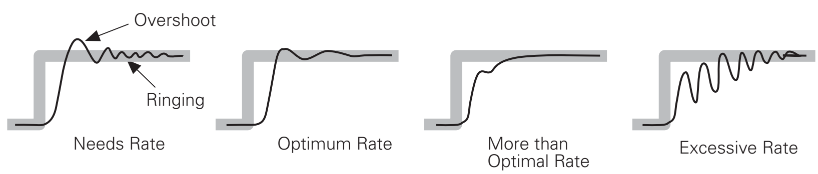
There is a good chance you do not. It is used primarily in systems performing dynamic tests. Consider this scenario: You have a specimen that is quite springy (such as fiberglass). The test is calling for rapid changes in direction (say, for example, more than 5 times a second) and high velocities. Proportional gain needs to be set quite high to get this kind of response. Because things are changing so rapidly, the system is electrically noisy. If the system is making a rumbling sound, you could use some derivative gain.

On the other hand, it is unlikely for you to need derivative gain for soft materials such as elastomers.

Another quick (and incomplete) rule-of-thumb is to write down the ratings of your actuator and servovalve in kips and gallons per minute. If kip ÷ gpm>1, then derivative gain probably has little effect on the loop.

More about derivative gain

Derivative gain is used with dynamic test programs. It introduces a “derivative of the feedback signal.” This means it anticipates the rate of change of the feedback and slows the system response at high rates of change.



Derivative gain:

- Reduces ringing.
- Provides stability and reduces noise at higher proportional gain settings.
- Tends to amplify noise from sensors.
- Tends to decrease system response when set too high.

Keep in mind:

- Too much derivative gain can create instability at high frequencies, and too much proportional gain may cause a ringing or screeching sound.
- Too little derivative gain can make a rumbling sound. The correct amount of derivative gain results in the system running quietly.

Note *Series 256 and 257 Servovalves may require derivative gain applied to both the inner control loop and outer control loop.*

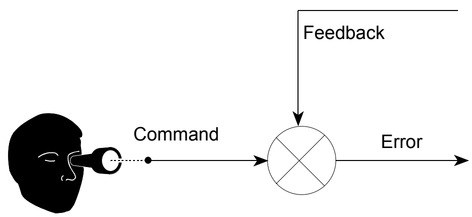
Note *Excessive negative (–) D Gain can cause your system to become unstable.*

Feed Forward (F or F2) Gain

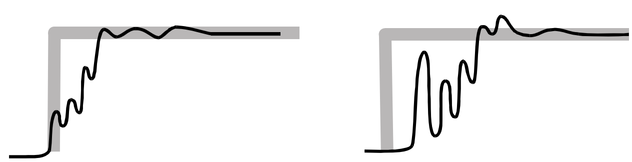
Feed Forward is a gain adjustment not needed for many systems. It is more likely needed on systems where you need to move a lot of oil fast to get the actuator moving. So it is more likely to be found on systems with large actuators, massive grips, or moving load cells. For our car example, and if you remember how carburetors work, feed forward is equivalent to the accelerator pump—that is the gizmo that gives a quick slug of gas when you suddenly floor the gas pedal.

This mode is like Derivative mode, except that it anticipates changes rather than reacts to them.

Feed forward watches the command side of the summing junction, and provides a derivative of the command. Remember that a derivative is proportional to the rate of change of a signal; therefore, the faster the command is changing (like during the leading/trailing edges of a squarewave), the greater the signal is.



Feed forward gain looks at the command side of the summing junction. The output is the derivative of that signal, indicating how fast the command is changing.



Correct feed forward. Inadequate feed forward.

So look at feed forward as a form of a "predictor" of where the actuator should be going. The signal gives the servovalve an early indicator to tell it that it needs to open faster than would be expected from the existing error signal.

More about Feed Forward Gain

Feed forward (F/F2 Gain) introduces a derivative of the command signal. It anticipates how large a valve opening is needed to reach the required response and adds that to the valve command—like compensating for phase lag.

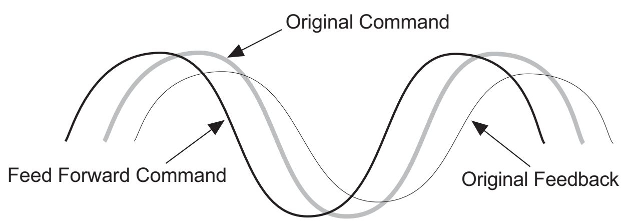
F Gain vs. F2 Gain

F Gain is applied to the current control mode before the forward loop filter. F2 Gain is applied after the forward loop filter.

When your forward loop filters are set to low frequencies it tends to limit the effectiveness of F Gain. F2 Gain may work better in this situation.

You would tend to use F Gain when there are frequencies you do not wish to excite. Using F Gain allows the forward loop filter to filter out these frequencies.

Adjusting F Gain or F2 Gain causes the command signal to start sooner. This causes the feedback signal to track the original command signal more closely.



F/F2 Gain

- Does not compensate for normal changes during testing (such as temperature changes, servovalve droop, and so forth).
- May be used to minimize phase lag.
- Should be used like derivative gain. However, F Gain applies to the test command signal while derivative gain applies to the feedback signal.
- Feed forward gain helps the servo-control loop react quickly to an abrupt change in the command.
- Is needed when testing a soft specimen in force control.

Stabilization Gain (S Gain)

Stabilization gain allows a second signal to be integrated into the composite command signal as a stabilizing factor. It enhances stability for systems that move large masses at *high speeds*. The second signal is generated by a special transducer such as ΔP (differential pressure) or accelerometer.

Stabilization controls will be available only if a stabilization resource was added to the control channel.

Delta P Stabilization

Delta P makes use of a differential pressure sensor that measures the difference in pressure at each end of the actuator. It compensates for hydraulic compliance (compressed hydraulic fluid acts like a spring). Delta P improves displacement control of heavy mass loaded systems.

Delta P is typically used on systems with large hydraulic fluid flow rates. This adjustment is usually needed when the natural frequency of the actuator is less than the 90º phase lag frequency of the servovalve. The servovalve 90º phase lag frequency can be found in the servovalve product literature.

The natural frequency can be approximated with the following formula:

$$\text{Actuator Frequency} = \frac{CA}{WV}$$

Where:
- C = constant for English (2500) or metric units (1060)
- A = actuator piston area expressed as in^2 (cm^2)
- W = any directly coupled mass including the actuator piston mass expressed in lbs (kg)
- V = hydraulic fluid volume contained inside the actuator and manifold expressed as in^3 (cm^3)

- If the system response deteriorates when adding delta P, then change the polarity of the signal. If changing polarity does not improve system response, try adjusting the stabilization filter.
- Check all amplitudes for overshoot. Do not allow more than 10% overshoot (preferably none) at any amplitude of a square wave response.
- Delta P will not compensate for additional compliance from swivels, linkages, test tables, and so forth. In this case, a mass accelerometer signal from an accelerometer may be used in place of a delta P signal for stabilization.

Acceleration Stabilization

Test systems with specimens affected by acceleration resonances can use a mass accelerometer signal for stabilization. Acceleration stabilization dampens the resonances (vibrations) affecting the specimen.

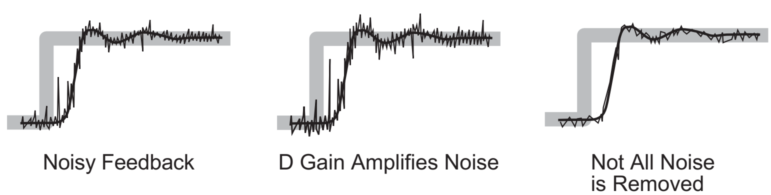
Typical systems that benefit from acceleration stabilization include:

- Load units that operate at high frequencies with massive grips
- Test systems that employ swivels, linkages, and test tables

Sensor feedback is provided by an accelerometer attached to (or near) the specimen. The controller converts this feedback into a stabilization signal which is combined with the composite command signal (post-PIDF correction). The “stabilized” command signal is then sent to the valve driver.

Forward Loop Filter (FL Filter)

FL filter adjustments compensate for noise in the servoloop—which usually comes from sensor feedback. FL filter adjustments establish a frequency bandwidth for the servo-loop command signal.



Keep in mind:

- By default, the FL filter is set to one-half the system rate.
- The minimum FL filter frequency setting is 0.01.
- Be sure the forward loop filter frequency is higher than any frequency in the test program. (Most testing occurs below 50 Hz.)
- Systems with moving load cells or heavy grips can produce a noisy force signal.
- If you observe a noisy sensor feedback signal, reduce the FL filter setting to about 100 (providing your test does not reach 100 Hz). If additional adjustment is needed, reduce the setting by 5 - 10 Hz at a time.

Tuning Characteristics of Control Modes

Each control mode has different tuning characteristics.

Displacement control

The displacement control mode (also called stroke control) uses an LVDT sensor in the actuator as the controlling feedback source. The displacement control mode typically:

- Requires tuning only when first set up.
- Does not require a specimen for tuning.
- Uses a square wave when tuning an LVDT but not when tuning a displacement gage.
- May not yield actuator movement if P gain is set too low.
- May yield rapid, noisy, and unstable actuator movement if P gain is set too high.

Force control

Force control uses a force sensor (also called a load cell) as the controlling feedback source. The force control mode typically:

- Requires tuning between tests, whenever a specimen is changed, and whenever changes are made to the force train.
- Requires a specimen to be installed.
- Uses a ramp waveform for initial tuning. However, if the desired results cannot be achieved with a ramp waveform, a squarewave is used for tuning.
- May yield sluggish response if P gain is set too low.
- May yield unstable response is P gain is set too high.

Strain control

Strain control uses an extensometer or strain gage bonded to the specimen as the controlling feedback source. The strain control mode typically:

- Requires tuning between tests, whenever a specimen is changed, and whenever changes are made to the force train.
- Requires a specimen to be installed (you may choose to use a broken specimen).
- Uses a ramp waveform for the initial tuning.

Note *Do not use a square waveform for tuning. A square wave can cause the extensometer to move or fall off the specimen, which can cause the system to go unstable.*

- May yield sluggish response if P gain is set too low.
- May yield unstable response is P gain is set too high.

Command sources

The program command source can come from an internal source (such as the Function Generator or the MultiPurpose TestWare application) or from an external device (such as an external profiler or function generator).

CLC control mode

Channel limited channel (CLC) control modes are used for specimen installation and removal. Channel limited channels require two feedback signals.

Creating a Tuning Program

The purpose of a tuning program is to produce a command that reflects the most demanding system response expected from a test.

Note *The Function Generator is very useful for quickly setting up a tuning program. If you use the same tuning program on a regular basis you may wish to create and save your tuning procedure using Basic TestWare™ or by using the optional MultiPurpose TestWare™ application.*

Initial tuning is best done with a waveform that has abrupt changes. This excites the system at frequencies likely to be unstable with excessive gain. Square and ramp waveforms are preferred. Final tuning can be done with the actual program command for the test.

Note *Always monitor the sensor feedback or error signal to evaluate the control accuracy.* *See "Monitoring Waveforms While Tuning" on page 42.*

Command waveforms

A typical tuning program is a low-amplitude (5% to 10% of full-scale), low-frequency (1 Hz to 2 Hz) square waveform.

The amplitude, frequency, and waveform type of a tuning program can be selected to reflect the capabilities of the testing system or the testing requirements.

Square and tapered square waveform

A square waveform requires the servovalve to open rapidly to a large opening. It is the most demanding waveform because it requires the maximum response from the servoloop system. It also places a large acceleration on the test system and specimen.

Tapered square waves taper from 0% to 100% amplitude at the beginning of execution, and from 100% to 0% at the end of execution.

- A square waveform is most useful for tuning displacement.
- A square waveform has an infinite velocity command.
- Do not use a square waveform when tuning a control mode that uses an extensometer. The large accelerations can cause the extensometer to move or fall off the specimen, which can cause the system to go unstable.
- Monitor the feedback or error signal to evaluate the system stability.

Ramp and tapered ramp waveform

A ramp waveform (also called a triangle waveform) requires the actuator to move at a constant rate. This requires the servovalve to move quickly between two discrete openings. Cycling a ramp waveform produces a triangle waveform.

Tapered ramp waves taper from 0% to 100% amplitude at the beginning of execution, and from 100% to 0% at the end of execution.

- A ramp waveform is useful for all levels of tuning.
- Use a ramp waveform if a square waveform creates excessive velocities or acceleration for the type of specimen being tested.
- Monitor the feedback or error signal to evaluate the system stability.

Sine and tapered sine waveform

A sine waveform (also called sinusoidal or haversine) requires the servovalve to move at a variety of rates.

Tapered sine waves taper from 0% to 100% amplitude at the beginning of execution, and from 100% to 0% at the end of execution.

Random function generator

When tuning AIC compensator configurations, it is necessary to generate random functions to properly simulate typical test conditions.

Random functions employ a pre-emphasis filter to make the convergence rate constant over all frequencies. The random function options include:

- Random - $1/F^2$
- Random - 1/F
- Random - Flat (none)
- Random - F
- Random - F^2

Frequency

A low-frequency waveform is adequate for most testing. Tests at higher frequencies cause a frequency shift that cannot be completely corrected with the PIDF adjustments.

- Do your initial tuning at a low frequency, and then fine tune at the highest frequency in your test program. Common values are 1–2 Hz.
- Servo adjustments that do not improve performance at high frequencies generally indicate that the servovalve is running at 100% capacity or the HPU is running at 100% capacity.

This characteristic can easily be seen when tuning with a sine waveform. The feedback waveform appears to be more like a ramp waveform when running at 100% capacity.

Amplitude

A system tuned at a low amplitude may become unstable at high amplitudes. Tuning should be accomplished under conditions similar to the anticipated usage.

- Use a moderate amplitude (5% to 10% full scale) for initial tuning.
- Be sure the maximum velocity of the tuning command is 10% to 50% of the maximum velocity of the system.
- Increase the amplitude for fine tuning.
- You may find it helpful to check tuning over a variety of amplitudes by creating a test that cycles once at each of the target amplitudes. If you have the optional MultiPurpose TestWare™ application, run the test to acquire timed data so you can evaluate the results for each amplitude.

About Auto Tuning

The auto-tuning feature tunes any PIDF control mode to a moderate level. It exercises the actuator with a sweep function while monitoring the feedback of the control mode being tuned. Then it calculates the control mode's PIDF tuning parameters.

Note *Standalone FlexTest SE Controllers are not equipped with Advanced or Advanced Only auto-tuning modes.*

Your controller includes three auto-tuning modes: Basic, Advanced, and Advanced Only. The Advanced auto-tuning mode automatically performs Basic auto-tuning before progressing to Advanced auto-tuning. The Advanced Only mode omits Basic auto-tuning and performs only Advanced auto-tuning.

Basic auto-tuning

When you run Basic auto-tuning, the auto-tuner disregards your current PIDF gain settings. It applies the minimum required drive signal to ramp the feedback to 80% of the auto-tuning limits. It then measures the relationship between the feedback velocity and the valve opening signal and then derives the minimum PIDF gains required to track the command.

The majority of tests will run adequately with the settings calculated through basic auto-tuning, however, advanced auto-tuning may be used to optimize the results obtained through basic auto-tuning.

Advanced and Advanced Only auto-tuning

When you run Advanced auto-tuning, the auto-tuner first does basic auto-tuning. It then runs a sine sweep to exercise the actuator to 20% of the auto-tuning limits with frequencies between 0.5 Hz and a user set maximum of 100 Hz.

Note *The advanced auto tuner will reduce the sweep amplitude if it detects a valve opening that is more than 50% of full scale.*

When you run Advanced Only auto-tuning, the auto-tuner skips basic auto-tuning and runs a sine sweep described earlier.

Advanced and Advanced Only controls

Selecting an Auto-Tuning Type of Advanced or Advanced Only displays Tracking and Sweep Freq controls in the Auto-Tuning applications control panel.

Tracking

Tracking specifies how closely the advanced tuner attempts to track the command. Tracking values should be appropriate for the test to be performed. Too high Tracking values may produce tuning values that are unstable for some systems and can cause auto-tuning to fail. The 50% default setting is usually a good starting point. If auto-tuning fails with this default setting, lower the Tracking value.

Sweep Freq

Sweep Freq specifies the upper frequency limit of the sine sweep used by the Advanced auto-tuner. The 20 Hz default setting is usually a good starting point.

For Advanced auto-tuning, you should change the sweep frequency to create a phase shift greater than 90º for 0% tracking (or 135º for 100% tracking) between the command and compensated command.

You can monitor the advanced tuner command and compensated command on the scope.

Other Tuning Considerations

Tuning with a dummy specimen

Specimens can be very expensive. A dummy specimen is an inexpensive material that has similar characteristics to the specimen selected for testing. The most important specimen characteristic is its spring rate.

The advantage of a dummy specimen is that it can simulate how your testing system reacts to real specimen. You can establish a more precise level of tuning with a dummy specimen.

Tuning with a real specimen

If you do not have a dummy specimen or if a dummy specimen is not practical, review the following recommendations if you must use a real specimen:

- Start your PIDF controls at minimum settings.
- Do not use a square waveform for a massive specimen or a specimen prone to vibrations.
- Adjust rate to minimize any oscillation, overshoot, or ringing in the waveform.
- Be very conservative by beginning with a ramp waveform to establish initial control. Then use a waveform that resembles the test waveform to provide a precise level of control.

Tuning without any specimen

A specimen is required to tune force and strain control modes. Initial force tuning may be accomplished with the actuator up against the force sensor. The actuator acts as a specimen reacting against the force sensor. Review the following recommendations if you must tune without a specimen:

- If you are using a load frame, adjust the load unit crosshead so the actuator can reach the force sensor.
- Carefully adjust the actuator using a tuned length control mode so it contacts the force sensor.
- Switch to force control before you proceed with initial tuning.

Compensating for specimen changes

Optimal system operation may require a level of detuning to compensate for specimen changes during a test.

- A highly tuned system provides the greatest level of response, but this places the system near the point of oscillation or instability.
- As a specimen changes characteristics during testing, the response of the system also changes. This can cause unstable operation.
- You may need to retune the system response when the characteristics of the specimen change during a test.
- For the greatest control accuracy, use a compensator.

Changing the range of tuning controls

It is possible that the amount of adjustment for a tuning control is too coarse or inadequate. Click the adjustment button (such as P Gain) and use the Range Select window to change the range of the adjustment. Reducing the range produces smaller steps between values (higher resolution) while increasing the range produces larger steps between values.

Example: Suppose the default range for the Proportional Gain adjustment is 50. Assume you are adjusting the gain and you reach the maximum adjustment (50). Clicking the P Gain slider label displays the P Gain range window where you can change the range of the adjustment. Change the range by typing a new value in the maximum entry field.

Monitoring Waveforms While Tuning

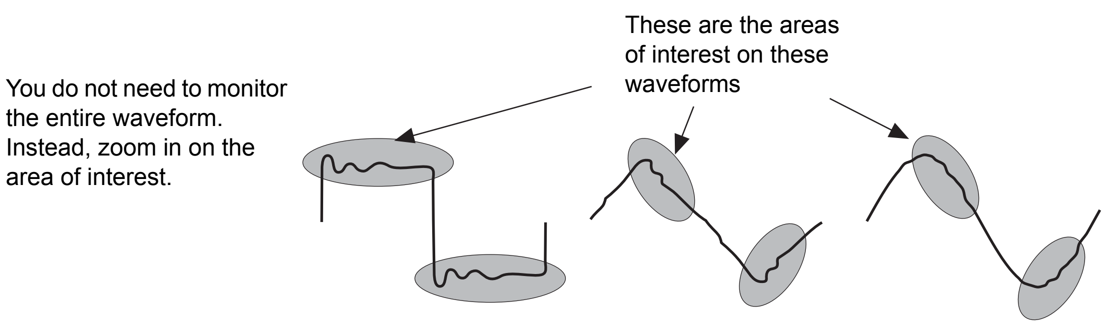
When you tune the servoloop you need to monitor the results of your adjustments. There are two ways to monitor a waveform during tuning.

- An oscilloscope is preferred.
- The controller scope is adequate if you do not have an oscilloscope.

Note *Set up your scope to monitor the area of the waveform that shows characteristics useful for tuning. You can monitor the sensor feedback or the error signal of the control mode.*

What to monitor

The accuracy of the waveform represents how well it reaches the amplitude of the command or how repeatable the end levels are. The peaks and valleys of triangle and sine waveforms should be consistent. Use the area of the square wave after the ringing settles to monitor the end levels.



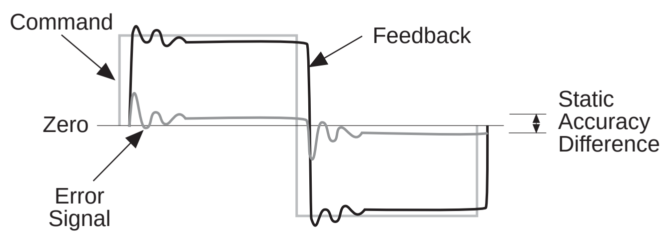
If the amplitude of the feedback cannot be achieved without going unstable, and the end levels are repeatable, simply increase the command to achieve the desired end levels.

Monitoring the error signal

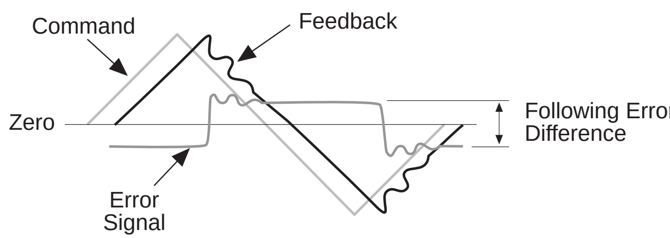
The error signal shows similar characteristics as a feedback signal. The error signal represents the difference between the command and sensor feedback. The following diagrams show the error signal characteristics for each type of waveform.

A square waveform is best suited to view the overshoot and ringing characteristics that occur when tuning a system. Review the following waveforms to determine the kind of characteristics that can be found in an error signal.

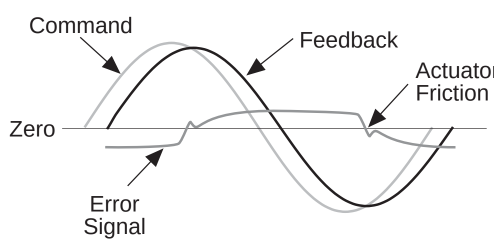
The error signal from a square wave should show the feedback ringing centered on the zero reference. A static accuracy difference in the error signal can be corrected with reset.



The square wave shape of the error signal represents the phase lag of the feedback signal.



The error signal from a sine should be a small amplitude sine waveform that looks like a rounded square waveform.



About Calibration

Calibration is the act of certifying:

- Part of the system
- Against a standard or known value
- To ensure that measured variables precisely represent the actual physical properties involved

All sensors require calibration to ensure that their outputs accurately represent the physical condition they sense (e.g., force or displacement). When you calibrate a sensor you are ensuring the test system properly interprets the sensor signal.

Sensors included with your test system are usually factory-calibrated, and the corresponding sensor calibration files are included with your system software. If you change a sensor or add a new sensor to your system, you must calibrate the new sensor/conditioner pair against a standard to ensure the sensor’s accuracy.

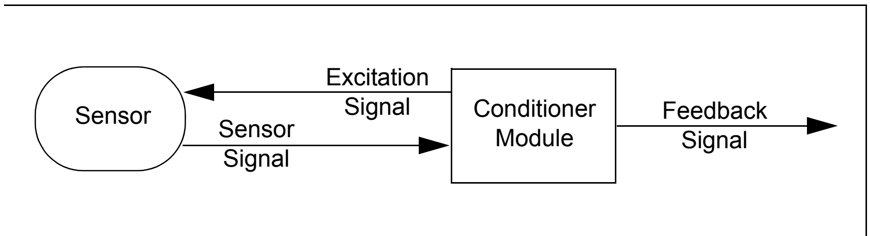
You must calibrate all sensors before they can be used to support control modes or auxiliary data channels.

System Calibration

System calibration is performed by a program that calibrates the analog-to-digital (A/D) converters and the digital-to-analog (D/A) converters of the digital controller. You input a precision 10-volt reference voltage, and monitor the output of each converter with a precision voltmeter. Any difference between the reference voltage and a converter output becomes a calibration factor. The calibration factor for each converter is recorded in a data file.

Sensor Calibration

Sensors convert a measured mechanical value (such as force, displacement, or pressure) into a corresponding electrical signal. Each sensor requires conditioning (such as AC or DC excitation) in order to output a feedback signal that can be used by your servo controller.



Sensor/Conditioner Signal Diagram

Sensor output

Each sensor/conditioner pair must be calibrated to output a voltage that is proportional to the measured output (which may be displacement, force, or some other dimension).

For example, a 10-cm LVDT/AC conditioner pair (connected to a 10-cm actuator) is typically calibrated to output:

- 0 volts at the piston midstroke position (0 cm)
- +10 volts at maximum piston retraction (–5 cm)
- –10 volts at maximum piston extension (+5 cm)

Sensor calibration data base

The calibration procedure creates a calibration data base for each range of a sensor. The data base that is created includes:

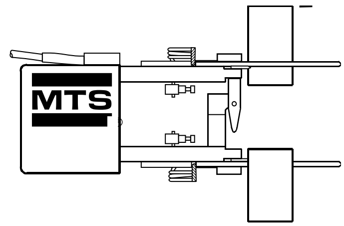
- Calibration data points
- Sensor information (model, type, serial number, calibration date)
- Equipment information (identifies the equipment used in the calibration)
- Conditioner information (serial number, model number, excitation voltage, circuit parameters)

Force Sensor Calibration

Calibrating a force sensor requires a load standard. A load standard can be a special calibrated force sensor with its own electronics or a set of calibrated dead weights.

Extensometer calibration

Extensometers require special test fixtures to aid in calibration.



LVDT calibration

LVDTs are calibrated with a dial indicator or ruler. The indicator is mounted between the actuator rod and a stationary point such as the load unit's platen. A typical LVDT has a positive and a negative output. This is usually considered as tension and compression, but it is actually a motion each way from its centerpoint. One output is calibrated with gain (typically compression) and the other output is calibrated with delta K (typically tension).

Shunt calibration

Shunt calibration is a feature available for dc conditioners. It checks the integrity of the conditioner/sensor combination. When a sensor range is calibrated, a shunt calibration resistor is selected.

The system gives you the capability of verifying calibration accuracy by shunting a precision resistor across one arm of the sensor's Wheatstone bridge. The resulting imbalance provides a reference value for later use.

Chapter 2

Tuning Procedures

This chapter contains step-by-step tuning instructions for MTS Series 793 Controllers. In this manual, MTS Series 793 Controllers include FlexTest IIm/CTC, FlexTest SE, FlexTest GT, and TestStar IIm Controllers.

About tuning procedures for specific controller models

For each task, instructions are provided for stand-alone FlexTest SE Controllers and Automated Controllers.

Standalone FlexTest SE Controllers refer to FlexTest SE Controllers configured to operate in the stand-alone mode (not equipped with a PC).

Automated Controllers refer to controllers equipped with MTS Series 793 Software. This includes FlexTest IIm/CTC, automated FlexTest SE (equipped with a PC in which Exclusive Control is assigned to Station Manager), FlexTest GT, and TestStar IIm Controllers.

Note *Automated FlexTest SE Controllers are equipped with a PC in which Exclusive Control is assigned to Station Manager. For more information about Exclusive Control, see the FlexTest SE Users manual.*

Where to find control descriptions for specific controller models

For a description of the specific tuning controls displayed on the front panel of stand-alone FlexTest SE Controllers, see the *FlexTest SE Users* manual.

For a description of the specific tuning controls displayed in the Series 793 Software included with Automated Controllers, see the *Series 793 Control Software* manual. This pertains to FlexTest IIm, automated FlexTest SE, FlexTest GT, and TestStar IIm Controllers.

Contents

When to Tune

Tuning is needed whenever any of the following events occurs:

- A gross change in the compliance or size of the test specimen. *For example*, you were testing steel and change to rubber.
- The servohydraulic configuration has changed. *For example*, a servovalve is replaced or changed to a different capacity.
- The system is sluggish (slow to react or not reaching the desired peaks). However, this is not always a tuning problem; it could be insufficient velocity capability such as a low-capacity servovalve.
- If a control channel or sensor is recalibrated.
- The system is unstable (indicated by a humming or screeching sound).
- When you observe poorly controlled accuracy.
- When you create a new control mode, or, if the sensor for a control mode is changed.
- The end levels or frequencies are significantly different from those observed earlier in the test. *For example*, you notice that the specimen characteristics change during the test (this could also mean the specimen is failing).

Checklist

Use this checklist when you tune a system. You need to determine the following:

- What type of control mode do you wish to tune?
  Read "Tuning Characteristics of Control Modes" on page 33.
- What controls should you use?
  Read "How the Tuning Controls Work" on page 20.
- What kind of a tuning program should you use?
  Read "Creating a Tuning Program" on page 35.
- Do you have a dummy specimen?
  Read "Other Tuning Considerations" on page 40.
- Where do you connect the oscilloscope and what signal do you monitor?
  Read "Monitoring Waveforms While Tuning" on page 42.

What to do before you tune

The following are tasks that should be completed before you tune. It is not necessary to perform every task each time you tune. The condition of your system dictates which of the following tasks you must perform.

For example, a new system or a system under complete recalibration requires all of the following to be completed. If you are performing periodic or fine-tuning, review the following and determine which tasks you need to complete.

- Connect an oscilloscope to your system or use the controller scope. You need to monitor the sensor signal or error signal for the control mode you intend to tune. See "Monitoring Waveforms While Tuning" on page 42 for help.
- Balance the servovalve. The electrical valve balance adjustment compensates for minor mechanical imbalance—it is an intermediate adjustment. See "How to Balance the Servovalve" on page 60 for help.
- Calibrate each sensor used for a control mode or data acquisition. Perform the appropriate calibration procedure.
- If your sensor calibration schedule does not require calibration at this time, perform a shunt calibration check to determine if your DC sensor/DC conditioner is within tolerance. See "Shunt Calibration" on page 126 for help.
- If you have a three-stage (Series 256 or 257) servovalve, tune the inner loop (gain and rate) before tuning the outer loop. The rules for inner loop tuning are similar to those of the outer loop. See "How to Manually Tune Three-Stage Servovalves" on page 93 for help.

Tuning controls review

The following is a brief review of the most prominent tuning controls:

- Proportional gain (P Gain) increases system response.
- Integral gain (I Gain) increases system accuracy during static or low-frequency operation and maintains the mean level at high frequency operation.
- Derivative gain (D Gain) improves the dynamic stability when high proportional gain is applied.
- Feed forward gain (F Gain) increases system accuracy during high-frequency operation.
- Forward loop filter (FL Filter) adjustments establish a frequency bandwidth for the servoloop command signal.

Getting started

When you set out to tune your system, it is best to run auto-tuning first. Auto-tuning establishes reasonable tuning levels that will be adequate for most control modes. See "How to Auto-Tune" on page 88 for more information.

If the results from auto-tuning are not satisfactory, you should create a tuning function, and then manually tune each control mode

Tuning for the First Time

If you are unfamiliar with the tuning controls, review the following guidelines. Before you start tuning you should:

- Define upper and lower limits for the displacement and force sensor before you start tuning.
- Tune the displacement control mode first since no specimen is needed.
- Note the value of the tuning control before adjusting it so you can return it to that value if necessary.
- Make small initial tuning adjustments. If the waveform does not appear to change, increase the adjustments.

What if you adjust something wrong?

If you make an inappropriate adjustment, the system will go unstable or shut down. An unstable system produces a humming or screeching sound. A system shutdown will display an error message.

If an adjustment causes the system to go unstable, quickly readjust the control until the noise stops. If you cannot eliminate the sound, shut down the system by pressing the **Station Stop** or **Emergency Stop** switch.

Important *In multi-station configurations, pressing Emergency Stop will shut down the HPU and all stations in the interlock chain. If your system is equipped with a Remote Station Controller, pressing Station Stop shuts down the HSM for the specific station only.*

If an adjustment causes the system to shut down, readjust the control to the level where the system was last stable. Then reset the system and continue tuning.

Saving the tuning parameters

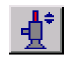
The tuning values are saved as part of the controller parameter set. The parameter set can save one set of tuning values for each control mode.

How To Warm Up Station Hydraulics

It is good practice to warm up station hydraulics before tuning (or testing) by exercising the actuator without a specimen. Remove any specimen and run the system in displacement control for at least 30 minutes using a 80% full-scale length command at about 0.1 Hz.

1. Select the following settings in the function generator.

   Standalone FlexTest SE Controllers: Select **Tuning** > **Manual** > **FG**

   Automated Controllers: Click  on **Station Manager**:

CONTROL	SETTING
Control Channel (Automated Controllers only)	The control channel associated with the valve you are adjusting.
Control Mode	Displacement
Adaptive Compensator	None
Target Setpoint	0
Amplitude	80% of the full-scale actuator displacement
Frequency	0.1 Hz
Wave Shape	Sine

WARNING

A crush zone exists between the actuator and any equipment in the path of its movement. Immediate and unexpected actuator response is possible when you apply hydraulic pressure to your system.

Unexpected actuator movement can cause injury to personnel, damage to equipment, or both.

Stay clear of the actuators when applying hydraulic pressure.

2. If necessary, turn on hydraulic pressure.

Note *The HPU can be configured for “first on”. If this is the case, start the appropriate HSM.*

A. In the power selection box, click (Low) and then (High) for the HPU. If an HPU is not listed, start the HPU at the pump.

B. If an HSM is present, click (Low) and then (High) for the appropriate HSM.

3. Check system interlocks

If the **Hydraulic Interlock** or **Program Interlock** indicator is lit, determine the cause, correct it, and then click **Reset**.

If either interlock indicator lights again, you will need to determine the cause of the interlock and correct it before proceeding.

4. Press **Run** to start the function generator.

5. Open the **Tuning** submenu or panel.

Standalone FlexTest SE Controllers:

Select **Tuning** > **Manual**.

Automated Controllers:

A. Click to display the **Tuning** panel.

B. In the **Tuning** panel, click the **Adjustments** tab.

6. If necessary, select an access level of **Tuning**.

Standalone FlexTest SE Controllers: Config > **Access Level** > **Tuning**.

Automated Controllers: In the **Station Manager** window’s toolbar, select an access level of **Tuning**.

7. Observe actuator response. If necessary, correct **P Gain** during warm up.

   If the actuator responds in a sluggish manner, increase the **P Gain** setting. If you hear an unusual or unexpected sound, decrease the **P Gain**.

   Standalone FlexTest SE Controllers:

   Select **Tuning** > **Manual** > **P Gain**.

   Automated Controllers:

   A. On the Station Manager window's **Display** menu, select **Station Setup**.

   B. Click the **Channel Tuning** icon to open the **Tuning** panel, the click the **Adjustments** tab to display the **P Gain** control.

8. After 30 minutes, click **Stop**.

9. Remove hydraulic pressure from the station.

How to Set Servovalve Polarity

Servovalve polarity refers to the direction the servovalve moves the actuator in response to a positive command. It can be set to normal or invert.

Typically, a servovalve with a normal polarity extends the actuator in response to a positive command. Conversely, a servovalve with an inverted polarity retracts the actuator in response to a positive actuator command.

Before you can set servovalve polarity, you must determine if the current servovalve polarity follows the normal convention.

The procedures that follow determines servovalve polarity by having you observe actuator movement while applying a positive Setpoint command to the actuator. Procedures for both Standalone and Automated Controllers are described.

Please note the following:

- The polarity of the servovalve must be checked before sensor calibration begins and before hydraulic pressure is applied for the first time.
- The polarity of any servovalve is generally set when the valve is installed.

Important *The combination of the conditioner polarity and the servovalve polarity affects the final output signal. The conditioner polarities should be set before the servovalve polarity because they do not need hydraulics to be turned on. In general, you will set the conditioner and servovalve polarity the same.*

1. Get things ready.

   Standalone FlexTest SE Controllers:

   A. Ensure the actuator can be fully extended without contacting anything. You may need to remove any obstructions.

   B. Press the **Status** button twice to display the **Status** menu, and for **Control Mode**, select *displacement*.

   C. For **Access Level**, select **Tuning**.

   Automated Controllers:

   A. Ensure that the actuator can be fully extended without contacting anything. You may need to remove any obstructions.

B. You need displacement control mode. If you have not created this type of a control mode, create it now.

C. On the **Station Manager** Toolbar, select **Tuning** in the access level box.

2. If necessary, enter an initial tuning value for **P Gain** (first time only).

The actuator cannot move unless an adequate P Gain value is applied. If you already have an adequate P Gain setting for the displacement control mode, skip this step.

Note *For three-stage servovalves, the initial maximum P Gain setting is 0.8, so enter an initial value 0.5.*

Standalone FlexTest SE Controllers:

A. Select **Tuning** > **Manual** > **P Gain**.

B. In **P Gain**, enter **1**.

Automated Controllers:

A. On the Station Manager **Display** menu, select **Station Setup**,

B. Ensure that the correct displacement control channel is selected in the navigation panel.

C. Click the Channel Tuning icon to open the **Tuning** panel.

D. In the **P Gain** box, enter **1**.

3. Set the polarity of the servovalve.

Standalone FlexTest SE Controllers:

Select **Setup** > **Output** > **Polarity: Normal**

Automated Controllers:

A. Ensure that the correct displacement control channel is selected in the navigation panel.

B. Click the **Channel Drive** icon to open the **Channel Drive** panel, and then click the **Valve** tab.

C. Select **Normal** (default).

4. If necessary, clear hydraulic interlocks.

   If the **Hydraulic Interlock** indicator is lit, determine the cause, correct it, and then press reset. If an interlock indicator lights again, you will need to determine the cause and correct it before proceeding.

5. Apply hydraulic pressure to the station.

6. Move the actuator.

Note *The following conditions assume you want a positive command to retract the actuator.*

Standalone FlexTest SE Controllers:

A. Enable the front panel Dial.

B. Press the **Status** button twice to display the **Status** menu, and select **Setpoint**. While observing the actuator, use the Dial to slowly apply a positive **Setpoint** command to the actuator.

Automated Controllers:

A. Click the **Manual Command** button to open the **Manual Command** window.

B. In the **Channel** selection box, select the desired control channel.

C. In the **Control Mode** selection box, ensure that displacement control mode is selected.

D. Click on the **Enable Manual Command** check box to enable manual command.

E. On the **Station Controls** panel, ensure that the **Master Span** is set for 100%.

F. On the **Manual Command** window, increase the **Manual Cmd** adjustment to apply a positive command to the actuator.

7. Interpret the actuator movement.

    - If the actuator extends when a positive command is applied, the servovalve polarity is correct.
    - If the actuator retracts when a positive command is applied (and the polarity setting is **Normal**), some electrical element that affects the servovalve (such as conditioner polarity or cable orientation) has been reversed and should be remedied.
    - If the actuator begins in full retraction and applying a positive command does not extend it, zero the command, remove hydraulic pressure, and change the servovalve polarity. Then retry this test. If it still does not move, return to Step 2 and increase the gain setting.
    - If the actuator begins in full extension and applying a negative command does not retract it, zero the command, remove hydraulic pressure, and change the servovalve polarity. Then retry this test. If it still does not move, return to Step 2 and increase the gain setting.
    - If the actuator does not move at all, return to Step 2 and increase the gain setting.

8. Set servovalve polarity to achieve desired actuator movement.

How to Balance the Servovalve

Balancing the servovalve involves a mechanical procedure performed on the servovalve itself to achieve gross mechanical balance, and an electrical adjustment performed with the controller's **Valve Balance** control to fine-tune the mechanical adjustment.

The mechanical procedure must be done before the electrical adjustment, and is typically performed at system installation, when a new servovalve is installed in an existing system, and when performance warrants it. The mechanical procedure is detailed in the servovalve product manual (typically included in the system documentation set).

The electrical adjustment is typically performed much more frequently than the mechanical adjustment. The electrical adjustment is performed with the **Valve Balance** control, which adjusts the electrical input to the servovalve to compensate for minor mechanical imbalances. When the valve balance adjustment is complete, there will be no (or minimal) hydraulic fluid flow when the servovalve's output signal is at null. The electrical valve balance procedure is detailed in the following pages for both Standalone and automated Controllers.

If the servovalve cannot be balanced with the **Valve Balance** control, it may be an indication of a major imbalance that requires a mechanical adjustment before further electrical adjustments are made.

Valve clamping and servovalve balance

Some systems use valve clamping as a means to control actuator behavior when an interlock occurs. However, to clamp properly the servovalve must be balanced before the interlock occurs.

WARNING

Unexpected actuator movement is possible when the servovalve is clamped.

Unexpected actuator movement can cause injury and equipment damage.

Your controller's hardware interface file (.hwi) includes options to clamp the servovalve when a hydraulic interlock occurs (these options cause the actuator to stop, fully extend, or fully retract). However, if the servovalve is imbalanced, it may move unexpectedly when clamped. Ensure the servovalve is balanced before using your test system.

1. Get things ready.

   A. Select the **Calibration** access level.

   B. Remove any specimen.

   C. Apply hydraulic pressure.

WARNING

Enabling the front panel Dial (Standalone FlexTest SE Controllers) or Enable Manual Command (automated controllers) allows you to manually position actuators.

A moving actuator can injure anyone in its path.

Always clear the actuator area before manually adjusting actuator position.

---

2. Position the actuator at or near its midstroke position.

   Standalone FlexTest SE Controllers:

   A. Select **Status** > **Control Mode** > *displacement*

   B. Select **Status** > **Setpoint**

   C. Enable the Dial.

   D. Use the Dial to adjust the **Setpoint** to position the actuator.

   Automated Controllers:

   A. In the **Station Controls** panel's toolbar, click . In the **Manual Command** window:

   B. Select the **Channel** whose valve balance needs checking.

   C. For the **Control Mode**, select a displacement control mode.

   D. Select **Enable Manual Command**.

   E. Use the **Manual Cmd** to position the actuator at or near its midstroke position.

3. Record and zero displacement **I Gain**.

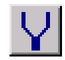
   Standalone FlexTest SE Controllers:

A. Select **Tuning** > **Manual** > **I Gain**

B. Write down the current displacement **I Gain**.

C. Zero the **I Gain**.

Automated Controllers:

A. In the **Station Setup** window, click .

B. In the **Tuning** panel, click the **Adjustments** tab. In this tab:

C. Write down the current **I Gain**.

D. Zero the **I Gain**.

4. Setup a meter to view displacement error.

Standalone FlexTest SE Controllers:

A. Select **Meters**.

B. Select an existing meter, such as **Meter 1**, or select **<<Add Meters>>** to create a new meter, and select it.

C. For **Meter Type**, select **Timed**.

D. For **Signal**, select **Ch Error**.

Automated Controllers:

A. Select the meters icon on the Station Manager tool bar.

B. Select the **Meter 1 - Setup** button.

C. For **Meter Type**, select **Timed**.

D. In **Signal Selection**, select the channel whose valve balance needs checking. For **Signal**, select **Displacement Abs. Error**.

5. Zero displacement error with the **Valve Balance** control.

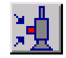
Standalone FlexTest SE Controllers:

A. Select **Setup** > **Output** > **Valve Balance**

B. Enable the Dial.

C. While observing **Ch Error** on the Meters panel, adjust the **Valve Balance** control by rotating the Dial until **Ch Error** is zero.

Automated Controllers:

A. In the **Station Setup** window, click .

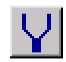
Three-stage valves: In the **Drive** panel, click the **Valve** tab.

B. While observing **Displacement Abs. Error** on the Meters panel, adjust the **Valve Balance** control until **Displacement Abs. Error** is zero.

6. Return displacement **I Gain** to its original setting.

Standalone FlexTest SE Controllers: Select **Tuning** > **Manual** > **I Gain**

Automated Controllers: I

A. In the **Station Setup** window, click .

B. In the **Tuning** panel, click the **Adjustments** tab.

How to Balance Dual Valves

Use the following procedure if you need to balance dual servovalves.

1. Get things ready.

A. If necessary, select the tuning access level.

B. Remove any specimen.

C. Determine which servovalve of the dual valve pair you want to balance first, then mount a blocking plate on the port of the other servovalve.

Note *When installing the blocking plate ensure that its holes are aligned with the servovalve port holes and a gasket is used.*

D. Apply hydraulic pressure.

WARNING

Selecting the Enable Manual Command allows you to manually position actuators.

A moving actuator can injure anyone in its path.

Always clear the actuator area before selecting Enable Manual Command.

2. Position the actuator at midstroke.

   Standalone FlexTest SE Controllers:

   A. Enable the front panel Dial.

   B. Press the **Status** button twice to display the **Status** menu, and select **Setpoint**. While observing the actuator, use the Dial to position the actuator at or near its midstroke position.

   Automated Controllers:

   A. In the **Station Controls** panel's toolbar, click  .

   B. In the **Manual Command** window, select the **Channel** with the dual valves that need balancing.

   C. For the **Control Mode**, select a displacement control mode.

   D. Select **Enable Manual Command**.

   E. Use the **Manual Cmd** to position the actuator at or near its midstroke position.

3. Record and zero displacement **I Gain**.

   Standalone FlexTest SE Controllers:

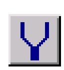
   A. Select **Tuning** > **Manual** > **I Gain**

   B. Write down the current displacement **I Gain**.

   C. Zero the **I Gain**.

   Automated Controllers:

   A. In the **Station Manager** window's **Display** menu, select **Station Setup**.

   B. In the **Station Setup** window navigation pane's **Channels**, select the channel with the dual valves that need balancing.In the **Station Setup** window, click  .

   C. In the **Tuning** panel, click the **Adjustments** tab. In this tab:

   D. Write down the current **I Gain**.

   E. Zero the **I Gain**.

4. Setup a meter to view displacement error.

   Standalone FlexTest SE Controllers:

   A. Select **Meters**.

   B. Select an existing meter, such as **Meter 1**, or select **<<Add Meters>>** to create a new meter, and select it.

   C. For **Meter Type**, select **Timed**.

   D. For **Signal**, select **Ch Error**.

   Automated Controllers:

   A. Select the meters icon on the Station Manager tool bar.

   B. Select the **Meter 1 - Setup** button.

   C. For **Meter Type**, select **Timed**.

   D. In **Signal Selection**, select the channel whose valve balance needs checking. For **Signal**, select **Displacement Abs. Error**.

5. Zero displacement error with the **Valve Balance** control.

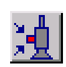
   Standalone FlexTest SE Controllers:

   A. Select **Setup** > **Output** > **Valve Balance**

   B. Enable the Dial.

   C. While observing **Ch Error** on the Meters panel, adjust the **Valve Balance** control by rotating the Dial until **Ch Error** is zero.

   Automated Controllers:

   A. In the **Station Setup** window, click .

   B. While observing **Displacement Abs. Error** on the Meters panel, adjust the valve balance control for the non-blocked servovalve (**Valve Balance 1** or **Valve Balance 2**) until **Displacement Abs. Error** is zero.

6. Balance the other servovalve of the dual valve pair.

   A. Remove the blocking plate from the port of the other servovalve.

   B. Reinstall the servovalve.

   C. While observing **Displacement Abs. Error** on the Meters panel, adjust the valve balance control for the other servovalve (**Valve Balance 1** or **Valve Balance 2**) until **Displacement Abs. Error** is zero.

7. Return displacement **I Gain** to its original setting.

   Standalone FlexTest SE Controllers:

   Select **Tuning** > **Manual** > **I Gain**

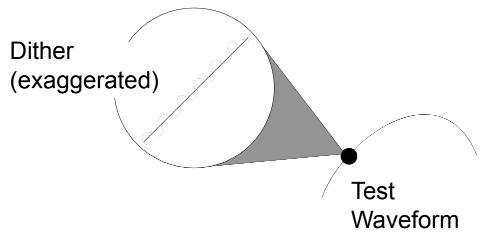
   Automated Controllers:

   A. In the **Station Setup** window, click .

   B. In the **Tuning** panel, click the **Adjustments** tab.

How to Adjust Dither

Dither is a small, high frequency sine wave applied to a servovalve's spool to improve the valve's response to low amplitude signals by reducing sticking.



The following are signs of an improper dither adjustment:

- Dither amplitude is too low—While running a sinusoidal test on a properly tuned system, you notice that the waveform distorts at its maximum and minimum points. This will normally be more apparent during a test that has either a low frequency or a low amplitude test waveform.
- Dither amplitude is too high—You hear unusual sounds, such as hammering, squealing, or pounding coming from the test system.

There are two methods for checking and adjusting dither. Method 1 uses the controller's scope. Method 2 uses your hearing.

Method 1:

1. Select an access level of **Tuning**.
2. Remove any specimen.

3. Create a program with the function generator as follows:

CONTROL	SETTING
Channel (automated)	Select the channel whose dither needs checking.
Type	Cyclic
Wave Shape	Ramp
Control Mode	*displacement*
Target Setpoint	0 mm
Amplitude	5 mm
Frequency	0.001 Hz
Compensator	None

4. Select the scope and set up scope parameters to display the channel's command and feedback signals.

WARNING

Applying station hydraulic pressure can put actuators in motion.

A moving actuator can injure anyone in its path.

Always clear the actuator area before applying hydraulic pressure.

5. Apply station hydraulic pressure.
6. Press **Run** to start the displacement command.
7. Use the scope to observe the feedback signal.

   If the feedback signal shows a smooth ramp, you do not need to adjust the dither amplitude.

   If the feedback signal shows a jagged ramp—caused by the actuator sticking before moving—continue on to the next step to adjust the dither amplitude.

Note *If you hear an unusual sound coming from the servovalve, the dither amplitude is set too high.*

8. Increase **Dither Amplitude** until the feedback is smooth.

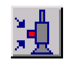
   Standalone FlexTest SE Controllers:

   Select **Setup** > **Output** > **Dither Amplitude**

   Automated Controllers:

   A. In the **Station Manager** window's **Display** menu, select **Station Setup**.

   B. In the **Station Setup** window navigation pane's **Channels**, locate and select the channel whose servovalve dither you want to adjust.

   C. In the **Station Setup** window, click .

   Three-stage valves: In the **Drive** panel, click the **Valve** tab.

Method 2:

1. Select an access level of **Tuning**.
2. Remove any specimen.
3. Apply hydraulic pressure to the station.
4. Increase **Dither Amplitude** until you can hear the dither and then decrease **Dither Amplitude** until the noise goes away.

Dither Frequency adjustment

In addition to **Dither Amplitude**, your Controller is equipped with a **Dither Frequency** control.

The default dither frequency is 528 Hz, which is effective for most applications, and should not require adjustment. However, if the dither frequency begins to resonate with test frequencies, adjustment may be necessary.

How to Manually Tune the Control Loop

Tasks related to manual tuning

The following are tasks that should be completed before you tune. It is not necessary to perform every task each time you tune. The condition of your system dictates which of the following tasks you must perform.

For example, a new system or a system freshly recalibrated requires all of the following to be completed. If you are performing periodic or fine-tuning, review the following and determine which tasks you need to complete.

- Balance the servovalve. The electrical valve balance adjustment compensates for minor mechanical imbalance—it is an intermediate adjustment. See "How to Balance the Servovalve" on page 60.
- Calibrate each sensor used for a control mode or data acquisition. Perform the appropriate calibration procedure.
- If your sensor calibration schedule does not require calibration at this time, perform a shunt calibration check to determine if your DC sensor/DC conditioner is within tolerance. See "Shunt Calibration" on page 126.
- If you have a three-stage (Series 256 or 257) servovalve, tune the inner loop (gain and rate) before tuning the outer loop. The rules for inner loop tuning are similar to those of the outer loop. See "How to Manually Tune Three-Stage Servovalves" on page 93.
- If your Controller is equipped with the optional auto-tuning feature, it is best to run auto-tuning first. Auto-tuning establishes reasonable tuning levels that will be adequate for most control modes. If the results from auto-tuning are not satisfactory, you should manually tune each control mode. See "How to Perform Advanced Tuning Techniques" on page 88.

Tuning the Displacement Control Mode

A displacement control mode uses the feedback signal from an LVDT (linear variable differential transformer). You do not need a specimen to tune a displacement control mode.

When to tune

A displacement control mode typically needs to be tuned only when recalibrated. However, you may want to retune the displacement control mode if:

- The fixtures attached to the actuator have changed (such as grips). The main tuning factor is a change in the mass attached to the actuator.
- Any time hydraulic system potential has changed, such as after servovalve, hose, or pump replacement.
- You want to fine tune the control mode.
- The sensor range has changed.
- You feel system response should be improved or reduced.

Prerequisites

Be sure the following conditions are present before you begin tuning the displacement control mode:

- Hydraulic pressure is off
- The specimen is not installed

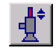
Procedure

This basic displacement tuning procedure should work for most applications—consider it a guideline. You should be familiar with the background information presented in this chapter so you can modify the following procedure for your specific system.

1. Select the **Tuning** access level.

2. Select the following settings in the function generator.

   Standalone FlexTest SE Controllers: Tuning > **Manual** > **FG**

   Automated Controllers: Click  on **Station Manager**.

CONTROL	SETTING
Wave Shape	Square
Frequency	1 Hz
Target Setpoint	0 mm
Amplitude	10% of full scale

3. Set up the Scope.

Note *You can use an oscilloscope instead of the software scope if you want. To do that you must define a Readout channel to connect the oscilloscope.*

Standalone FlexTest SE Controllers:

Select **Scope** and set up scope parameters to display the displacement feedback signal.

Note *If your FlexTest SE Controller is not equipped with the optional Scope, use an external oscilloscope.*

Automated Controllers:

A. On the **Display** menu select **Scope**.

B. Select the displacement signal for display.

C. Set the **Trace Time** to 5 seconds.

D. Ensure **Auto-Scale** is on (the default position is ON).

Note *To improve your view of the waveform, click the **Rescale** button to maximize the waveform on the display.*

WARNING

Do not place any part of your body in the path of a moving actuator.

A crush zone exists between the actuator and any equipment in the path of its movement. Immediate and unexpected actuator response is possible when you apply hydraulic pressure to your system.

Stay clear of the actuators when applying hydraulic pressure.

4. If necessary, turn on hydraulic pressure (see page 54).
5. Ensure that the displacement control mode is selected.

   Standalone FlexTest SE Controllers: Press the Back button (or select **Tuning > Manual** > **Control Mode**).

   Automated Controllers: On the **Manual Command** window, ensure that displacement is selected for **Control Mode**.
6. Check system interlocks

   Standalone FlexTest SE Controllers:

   If the **Hydraulic Interlock** or **Program Interlock** indicator is lit, determine the cause, correct it, and then click **Reset**.

   If either interlock indicator lights again, you will need to determine the cause of the interlock and correct it before proceeding.

   Automated Controllers:

   If the **Interlock** indicator is lit, click **Reset**. If the indicator lights again, you must determine the cause and correct it before proceeding.
7. Open the **Tuning** submenu or panel.

   Standalone FlexTest SE Controllers:

   Select **Tuning** > **Manual**

   Automated Controllers:

   A. Click  to display the **Tuning** panel.

   B. In the **Tuning** panel, click the **Adjustments** tab.

C. Select the **Show References** check box.

Notice the **Reference** column on the right side of the window. This column shows the current set of tuning parameters. Use the buttons to update reference settings with new values or replace the current values with the last set that worked properly.

Note *The **Reference** settings are saved with the parameter set.*

8. Adjust the **P Gain** and **D Gain** tuning controls.

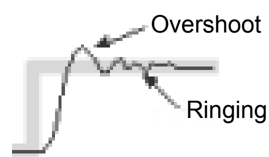
A. Start the tuning function generator.

B. Select **Continuous Sweep** on the internal or external scope.

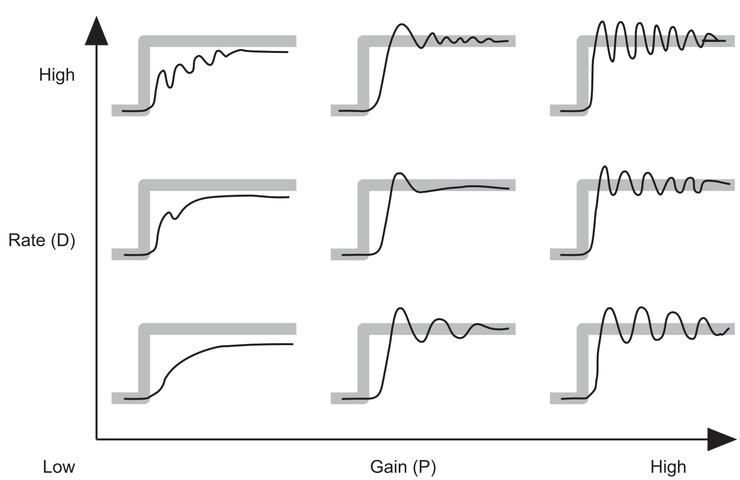
C. Increase the **P Gain** adjustment until you see a little overshoot and a little ringing.

D. Increase the **D Gain** adjustment to reduce the overshoot and ringing.

E. Repeat C and D until you achieve a optimum waveform.



The middle waveform is a optimum waveform. In some cases the optimum waveform will have no overshoot or ringing, and the waveform will look more like a square waveform with rounded corners.



Unstable sounds

For actual testing, if your system goes unstable it will sound unstable—that is, it will emit an annoying high-pitched sound that is quite different from the usual tuning sound (“ka-chunk, ka-chunk”). If your system begins to go unstable, quickly readjust the control that caused the instability to return the control to its previous setting.

Rule-of-thumb

Adjust the **P Gain** and **D Gain** controls as high as possible without going unstable.

9. Adjust the **I Gain** tuning control.

   Set up a peak/valley meter to monitor the peaks and valleys of the sensor signal. The peaks and valleys should be balanced. Before adjusting reset (**I Gain**), be sure the feedback signal is repeatable (that is, the same peaks and valleys are achieved).

   For example, assume the test command is centered on zero and the meter displays +3 mm and -5 mm. You want to adjust the reset (**I Gain**) control to achieve ±4 mm.

   If the command is not centered on zero, monitor the difference between peaks and valleys of the sensor feedback to the upper and lower levels of the test command. Any difference should be the same.

Note *You can also use the Scope (optional for FlexTest SE) or an external oscilloscope to adjust I Gain by monitoring the Error signal. For more information, see* *“How to Use Error to Tune I Gain” on page 102.*

10. Save your tuning settings.

    Standalone FlexTest SE Controllers: Setup > **Open/Save Parameters** > **<<Save>>**

    Automated Controllers: On the Station Manger **File** menu, select **Save Parameters As**.

    You can either select an existing parameter set or enter the name of a new parameter set to save.

About saving elements of a parameter set

It is important that you save your parameter set as you complete the various parts that make up a parameter set. Throughout this manual you will be performing discrete procedures while building a single parameter set.

- If you have already established your default parameter set for the current station and you are creating a new parameter set for a specific test, save the parameters with a different name.
- Different tests and/or specimens may require different parameter sets.

Tuning the Force Control Mode

To complete this task, you will make sure the force tuning values established in your station parameter set are appropriate for the test you are about to run. To do this, you will:

- Create and apply a simple tuning program.
- Evaluate the current force tuning values by comparing command and feedback signals.

Once established, displacement tuning values are unlikely to require adjustment; in contrast, optimal force tuning values are a function of your specimen's compliance and often change over time, or even from test-to-test. You should also tune force whenever you make any change to the force train (such as changing fixtures).

Prerequisites

Be sure the following conditions are present before you begin tuning the force control mode:

Standalone Controller and Automated Controllers:

- Hydraulic pressure is off.
- The specimen is not installed

Automated Controllers only:

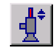
- You have created a station configuration file.
- You have created a station parameter set.

Procedure

The following is a step-by-step tuning procedure for a force control mode. It is a basic procedure that should work for most applications. However, you should consider it a guideline. The background information presented in this chapter should help you modify the following procedure for your specific system.

1. Select the following settings in the tuning function generator.

   Standalone FlexTest SE Controllers: Tuning > **Manual** > **FG**

   Automated Controllers: Click  on **Station Manager**

CONTROL	SETTING
Wave Shape	Ramp
Frequency	1 Hz
Target Setpoint	0 N
Amplitude	10% of full scale

2. Set up the Scope.

Note *You can use an oscilloscope instead of the software scope if you want. To do that you must define a Readout channel to connect the oscilloscope.*

Standalone FlexTest SE Controllers:

Select **Scope** and set up scope parameters to display the force feedback signal.

Note *If your FlexTest SE Controller is not equipped with the optional Scope, use an external oscilloscope.*

Automated Controllers:

A. On the **Display** menu select **Scope**.

B. Select the **Force Abs. Error** signal for display.

C. Set the **Trace Time** to 2 seconds.

D. Ensure **Auto-Scale** is on (the default position is ON).

Note *To improve your view of the waveform, click the **Rescale** button to maximize the waveform on the display.*

⚠ WARNING

Do not place any part of your body in the path of a moving actuator.

A crush zone exists between the actuator and any equipment in the path of its movement. Immediate and unexpected actuator response is possible when you apply hydraulic pressure to your system.

Stay clear of the actuators when applying hydraulic pressure.

3. Turn on hydraulic pressure (see page 54).
4. Ensure that the displacement control mode is selected.

   Standalone FlexTest SE Controllers: Press the Back button (or select **Tuning > Manual** > **Control Mode**).

   Automated Controllers: On the **Manual Command** window, ensure that displacement is selected for **Control Mode**.
5. Install a dummy specimen.

   Standalone FlexTest SE Controllers:

   A. Enable the Dial.

   B. Adjust the Dial to position the actuator during specimen installation.

   Automated Controllers:

   A. On the **Manual Command** window. Click **Enable Manual Command**.

   B. Adjust the **Manual Command** window slider to position the actuator during specimen installation.
6. Switch to the force control mode.

Note *For Automated Controllers, ensure the **Master Span** control on the **Station Controls** panel is set to100%.*

7. Check system interlocks.

   Standalone FlexTest SE Controllers:

   If the **Hydraulic Interlock** or **Program Interlock** indicator is lit, determine the cause, correct it, and then click **Reset**.

   If either interlock indicator lights again, you will need to determine the cause of the interlock and correct it before proceeding.

   Automated Controllers:

   If the **Interlock** indicator is lit, click **Reset**. If the indicator lights again, you must determine the cause and correct it before proceeding.

8. Open the Tuning submenu or panel.

   Standalone FlexTest SE Controllers: Tuning > Manual

   Automated Controllers:

   A. Click  to display the **Tuning** panel.

   B. In the **Tuning** panel, click the **Adjustments** tab.

   C. Select the **Show References** check box.

   Notice the **Reference** column on the right side of the window. This column shows the current set of tuning parameters. Use the buttons to update reference settings with new values or replace the current values with the last set that worked properly.

Note *The **Reference** settings are saved with the parameter set.*

9. Adjust the **P Gain** and **D Gain** tuning controls.

   Standalone and Automated Controllers:

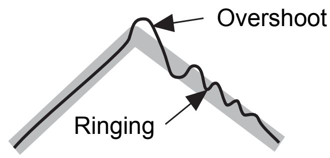
   A. Start the function generator.

   B. On the **Scope** menu, select **Continuous** for **Sweep Mode**.

   C. On the **Manual** Tuning submenu, increase the **P Gain** adjustment until you see a little overshoot and a little ringing.

   D. Slowly increase the **D Gain** adjustment to reduce the overshoot and ringing. Small adjustments of D can have large effects on the system.

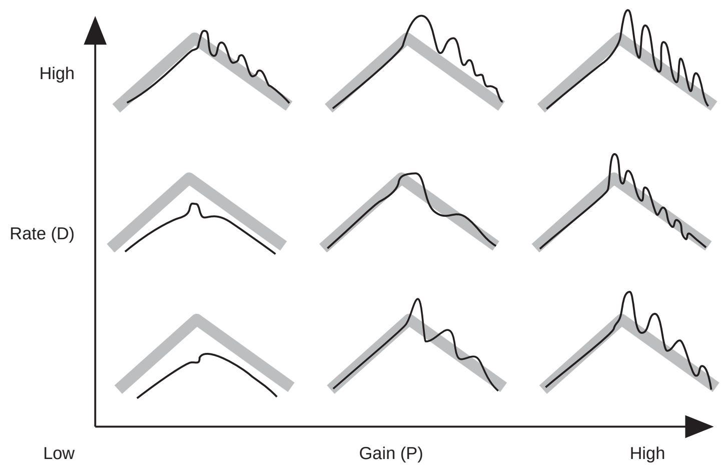
E. Repeat C and D until you achieve a optimum waveform.



Unstable sounds

For actual testing, if your system goes unstable it will sound unstable—that is, it will emit an annoying high-pitched sound (accompanied by high-frequency actuator movement) that is quite different from the usual tuning sound ("ka-chunk, ka-chunk"). If your system begins to go unstable, quickly readjust the control that caused the instability.

The middle waveform is the optimum waveform. In some cases the waveform will have no overshoot or ringing.



10. Adjust the **I Gain** tuning control.

Standalone and Automated Controllers:

Set up a peak/valley meter to monitor the peaks and valleys of the sensor signal. The peaks and valleys should be balanced. Before adjusting reset (**I Gain**), be sure the feedback signal is repeatable (that is, the same peaks and valleys are achieved).

If the command is not centered on zero, monitor the difference between peaks and valleys of the sensor feedback to the upper and lower levels of the test command. Any difference should be the same.

Note *You can also use the optional Scope or an external oscilloscope to adjust I Gain by monitoring the Error signal. For more information, see* *"How to Use Error to Tune I Gain" on page 102.*

11. Save your tuning settings.

    Standalone FlexTest SE Controllers: Setup > **Open/Save Parameters** > **<<Save>>**

    Automated Controllers: On the Station Manager **File** menu, select **Save Parameters As**.

    You can either select an existing parameter set or enter the name of a new parameter set to save.

About saving elements of a parameter set

It is important that you save your parameter set as you complete the various parts that make up a parameter set. Throughout this manual you will be performing discrete procedures while building a single parameter set.

- If you have already established your default parameter set for the current station and you are creating a new parameter set for a specific test, save the parameters with a different name.
- Different tests and/or specimens may require different parameter sets.

Tuning the Strain Control Mode

A strain control mode typically uses the feedback signal from an extensometer. You need a specimen installed to tune a strain control mode.

Guidelines

- Use a triangle waveform for the initial tuning.
- Do not use a square waveform for tuning. A square wave can cause the extensometer to move or fall off the specimen, which can cause the system to go unstable.
- If gain is too low, the system may be sluggish or unresponsive with large static offsets; or it may be uncontrollable.
- If you observe a noisy extensometer feedback signal, use the **FL Filter** setting to help suppress any unwanted mechanical resonance.

When to tune

A strain control mode usually only needs to be tuned once. However, you may want to retune a strain control mode if:

- The type of specimen has changed.
- Any changes are made in the force train.
- Any time hydraulic system potential has changed, such as after servovalve, hose, or pump replacement.
- You want to fine tune the control mode.
- You deem it necessary as a result of scheduled system calibration or you feel system response should be improved or reduced.

Prerequisites

Be sure the following items are completed before you begin tuning the strain control mode:

- The specimen is installed (you may choose to use a broken specimen).
- You have created a station configuration file.
- You have created a station parameter set.

Tuning procedure

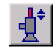
This basic strain tuning procedure should work for most applications—consider it a guideline. You should be familiar with the background information presented in this chapter so you can modify the following procedure for your specific system.

1. Select an access level of **Tuning**.

2. Define the strain command.

   This step defines the tuning command using the **function generator**.

   Standalone FlexTest SE Controllers: Tuning > **Manual** > **FG**

   Automated Controllers: Click  on **Station Manager**.

CONTROL	SETTING
Wave Shape	Ramp
Frequency	1 Hz
Target Setpoint	0 mm
Amplitude	Set an initial amplitude of zero. After verifying system control, increase the amplitude to a reasonable level (typical: 0.001 mm/mm).

3. Set up the Scope.

Note *You can use an oscilloscope instead of the software scope if you want. To do that you must define a Readout channel to connect the oscilloscope.*

Standalone FlexTest SE Controllers:

Select **Scope** and set up scope parameters to display the strain feedback and strain command signals. Set **Trace Time** to 2 seconds and ensure that **Auto-Scale** is on.

Automated Controllers:

A. On the **Display** menu select **Scope**.

B. Select the strain command signal for Channel A.

C. Select the strain feedback signal for Channel B

D. Set the **Trace Time** to 2 seconds.

E. Ensure **Auto-Scale** is on (the default position is ON).

Note *To improve your view of the waveform, click the **Rescale** button to maximize the waveform on the display.*

WARNING

Do not place any part of your body in the path of a moving actuator.

A crush zone exists between the actuator and any equipment in the path of its movement. Immediate and unexpected actuator response is possible when you apply hydraulic pressure to your system.

Stay clear of the actuators when applying hydraulic pressure.

4. Turn on hydraulic pressure (see page 54).
5. Select the force control mode.

   Standalone FlexTest SE Controllers: Select **Tuning > Manual** > **Control Mode** > **Force**.

   Automated Controllers:

   A. In the **Station Controls** panel toolbar, click  to display the **Manual Command** window.

   B. In the **Manual Command** window, select the appropriate **Channel** associated with the strain sensor signal you are tuning.

   C. For the **Control Mode**, select **Force**.
6. Install a dummy or broken specimen.

   Standalone FlexTest SE Controllers:

   A. Enable the Dial.

   B. Adjust the Dial to position the actuator during specimen installation.

   Automated Controllers:

   A. On the **Manual Command** window. Click **Enable Manual Command**.

   B. Adjust the **Manual Command** window slider to position the actuator during specimen installation.

7. Select strain for control mode.

   Standalone FlexTest SE Controllers: Select **Tuning > Manual** > **Control Mode** > **Strain**.

   Automated Controllers:

   In the **Manual Command** window, select **Strain** for **Control Mode**.

8. Ensure that Span has been set to 100%.

   Standalone FlexTest SE Controllers: Select **Status > Span**

   Automated Controllers:

   On the **Station Controls** panel, ensure the **Master Span** is set for 100%.

9. Check system interlocks

   Standalone FlexTest SE Controllers:

   If the **Hydraulic Interlock** or **Program Interlock** indicator is lit, determine the cause, correct it, and then click **Reset**.

   If either interlock indicator lights again, you will need to determine the cause of the interlock and correct it before proceeding.

   Automated Controllers:

   If the **Interlock** indicator is lit, click **Reset**. If the indicator lights again, you must determine the cause and correct it before proceeding.

10. Set up the Tuning panel.

    Standalone FlexTest SE Controllers:

    Select **Tuning > Manual**

    Automated Controllers:

    A. In the **Station Setup** window navigation pane, select the channel that uses the strain signal you intend to tune.

    B. Click  to display the **Tuning** panel.

    C. In the **Tuning** panel, click the **Adjustments** tab.

D. Select the **Show References** check box.

Notice the **Reference** column on the right side of the window. This column shows the current set of tuning parameters. Use the buttons to update reference settings with new values or replace the current values with the last set that worked properly.

Note *The **Reference** settings are saved with the parameter set.*

11. Adjust the P Gain.

Standalone and Automated Controllers

A. Set an initial **P Gain** of at least 1000.

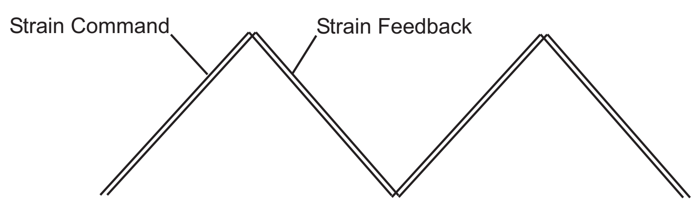
B. Start the function generator.

C. After system control is verified, slowly increase **Amplitude** on the function generator.

D. Select **Continuous Sweep** on the Scope.

E. Use the scope to monitor the strain command and strain feedback signals.

F. Adjust the **P Gain** achieve the following optimum waveforms that show strain feedback closely tracking strain command:



12. Adjust the D Gain.

A. On the scope, monitor the DC error waveform.

B. Increase the **D Gain** to achieve an optimum waveform.

Instability

For actual testing, if your system goes unstable it will emit an annoying high-pitched sound. If your system begins to go unstable, quickly readjust the control that caused the instability to return the control to its previous setting.

Rule-of-thumb

Adjust the **P Gain** and **D Gain** controls as high as possible without going unstable.

If instability is present, a **P Gain** or **D Gain** value approximately 1/2 the current value is appropriate.

13. Adjust the **I Gain** tuning control.

    A. Set an initial **I Gain** that is 10-50% of your current **P Gain** setting.

    B. Monitor the dc error using a scope or meter.

    C. Change the command to disrupt the system by setting **Valve Balance** to a different value.

    Standalone FlexTest SE Controllers:

    Select **Setup > Output > Valve Balance**

    Automated Controllers:

    Adjust the **Valve Balance** control on the **Drive** panel. The error should return to zero within 5–10 seconds. If not, increase the reset (**I Gain**) setting and repeat the procedure until the error zeros itself within a reasonable time period.

14. Save your tuning settings.

    Standalone FlexTest SE Controllers: Setup > **Open/Save Parameters** > **<<Save>>**

    Automated Controllers: On the Station Manager **File** menu, select **Save Parameters As**.

    You can either select an existing parameter set or enter the name of a new parameter set to save.

About saving elements of a parameter set

It is important that you save your parameter set as you complete the various parts that make up a parameter set. Throughout this manual you will be performing discrete procedures while building a single parameter set.

- If you have already established your default parameter set for the current station and you are creating a new parameter set for a specific test, save the parameters with a different name.
- Different tests and/or specimens may require different parameter sets.

How to Perform Advanced Tuning Techniques

The following techniques require product features that may be optional for your controller.

How to Auto-Tune

When you run auto-tuning, the controller disregards your current PIDF gain settings and applies the minimum required drive signal to ramp the feedback to 80% of the auto-tuning limits. It then measures the relationship between the feedback velocity and the valve opening signal and then derives the minimum PIDF gains required to track the command. It's good practice to auto-tune the displacement control mode first, then install a dummy specimen and auto-tune the force control mode.

Auto-tuning the displacement control mode

1. Select an access level of **Tuning**.

   Standalone FlexTest SE Controllers: Status > **Access Level** > **Tuning**

   Automated Controllers: In the **Station Manager** window's toolbar, select an access level of **Tuning**.

2. If necessary, remove the specimen.

3. Set and enable the displacement feedback signal's limits (typically just outside the signal's full-scale range).

   Standalone FlexTest SE Controllers: Setup > *displacement* > **Limits**

   Automated Controllers: In the **Station Setup** window's navigation pane, click **Detectors** and then **Limits**.

   See "How to Set Limit Detectors" in the *MTS Series 793 Control Software* manual for more about setting limit detectors.

4. Set up auto-tuning parameters.

   Standalone FlexTest SE Controllers:

   A. Select **Tuning** > **Auto-Tuning**.

   B. For **Control Mode**, select *displacement*.

   C. For **Mode to Tune**, select *displacement*.

D. For **Actuator Type**, select the type you have.

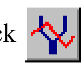
The actuator is typically equipped with a label that identifies whether or not it is hydrostatic.

Note *If you receive a “Feedback is not responding to drive signal” message during tuning, select **Hydrostatic**. This setting allows more and faster valve movements, which results in more actuator movement.*

E. For **Upper Limit** and **Lower Limit**, set the upper and lower limits for actuator travel during auto-tuning.

Auto-tuning exercises the actuator within 80% of these limits.

Automated Controllers:

A. In the **Station Manager** window, click  to open the **Auto-Tuning** control panel.

B. For **Control Channel**, select the channel to be auto-tuned.

C. For **Control Mode**, select a displacement control mode.

D. For **Mode to Tune**, select the displacement mode.

E. For **Auto-Tuning Type**, select **Basic, Advanced**, or **Advanced Only**.

Basic provides an adequate level of tuning for most control modes.

Advanced automatically performs **Basic** auto-tuning followed by a sweep function that provides a higher level of tuning based on **Tracking%** values.

Advanced Only performs only the sweep function (using the **Tracking%** values).

F. For **Actuator Type**, select **Normal** or **Hydrostatic**.

For most cases select **Normal**. If you receive a “Feedback is not responding to drive signal” message during tuning, select **Hydrostatic**. This setting allows more and faster valve movements, which results in more actuator movement.

G. For **Upper Limit** and **Lower Limit**, set the upper and lower limits for actuator travel during auto-tuning.

Basic auto-tuning exercises within 80% of these limits.

Advanced and **Advanced Only** auto-tuning functions exercise the actuator within 20% of these limits. If the limits are exceeded, the auto-tuner will quit and trip an interlock.

H. For **Advanced** and **Advanced Only** auto-tuning—Set the **Tracking%** value.

The 50% default setting is appropriate for most systems.

I. For **Advanced** and **Advanced Only** auto-tuning—Set the **Sweep Freq**.

The **Sweep Freq** sets the upper frequency limit of the sine sweep. The 20 Hz default setting is a good starting point.

WARNING

Pressing the Run button will put the actuator in motion.

A moving actuator can injure anyone in its path.

Always clear the actuator area before pressing the **Run** button.

Note *While auto-tuning is in process you cannot changes channels or control modes. Also, the active and auto-tuning signal's tuning parameters will be disabled.*

5. Press **Run** to start auto-tuning, and if desired, accept tuning values.

While auto-tuning is in progress, the controller displays:

> "Auto Tuning in Progress...To terminate auto-tuning before completion, press <Stop>."

When auto-tuning is complete, the controller displays:

> "Auto Tuning for this mode has completed successfully."

Also, when auto-tuning is complete, the results are displayed showing **Current** tuning values and **Reference** values.

Press **Accept** to apply the **Reference** values.

6. Save the auto-tuning values.

   Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters** > **<<Save>>**

   Automated Controllers: In the **Station Manager** window's **File** menu, select **Save Parameters** to save the **New Values**.

   You may save auto-tuning values to an existing parameter set or to a new parameter set.

Auto-tuning the force control mode

1. Install a dummy specimen.
2. Set and enable the force feedback signal's limits (typically just outside the signal's full-scale range).

   Select **Setup** > **Force** > **Limits**

3. Set up auto-tuning parameters:

   A. Select **Tuning** > **Auto-Tuning**.

   B. For **Control Mode**, select *displacement.*

   C. For **Mode to Tune**, select *force*.

WARNING

Pressing the Run button will put the actuator in motion.

A moving actuator can injure anyone in its path.

Always clear the actuator area before pressing the Run button.

Note *While auto-tuning is in process you cannot changes channels or control modes. Also, the active and auto-tuning signal's tuning parameters will be disabled.*

4. Press **Run** to start auto-tuning.

   The controller displays the following (or a similar) message:

   "The 'Mode to Tune' ('Force') is not the control mode which will be active during auto-tuning. Ensure that the active 'Control Mode' is tuned prior to proceeding. If the selected 'Mode to Tune' requires feedback from a specimen (ex: Force/Torque/Strain), ensure that a specimen is mounted."

   Select Yes (or Press **<<OK>>)** if you have tuned the channel's displacement mode and installed a specimen.

   When the Controller starts auto-tuning the following is displayed:

   > "Auto Tuning in Progress...To terminate auto-tuning before completion, press <Stop>."

   When auto-tuning is complete, the controller displays:

   > "Auto Tuning for this mode has completed successfully."

   Also, when auto-tuning is complete, the results are displayed showing **Current** tuning values and **Reference** values.

   Press **Accept** to apply the **Reference** values.

5. Save the auto-tuning values.

   Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters** > **<<Save>>**

   Automated Controllers: In the **Station Manager** window's **File** menu, select **Save Parameters** to save the **New Values**.

   You may save auto-tuning values to an existing parameter set or to a new parameter set.

How to improve auto-tuning results

You can attempt to further improve tuning using the following techniques:

- Use the auto-tuning settings as a starting point when manually tuning each control mode.
- If your feedback signal is noisy, use a tuning filter (see "About Tuning Filters" on page 115).

How to Manually Tune Three-Stage Servovalves

Note *For FlexTest SE Controllers, this procedure requires the optional Scope, or an external oscilloscope.*

Note *This section applies only to systems using three-stage servovalves such as the Model 497.15 or 493.15 Servovalve.*

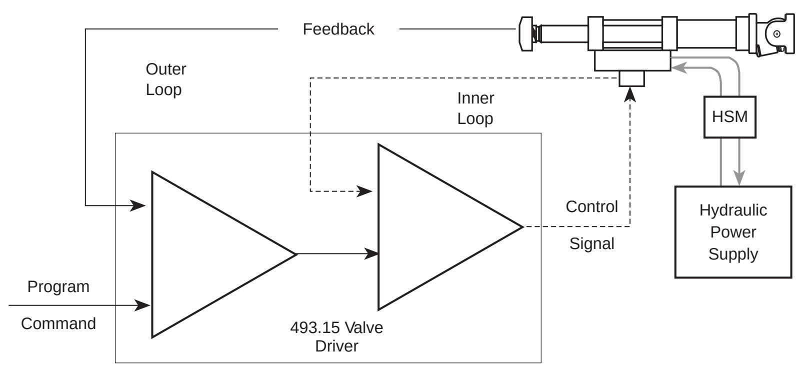
About the inner loop

Systems equipped three-stage servovalves have an inner control loop inside the test system's primary, or outer control loop.

The inner loop, like the outer loop, has gain and rate controls that can be adjusted to optimize performance. The inner-loop is tuned at system installation, and requires periodic fine tuning when the outer-loop becomes sluggish.

The inner loop is similar to a displacement control mode for the outer-loop. Three-Stage Valve Driver modules include the electronics necessary to support the inner control loop.

The innerloop (proportional) gain and rate (derivative) adjustments are the same types of adjustments as the proportional and derivative gain adjustments of the outerloop tuning controls.



Important *Always tune the inner loop without the hydraulics applied to the actuator. Perform the inner loop gain adjustments with hydraulic pressure removed from the main spool while maintaining pressure at the pilot stage. This prevents interaction between the inner and outer loops.*

Prerequisites

- The hydraulic fluid and the servovalve should be at operating temperature. See "When to Tune" on page 49.
- Command compensators should be turned off.
- The specimen should be removed.

Procedure

1. Remove hydraulic pressure from the main spool.
2. Disconnect the hydraulic service manifold (HSM) control cable from the controller.

   TestStar IIm, FlexTest GT, and FlexTest SE Controllers—At the back of the controller chassis, disconnect the cable from connector **J28**.

   FlexTest IIm/CTC Controllers—At the 497.05 Hydraulic Control module's rear panel, disconnect the cable from connector **J28**.

   Disconnecting this cable disables pressure to the main spool, but leaves pressure applied to the pilot stage of the servovalve.

   On systems with multiple HSMs, be sure to disconnect the correct cables.

Note *On systems with no HSM, remove the outer loop LVDT cable from the actuator to disable the outer loop.*

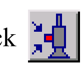
3. Apply hydraulic pressure.
4. Select an access level of **Tuning**.

   Standalone FlexTest SE Controllers: Config > **Access Level** > **Tuning**

   Automated Controllers: In the **Station Manager** window's toolbar, select an access level of **Tuning**.

5. Set the following valve drive conditioner parameters:

   Standalone FlexTest SE Controllers: Setup > **Output > Conditioner**

   Automated Controllers: In the **Station Setup** window, click  to display the **Drive** panel. In the **Drive** panel, click the **Conditioner** tab.

   A. Set **Excitation** to **10V**.

   B. Set **Phase** to between **10** and **30 deg**.

   C. Set **Offset** to **0** **V**.

   D. Set the **Gain** to **10**.

   E. Set the **Polarity** to **Normal**.

6. Configure a Meter to monitor the spool position signal.

   Standalone FlexTest SE Controllers:

   Select **Meters** > **Meter 1**

A. For **Meter Type**, select **Timed**.

B. For **Signal**, select **Spool Position**.

C. For **Display Mode** and **Display Units**, select **Volts**.

D. Set a **Display Resolution**.

Automated Controllers:

A. On the **Station Manager** window's toolbar, select **Create Meters** on the **Meters** icon pull-down menu.

B. Select **Create Meters** again to display a second **Meters** window.

C. In the **Meters** window, click the Meter Setup button. Use the **Meter Setup** window to define the meter

D. For **Meter Type**, select **Timed**.

E. For **Signal Selection**, select the desired **Channel** name and **Spool Position** for **Signal** type.

F. For **Display Mode**, select **Volts**.

G. Set a **Display Resolution**.

7. Produce a **Spool Position** output signal of -10 V DC with the spool driven into the end cap.

Standalone FlexTest SE Controllers:

A. Reverse the **Conditioner > Polarity** setting to drive the inner loop spool into one of the end caps.

B. Adjust **Conditioner > Gain** until the Meter reads approximately -8 V DC.

C. Adjust **Conditioner > Phase** until the Meter displays maximum voltage.

The phase adjustment matches the phase of the inner loop LVDT feedback with the 10 kHz demodulator reference signal. This adjustment provides a maximum output for the maximum LVDT spool position offset.

Note *This adjustment must be set for the initial calibration, servovalve replacement, cable replacement, or valve driver replacement. Once the phase is correctly set, readjustment is not necessary during routine calibration.*

D. Readjust **Conditioner > Gain** until the Meter reads -10 V DC.

E. Return **Conditioner > Polarity** to its original setting.

Automated Controllers:

In the **Drive** panel **Conditioner** tab:

A. Reverse the **Polarity** setting to drive the inner loop spool into one of the end caps.

B. Adjust **Gain** until the meter reads approximately -8 V DC.

C. Adjust **Phase** until the meter displays maximum voltage.

The phase adjustment matches the phase of the inner loop LVDT feedback with the 10 kHz demodulator reference signal. This adjustment provides a maximum output for the maximum LVDT spool position offset.

Note *This adjustment must be set for the initial calibration, servovalve replacement, cable replacement, or valve driver replacement. Once the phase is correctly set, readjustment is not necessary during routine calibration.*

D. Readjust **Gain** until the meter reads -10 V DC.

E. Return **Polarity** to its original setting.

8. Produce a **Spool Position** output signal of +10 V DC with the spool driven into the opposite end cap.

Standalone FlexTest SE Controllers:

A. Reverse the **Conditioner > Polarity** setting to drive the inner loop spool into the other end cap.

B. Check the Meter. It should read +10 V DC (±0.5 V DC).

If the voltage is correct, proceed to the next step in this procedure.

If the voltage is off by more than 0.5 V, you may need to mechanically center the pilot spool. Complete this procedure, then recheck spool position voltages at each endcap before you resume inner loop tuning.

C. Return **Conditioner > Polarity** to its original setting.

Automated Controllers:

In the **Drive** panel, click the **Valve** tab.

In the **Valve** tab, produce a **Spool Position** output signal of +10 V DC with the spool driven into the opposite end cap.

A. Reverse the **Polarity** setting to drive the inner loop spool into the other end cap.

B. Check the meter. It should read +10 V DC (±0.5 V DC).

If the voltage is correct, proceed to the next step in this procedure.

If the voltage is off by more than 0.5 V, you may need to mechanically center the pilot spool. Complete this procedure, then recheck spool position voltages at each endcap before you resume inner loop tuning.

C. Return **Polarity** to its original setting.

9. Monitor the spool position signal with a scope.

Standalone FlexTest SE Controllers: Press **Scope** to monitor the spool position signal.

Note *If your FlexTest SE Controller is not equipped with the optional Scope, use an external oscilloscope.*

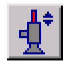
Automated Controllers:

A. In the **Station Manager** window's toolbar, click  once to display a single **Scope** window.

B. In the **Scope** window's toolbar, click  to open the **Setup for Scope** window.

10. Create a program with the function generator application.

    Standalone FlexTest SE Controllers: Select **FG** and select the following settings to set up a tuning program.

    Automated Controllers: In the **Station Manager** window's navigation pane, click .

CONTROL	SETTING
Type	Cyclic
Wave Shape	Square
Control Mode	*displacement*
Target Setpoint	0 mm
Amplitude	50% of full scale
Frequency	1 Hz
Compensator	None

11. Start the function generator

    Standalone FlexTest SE Controllers: Press **Run** to start the displacement command.

    Automated Controllers: In the **Station Controls** panel, click  to start the **Function Generator**.

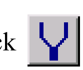
12. Observe the spool position signal on the Scope.

    If the **Spool Position** signal is too small to be properly displayed on the **Scope** window during tuning, increase the **Function Generator** panel's **Amplitude**.

    If the **Amplitude** setting does not amplify the spool signal as expected, increase the **P Gain**.

    Standalone FlexTest SE Controllers: Tuning > **P Gain**

    Automated Controllers:

    A. In **Station Setup** window's navigation pane click .

B. In the **Inputs** panel, click the **Adjustment** tab.

C. In the **Adjustment** tab, increase the **P Gain**.

13. Tune the inner loop.

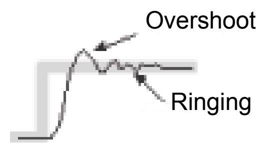
Standalone FlexTest SE Controllers: Setup > **Output** > **Inner Loop**

Automated Controllers: In the **Station Setup** window's **Drive** panel, click the **Inner Loop** tab.

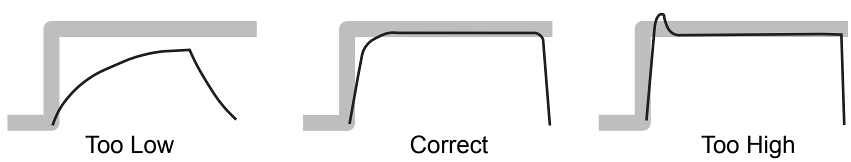
For optimal system response, tune the inner loop to be relatively less responsive and more stable than a typical outer loop.

A. For **Rate Input Selection**, select **Spool Position**.

B. Increase **Inner Loop Gain** until you see a little overshoot on the oscilloscope.



C. Slightly increase the **Inner Loop Rate** to eliminate this overshoot. When properly tuned, the waveform should be a square wave with rounded corners, having no overshoot.



Zero the Spool Position Signal

This task matches the electronic null of the spool position signal with the mechanical null position of the servovalve pilot spool.

During inner loop tuning, it may be necessary to complete this procedure if the spool position signal voltage is not approximately equal (though opposite polarity) at opposite endcaps of a servovalve.

1. Set the **Valve Balance** to zero.

   Standalone FlexTest SE Controllers: Select **Setup** > **Output** (3-stage) > **Valve Balance**

   Automated Controllers: On the **Drive** panel, click the **Valve** tab, then set the **Valve Balance** to zero.

2. Ensure that the **Offset** control is set to zero.

   Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Offset/Zero** > **Manual Offset**

   Automated Controllers: Click the **Conditioner** tab on the **Drive** panel, then check the **Offset** setting.

3. Apply hydraulic pressure.

WARNING

Do not remove the LVDT adjustment locknut or assembly when adjusting the servovalve LVDT spool position.

If it is removed, hydraulic fluid will spray from the servovalve at full pressure. You should refer to the servovalve product manual to identify the main stage LVDT spool adjustment.

4. Loosen (but do not remove) the LVDT locknut.

5. Adjust the LVDT in or out of the servovalve to provide a zero spool position signal.

6. Tighten the locknut while holding the LVDT in position.

How to Monitor Inner Loop Signals

Note *The following procedure does not apply to FlexTest IIm Controllers, see page 101.*

1. Connect a service calibration cable package (MTS part number 100-026-213) to connector **J3 Service** on the I/O carrier module.

2. Connect a DVM or oscilloscope to the appropriate **BNC Output Channel** on the service cable, depending on which slot the valve driver occupies in the I/O Carrier module.

3. In **Station Setup,** click the **Channel Drive** icon to display the **Drive** panel, and then click the **Conditioner** tab.

4. From the **Service Port Output**, select one of signals described in the following Service Port Output Signals list.

Note *The **Spool Position** signal is available to the digital meters or software scope.*

Service Port Output Signals

SIGNAL	DESCRIPTION
Valve Current	The final output to the servovalve. The voltage represents the current output [10 V (DC) = 50 mA; standard].
Demod Filter Output	The analog output of the demodulator prior to gain.
Innerloop Command	The input signal to the 3-Stage Valve Driver (the test program command).
Spool Position	The **Conditioner Out** signal summed with the **Spool Zero** signal.
Spool Offset	Signal that is summed with spool position to remove any DC offset. ±10 V represents ±4 V of zero summing.
Preamp Output	The raw AC input from the spool LVDT.
Conditioner Out	The conditioned feedback signal from the servovalve LVDT.
Voltage Reference (5V)	Internal board reference test only.

Monitoring inner-loop signals on FlexTest IIm Controllers

Inner-loop signals can be monitored with external meters via the tip jacks on the Model 497.15 3-Stage Valve Driver module. You must specify which signal is available from the tip jacks with the **Monitor Mux Output** list.

Note *These signals are not available to the built-in meters or scope.*

Inner Loop Signals

SIGNAL	DESCRIPTION
Valve Current	The final output to the servovalve. The voltage represents the current output (10 V DC=50 mA; standard).
Valve Balance	The amount of valve balance introduced by the **Valve Balance** control on the **Valve** tab of the **Drive** page.
Inner loop Cmd	The input signal to the 3-Stage Valve Driver (the test program command).
Inner loop Err	The difference between the **Inner loop Command** and the **Spool Position** signal.
Spool Position	The **Conditioner Out** signal summed with the **Spool Zero** signal.
Spool Zero	The amount of offset introduced by the **Offset** control on the **Valve** tab of the **Drive** page.
Conditioner Out	The conditioned feedback signal from the servovalve LVDT.
Ground	The signal common.

How to Use Error to Tune I Gain

Note *This procedure requires the optional Scope, or an external oscilloscope.*

This procedure pertains to manually tuning the **I Gain** control using the Error signal.

To perform this procedure for the displacement control mode, follow the procedure beginning on page 71, then use it as an alternate method to “Adjust the I Gain tuning control.” on page 75.

To perform this procedure for the force control mode, follow the procedure beginning on page 76, then use it as an alternate method to “Adjust the I Gain tuning control.” on page 80.

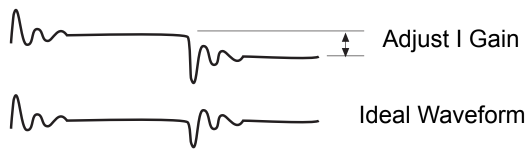
Setting up the Scope

Set up the Scope to view **Command** and **Error**, and select a **Trace Time** of 5 seconds. Also, ensure **Auto-Scale** is on (it is on by default).

Note *To improve your view of the waveform, click the* ***Rescale*** *button to maximize the waveform on the display.*

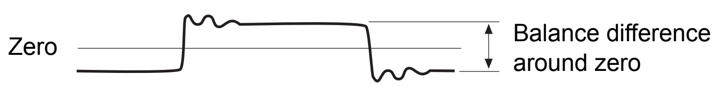
Using a square wave

Apply the tuning program with a square wave, and monitor the amplitude of the settled portion of the error signal. The settled portion of the error signal should be the same level for both segments, if not, adjust **I Gain** as required.



Using a ramp

Apply the tuning program with a ramp, and monitor the amplitude of the settled portion of the error signal. The settled portion of the error signal should be balanced, if not, adjust **I Gain** as required.



Upset recovery method

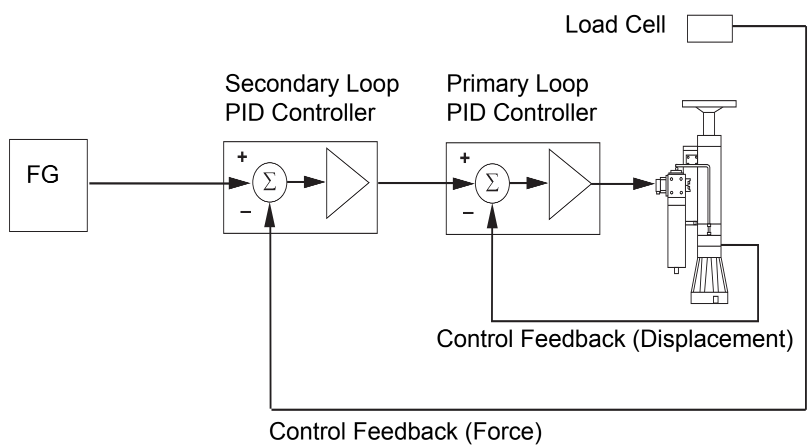
Monitor the error signal, then disrupt the system by changing the command by adjusting the **Setpoint** control with the Dial. When you do this, the error should return to zero within 5–10 seconds. If not, increase the reset (**I Gain**) setting and repeat the procedure until the error zeros itself within a reasonable time period.

About the Cascaded PIDF Control Mode

Note *Cascaded PIDF control mode is a keyed option. It is available when you purchase Model 793.21 Cascade Control.*

The Cascaded PIDF control mode is typically used for testing that requires a high degree of stability under dynamic conditions.

This control mode uses two control loops. The output of the outer (or secondary) control loop is used as the input to the inner (or primary) control loop, as if it were the final control element.



Cascaded PIDF Control Mode

How to Tune a Cascaded PIDF Control Mode

Tune the control modes that will supply the primary and secondary feedback signals

1. Select an access level of Tuning:

   Standalone FlexTest SE Controllers: Select **Tuning** > **P Gain**.

   Automated Controllers: In the **Station Manager** window’s toolbar, select an access level of **Tuning**.

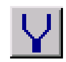
2. Display the controls for the control mode to be tuned.

   Standalone FlexTest SE Controllers: Select **Setup** > *desired* **Cascaded PIDF** *control mode* **> Tuning**.

   Automated Controllers:

   A. In the **Station Manager** window's **Display** menu, select **Station Setup**.

   B. In the **Station Setup** window navigation pane's **Channels**, locate and select the Cascaded PIDF control mode you are tuning.

   C. In the **Station Setup** window, click .

   D. In the **Tuning** panel, click the **Adjustments** tab.

3. Adjust the PIDF controls for the control mode asscciated with the outer control loop.

4. Save the outer loop tuning values.

   Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters > <<Save>>**.

   Automated Controllers: In the **Station Manager** window's **File** menu, select **Save Parameters**.

5. Note the base control mode in the Tuning window.

6. Adjust the PIDF controls for the control mode associated with the inner control loop.

7. Save the inner loop tuning values.

   Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters > <<Save>>**.

   Automated Controllers: In the **Station Manager** window's **File** menu, select **Save Parameters**.

About Channel Limited Channel (CLC) Control Modes

Use a channel limited channels (CLC) control mode for specimen installation and removal. Before CLC control modes can be tuned, they must first be defined in the Station Builder application.

A CLC control mode requires an active and a limiting feedback signal:

- The active feedback signal controls the actuator’s movement. It is normally the channel’s displacement feedback signal.
- The limiting feedback signal limits the actuator’s force. It is normally the channel’s force feedback signal.

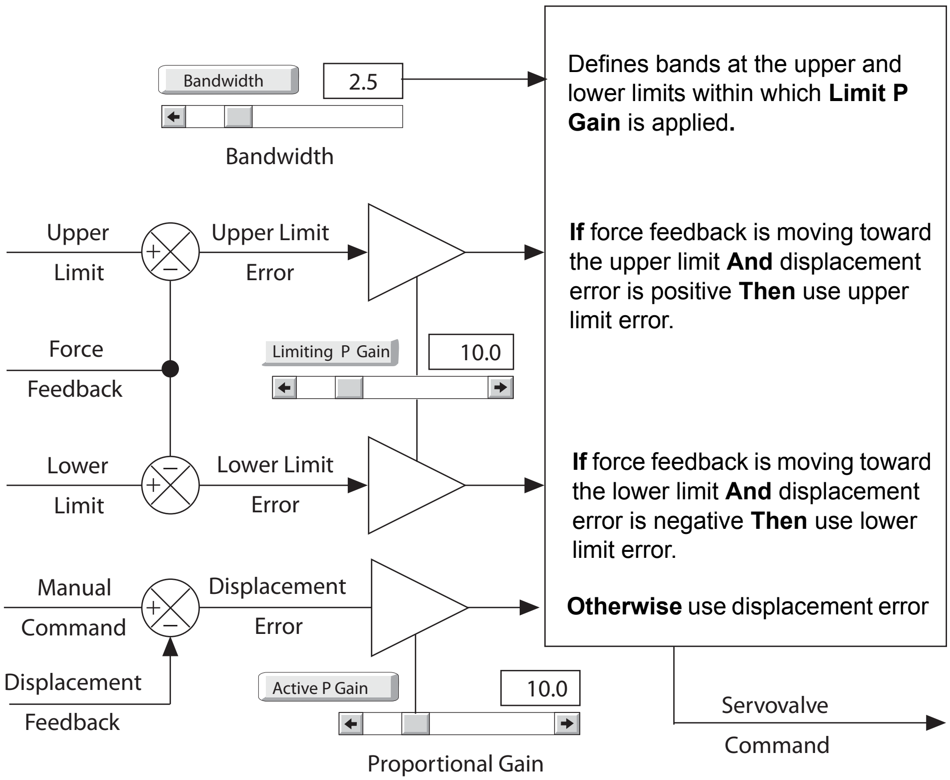
When CLC is used as the control mode, the controller will not allow the actuator to exceed limits set for either the active or limiting feedback signals:

- Interlocks can trip if the actuator’s active (displacement) feedback signal exceeds limits set for it in the **Station Setup** window’s **Limits** tab.
- The actuator’s limiting (force) feedback signal cannot exceed limits set for it in the **Station Setup** window’s **Adjustment** tab.

How to Tune a CLC Control Mode

Tune the control modes that will supply the active and limiting feedback signals

Channel Limited Channel Diagram



The CLC control mode uses one of three error signals. The **Limiting P Gain** adjustment acts as a conversion factor to scale the limit feedback to similar units as the active P feedback. The **Limiting P Gain** is turned on within the upper and lower limit bands defined by the **Bandwidth** control.

1. Select an access level of Tuning:

   Standalone FlexTest SE Controllers: Select **Tuning** > **P Gain**.

   Automated Controllers: In the **Station Manager** window's toolbar, select an access level of **Tuning**.

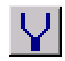
2. Display the CLC controls for the control mode to be tuned.

   Standalone FlexTest SE Controllers: Select **Setup** > *desired* **CLC** *control mode* **> Tuning**.

   Automated Controllers:

   A. In the **Station Manager** window's **Display** menu, select **Station Setup**.

   B. In the **Station Setup** window navigation pane's **Channels**, locate and select the CLC control mode you are tuning.

   C. In the **Station Setup** window, click .

   D. In the **Tuning** panel, click the **Adjustments** tab.

3. Set the gain for the active and limiting feedback signals.

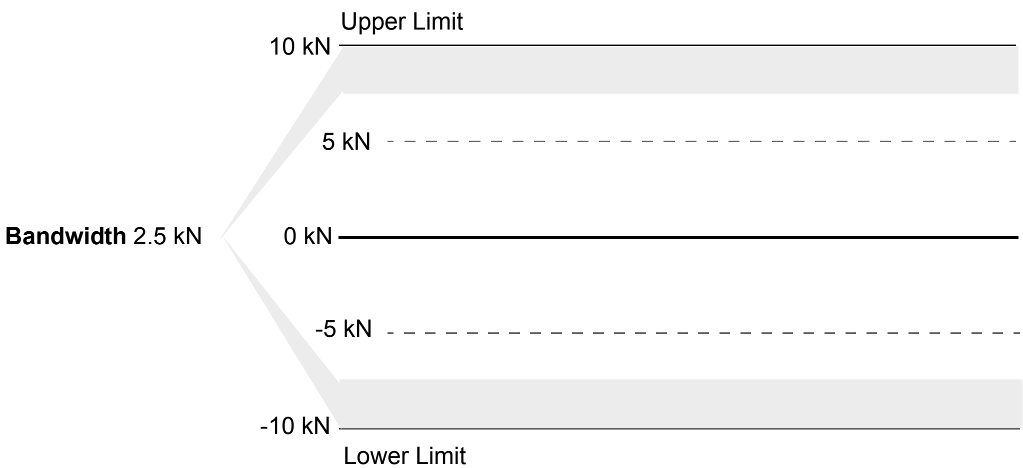
   A. For **Active P Gain**, enter the value used for the displacement control mode's **P Gain**.

   B. For **Limiting P Gain**, enter the value used for the force control mode's **P Gain**. In the CLC control mode, you use the **Limiting P Gain** control and the **Bandwidth** control (next step) together to moderate overshoot of the upper and lower limits.The proper adjustment of these controls is test dependent and may require several iterations.

4. Set the bandwidth for the application of **Limiting P Gain**.

   Use the **Bandwidth** control to define the bands in which **Limiting P Gain** is applied.

Setting the Limiting P Gain bandwidth of the limiting channel



Limiting P Gain is turned on only within the upper and lower bands. The bands are defined by the **Bandwidth** control, as shown in the illustration.

5. Select the CLC control mode to test system response.

   Adjust the **Active P Gain** if the actuator's displacement response is sluggish.

   Adjust the **Limiting P Gain** if the actuator's force response is sluggish.

6. Save the tuning values.

   Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters > <<Save>>**.

   Automated Controllers: In the **Station Manager** window's **File** menu, select **Save Parameters**.

About Dual Compensation Control Modes

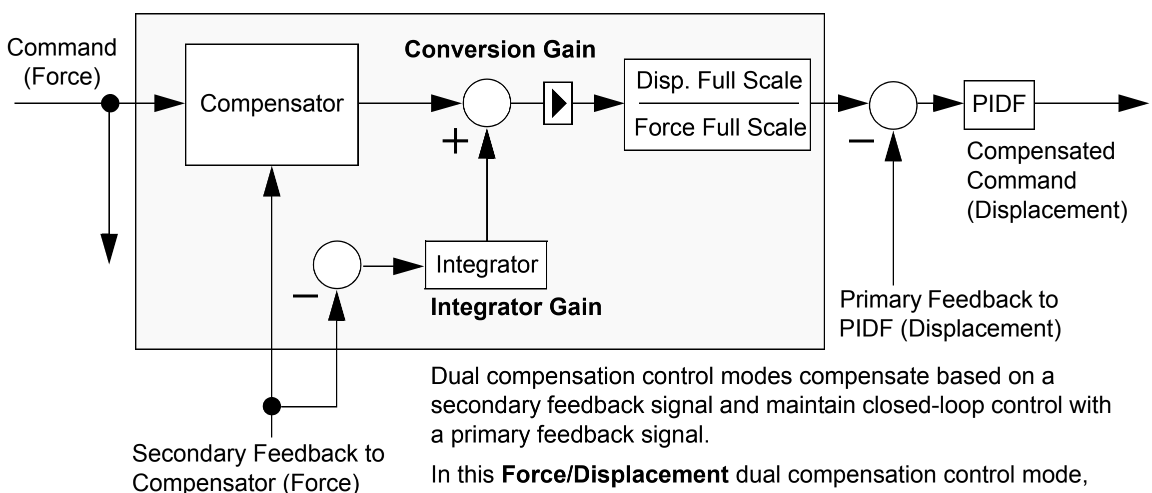
Before dual compensation modes can be tuned, they must first be defined in the Station Builder application.

Sometimes force feedback signals may be too noisy or otherwise unsuitable for use in control modes. For example, accelerometer feedback signals have only dynamic characteristics, making them unsuitable for use in a control mode.

Select a dual compensation control mode for a channel when the feedback for the desired control mode is unsuitable for maintaining closed-loop control.

A dual compensation mode requires a primary and a secondary feedback signal:

- The more stable primary feedback signal is used by the PIDF controller to maintain closed-loop control.
- The less stable secondary feedback signal is used for command compensation in command programs provided by the **Function Generator** and other applications.



Dual compensation control modes compensate based on a secondary feedback signal and maintain closed-loop control with a primary feedback signal.

In this **Force/Displacement** dual compensation control mode, programming and compensation use the secondary force feedback signal. The PIDF controller maintains closed-loop control using the primary displacement feedback signal.

Dual compensation controls

Dual Compensation controls display at the bottom of the **Station Setup** window's **Compensators** panel tabs when a dual compensation mode is selected in the navigation pane.

The **Integrator Gain** control becomes available by selecting, in the Station Builder application, the **Edit Dual Compensation Modes** window's **Mean and Amplitude Control**.

About compensation gain settings

When reading this section, assume that the Station Builder application has defined a **Force/Displacement** dual compensation control mode and that:

- The force signal is the less stable secondary feedback signal, used for command compensation. Command programs produced by the **Function Generator** and other applications use this signal's dimension.
- The displacement signal is the more stable primary feedback signal, used by the PIDF controller to maintain closed-loop control.

Conversion Gain

Conversion Gain applies the gain that converts the force command to a displacement command for a PIDF or external controller.

The force signal provided by the compensator is multiplied by the following equation to create the displacement signal used to program the PIDF or external controller.

$$\text{Conversion Gain Value x} \left(\frac{\text{Full Scale Displacement}}{\text{Full Scale Force}}\right)$$

The **Conversion Gain** setting depends on the specimen stiffness. See "Calculating conversion gain" on page 111

Integrator Gain

The **Integrator Gain** improves the static accuracy when the command is paused or stopped.

I Gain

For best performance, set **I Gain** as low as possible when using compensation methods that provide mean correction. These methods include peak/valley phase (PVP), peak/valley compensation (PVC), and arbitrary end-level compensation (ALC).

Note *When using PVC, setting **I Gain** too high may result in system instability.*

Calculating conversion gain

Use this method to calculate the proper **Conversion Gain** setting. Assume a **Force/Displacement** dual compensation control mode.

1. Set limits as appropriate and install the specimen.
2. Using the **Station Manager** window's **Function Generator**, excite the specimen in displacement control using a small amplitude sine wave.

3. Configure two **Peak/Valley** meters to measure force feedback and displacement feedback signals.

4. Calculate the specimen stiffness (K):

$$K = \frac{(\text{Force Peak} - \text{Force Valley})}{(\text{Displacement Peak} - \text{Displacement Valley})}$$

5. Calculate the **Conversion Gain** value:

$$\text{Conversion Gain} = \left(\frac{1}{K}\right) \times \left(\frac{\text{Full Scale Force}}{\text{Full Scale Displacement}}\right)$$

Note *For a more conservative estimate, use 80% of the calculated* ***Conversion Gain*** *value. When using asymmetrical* ***Fullscale*** *values enter the difference between the values.*

How to Tune a Dual Compensation Control Mode

1. Tune the control mode that supplies the primary feedback signal (base control mode).

2. Select an access level of Tuning:

   Standalone FlexTest SE Controllers: Select **Setup** > **Tuning**.

   Automated Controllers: In the **Station Manager** window's toolbar, select an access level of **Tuning**.

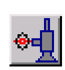
3. Display the compensation controls of the dual compensation control mode.

   Standalone FlexTest SE Controllers: Select **Setup** > *desired* **Dual Compensation** *control mode* **>** *desired compensation method*.

   Automated Controllers:

   A. In the **Station Manager** window's **Display** menu, select **Station Setup**.

   B. In the **Station Setup** window's navigation pane, locate and select the dual compensation control mode being tuned.

   C. In the **Station Setup** window, click .

   D. In the **Compensators** panel, click the tab for the compensation method being used.

4. In the selected **Compensation** tab, set the **Conversion Gain** and **Integrator Gain**.

   A. Set **Conversion Gain** to either:

   – The calculated conversion gain value. (See “Calculating conversion gain” on page 111 for the calculation formula.)

   – A value between **0.8** and **1.0**. (The stiffer the specimen, the smaller the value.)

   B. Set **Integrator Gain** to **0**.

5. Install a dummy specimen.

6. Set **Limits** to protect you, your equipment, and your specimen.

   Standalone FlexTest SE Controllers: See “About Limit Detectors” in the *FlexTest SE Users* manual for more information.

   Automated Controllers: See “About Limit Detectors” in the *MTS Series 793 Control Software* manual for more information.

7. Set up a simple test program using the **Function Generator (FG)**.

   A. For **Control Mode**, select the dual compensation control mode to be tuned.

   B. For **Command Type**, select **Cyclic**.

   C. Create a command with an amplitude and frequency appropriate for the specimen.

   D. For **Wave Shape**, select **Sine**.

   E. Select a **Compensator** method.

8. Configure the **Scope** window to monitor command and secondary (force) feedback signals.

   Standalone FlexTest SE Controllers: See “Scope” in the *FlexTest SE Users* manual for more information.

   Automated Controllers: See “About the Scope” in the *MTS Series 793 Control Software* manual for more information.

WARNING

Pressing the Run button will put the actuator in motion.

A moving actuator can injure anyone in its path.

Always clear the actuator area before pressing the Run button.

9. Start the test program.

   A. Apply station hydraulic power.

   B. Click or press to start the tuning program.

10. Adjust the **Conversion Gain** and **Integrator Gain**.

    A. For **Adaptation State**, select **Hold** and **Reset** or **Reset All**.

    B. Gradually increase the **Conversion Gain** until the scope shows that the secondary (force) feedback is approximately 80% of its commanded value.

       During normal operation, the compensator will increase the feedback amplitude until it matches the command amplitude.

    C. Increase the **Integrator Gain** if the scope shows that the primary and secondary signals are offset.

11. Save the tuning values.

    Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters > <<Save>>**.

    Automated Controllers: In the **Station Manager** window's **File** menu, select **Save Parameters**.

About Tuning Filters

Forward loop filters

The response of the mechanical system (valve, actuator, test specimen) limits the amount of controller gain you can use before the system becomes unstable.

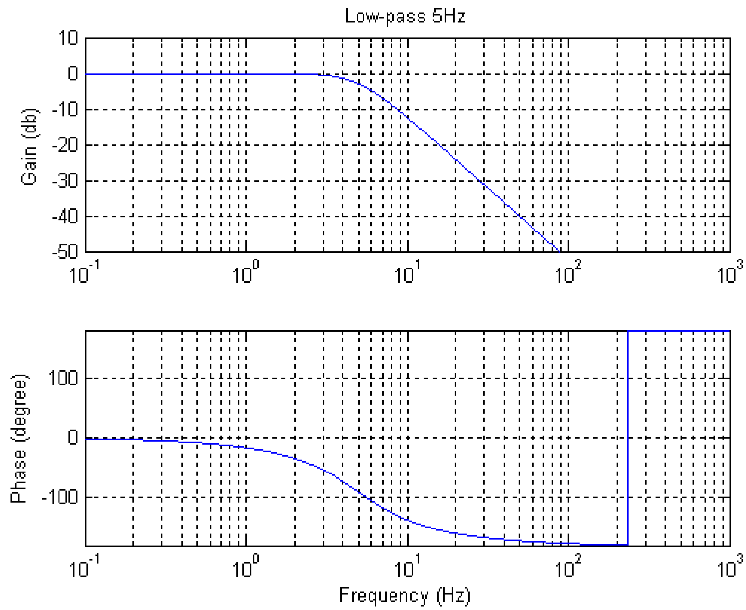
A filter in the forward path of the controller may be used to shape the system response. This may make it possible to increase the controller gain, improving command and feedback tracking while maintaining stability.

Forward loop filters are available for all control modes, and include:

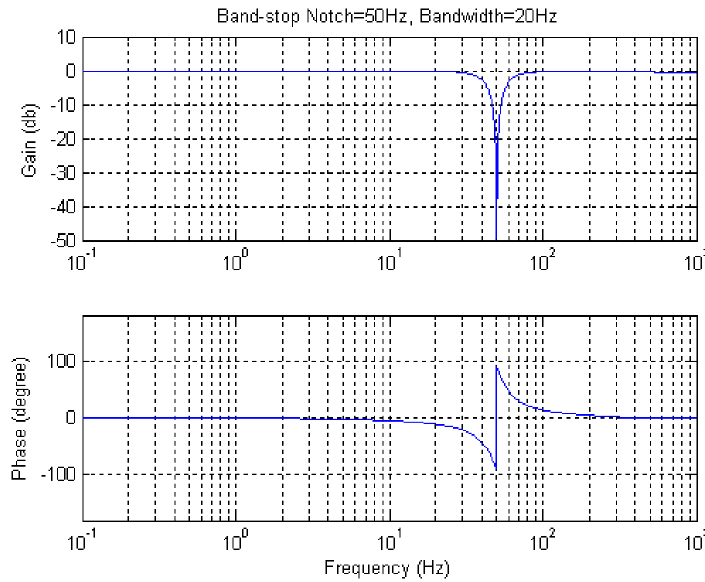
- A **Low-Pass** filter that attenuates signals above a specified frequency.
- A **Band-Stop** filter that attenuates signals in a specified band around a specified frequency.
- A **Break-Recover** filter that attenuates signals above the **Break** frequency. Phase lag of the filter is reduced at higher frequencies by limiting the filter attenuation at frequencies above the **Recover** frequency.
- A **Lead-Lag** filter that applies a lead-lag compensator with a maximum of 2 poles (lag) and 2 zeros (lead). Signals will be attenuated above the **Pole 1** and **Pole 2** frequencies. Phase lag of the filter can be reduced at higher frequencies by limiting the filter attenuation at frequencies above the **Zero 1** and **Zero 2** frequencies.

Forward loop filter responses

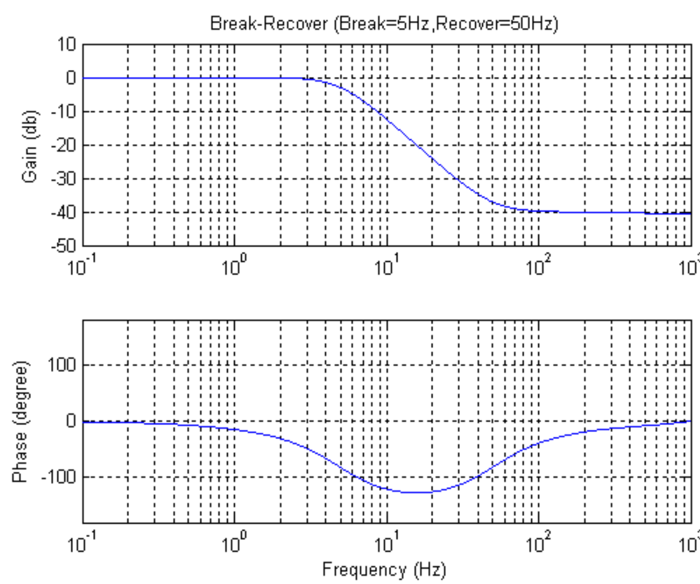
Refer to the following forward loop filter response curve examples when selecting a filter type for a desired system response.



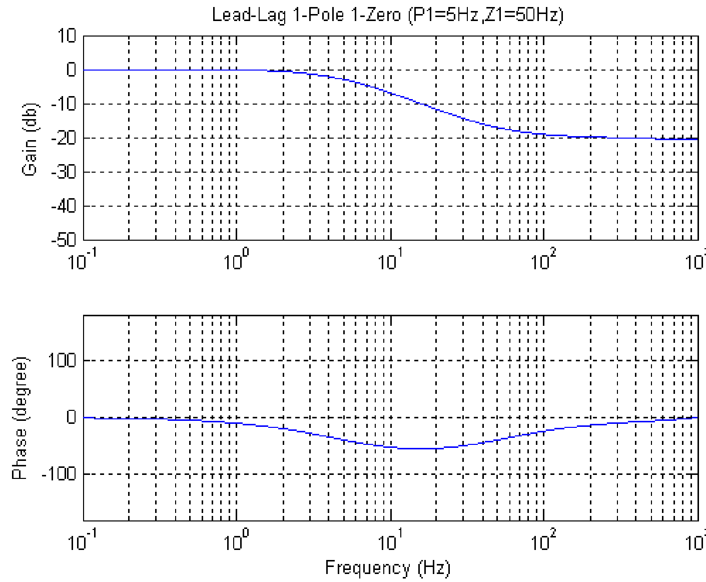
Low-Pass



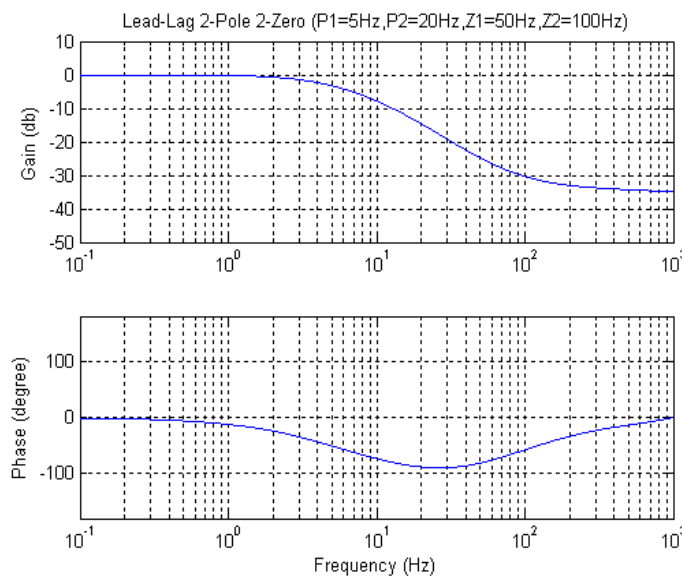
Band-Stop



Break-Recover



Lead-Lag 1



Lead-Lag 2

How to Enable a Tuning Filter

1. Select an access level of Tuning:

   Standalone FlexTest SE Controllers: Select **Setup** > **Tuning**.

   Automated Controllers: In the **Station Manager** window’s toolbar, select an access level of **Tuning**.

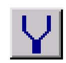
2. Display the **Filter** tab for the control mode being tuned.

   Standalone FlexTest SE Controllers: Select **Setup** > *desired control mode* > **Tuning > Filter Type**.

   Automated Controllers:

   A. In the **Station Manager** window’s **Display** menu, select **Station Setup**.

   B. In the **Station Setup** window’s navigation pane, locate and select the control mode being filtered.

   C. In the **Station Setup** window, click  .

   D. In the **Tuning** panel, click the **Filter** tab.

3. To select a **Forward Loop** filter, select and set up the desired filter type of **None**, **Low-Pass**, **Band-Stop**, **Break-Recover**, **Lead-Lag**.

   – For **Low-Pass** filters, set the **Frequency**.

   – For **Band-Stop** filters, set the **Notch** frequency and **Bandwidth**.

   – For **Break-Recover** filters, set the **Break** and **Recovery** frequencies.

   – For **Lead-Lag** filters, select the number of poles and zeros, then specify their frequencies.

4. Save filter values.

   Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters > <<Save>>**.

   Automated Controllers: In the **Station Manager** window’s **File** menu, select **Save Parameters**.

Stabilization filters

Stabilization filters are available for control modes equipped with stabilization resources and include:

- A **1 Hz High-pass** filter that attenuates signals below 1 Hz.
- A **Band-pass** filter that attenuates signals outside of a user-definable band.

To select a **Stabilization** filter, select and set up the desired filter type of **1 Hz High-pass** or **Band-pass**.

  – For **Band-pass** filters, set the frequency band with the **Frequency Limits** control.

Note *Some systems with a higher actuator frequency may benefit by selecting the following* ***Frequency Limits****: a low cut-off frequency that is approximately the actuator frequency and a high cut-off frequency approximately 5-10 times the actuator frequency.*

Chapter 3

Calibration Procedures

This chapter contains step-by-step calibration instructions for MTS Series 793 Controllers. In this manual, MTS Series 793 Controllers include FlexTest IIm/CTC, FlexTest SE, FlexTest GT, and TestStar IIm Controllers.

About calibration procedures for specific controller models

For each task, instructions are provided for stand-alone FlexTest SE Controllers and Automated Controllers.

Standalone FlexTest SE Controllers refer FlexTest SE Controllers configured to operate in the stand-alone mode (not equipped with a PC).

Automated Controllers refer to controllers equipped with MTS Series 793 Software. This includes FlexTest IIm/CTC, automated FlexTest SE, FlexTest GT, and TestStar IIm Controllers.

Note *Automated FlexTest SE Controllers are equipped with a PC in which Exclusive Control is assigned to Station Manager. For more information about Exclusive Control, see the FlexTest SE Users manual.*

Note *Because of hardware variations and optional features, some of the steps in the procedures may not apply to your specific controller model. Steps that apply only to specific models and options are qualified.*

Where to find control descriptions for specific controller models

For a description of the specific calibration controls displayed on the front panel of stand-alone FlexTest SE Controllers, see the *FlexTest SE Users* manual.

For a description of the specific calibration controls displayed in MTS control software included with Automated Controllers, see the *MTS Series 793 Control Software* manual. This pertains to FlexTest IIm, automated FlexTest SE, FlexTest GT, and TestStar IIm Controllers.

Contents

Pre-Calibration Considerations

Before you start sensor calibration, *be sure* the following are true:

- The sensors are properly connected to the controller.
- A configuration file has been created that includes the hardware resources associated with the sensors you want to calibrate.
- You have completed an initial, nominal tuning of the sensor channel you are calibrating. This is especially important if you have not calibrated the sensor before.
- The hydraulics are warmed up (see System warm-up below).
- Conditioner **Gain** is set to 1.
- You know your signal polarity (see below).

System warm-up

Be sure that both the hydraulic fluid and the servovalve are at operating temperature before calibration. Remove any specimen and run the system in displacement control for at least 30 minutes using a 80% full-scale length command at about 0.1 Hz.

Signal polarity

Some test systems are configured to extend the actuator in response to a positive command, while other test systems are configured to retract the actuator in response to a positive command. Conditioner polarity determines feedback polarity.

You *must know* how your test system is configured so you can determine the appropriate polarity for the values used in this chapter. The valve polarity is established first (see “How to Set Servovalve Polarity” on page 56).

Full-range conditioners

All MTS Series 793 Controllers except FlexTest IIm/CTC Controllers may be equipped with full-range conditioners (e.g. Model 493.25 DUCs). Consider the following when calibrating sensors that use full-range conditioners:

- Full-range conditioners allow a gain/linearization calibration option which require you to set up a linearized data table during sensor calibration.

- When using linearized data, you must retain copies of the initial calibration report (containing non-linearized data) and the calibration report after applying linearization.
- When calibrating sensors that use a full-range conditioner, **Electrical Zero Lock** on the **Offset/Zero** menu must be set to **Lock**. Readjustment of electrical zero after calibration will change the point at which linearization takes place, disturbing other calibration settings.

Default sensor file locations

In MTS Series 793 software version 3.5x or earlier, the default location of sensor calibration files is:

C:\MTS software product name (for example, “FTGT”)\calib

In MTS Series 793 software version 4.0 or later, the default location of sensor calibration files is:

C:\MTS 793\Calibration Files.

Sensor calibration files in Projects

A Project is a folder that contains or references files that are used and generated by MTS 793 applications. When you start Station Manager, you select a Project. By default, Projects do not contain sensor calibration files directly, but reference their location in the Calibration Files subdirectory on disk.

You can use the Project Manager application to edit the Project Settings file to change the location of sensor calibration files.

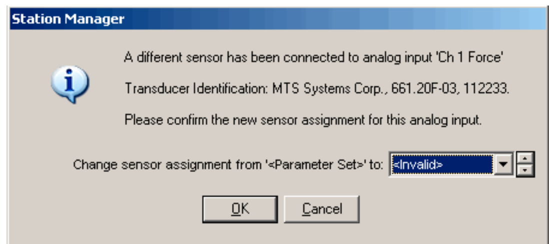
For more information about the Project Manager and Projects, see the *MTS Series 793 Control Software* manual (PN 100-147-130) and the *MTS Series 793 Controller Overview* manual (PN 100-162-928).

About TEDS Sensors

Note *Only controllers that use Series 494 Hardware support the use of MTS TEDS (transducer electronic data sheet) sensors.*

TEDS sensors have built-in memory chips that store basic TEDS information (manufacturer, model, number, and serial number).

When you connect an initialized TEDS device to a conditioner, the Station Manager application reads the basic TEDS information from the device, and a sensor assignment window appears.



The sensor file list in this window only lists sensor files that match the basic TEDS information, conditioner type, and dimension. The sensor assignment window contains the same sensor assignment list found in the Station Setup window.

TEDS devices

Available TEDS devices include:

- MTS sensors that include basic TEDS information saved in an integral TEDS chip that is built into the sensor.
- MTS TEDS Transducer ID modules that include a chip that stores basic TEDS information for a specific sensor. The TEDS module connects to the sensor.

Shunt Calibration

You can verify the calibration accuracy of a DC sensor/conditioner pair through shunt calibration. Shunt calibration works by shunting a precision resistor across one arm of the sensor's Wheatstone bridge. The resulting imbalance provides a reference value that is recorded on the calibration data sheet that accompanies the sensor.

Note *With systems that use Series 494 hardware, you can use the HWI Editor application to select the arm of the bridge where the shunt calibration resistor willl be applied.*

A current shunt calibration value, taken before a test, should be compared to the shunt calibration reference value recorded when the sensor was last calibrated. If the reference value and the current value differ too greatly, the sensor/conditioner pair should be recalibrated to establish a new shunt reference value.

Significant variations between current and reference values may occur if the excitation voltage has drifted, or the sensor has been damaged or has changed if some other way. It is possible to adjust excitation to compensate for small to moderate changes in the shunt calibration value.

When to use shunt calibration

You should perform a shunt calibration check when:

- You start a new test.
- You move a sensor to a different DC conditioner.
- You swap a DC conditioner module.
- You recalibrate a DC sensor.
- You change the sensor cable (resistance may differ).

Note *Shunt calibration can not be used to compensate for different length cables.*

Note *You cannot check shunt calibration of a sensor being used with the active control mode when hydraulic pressure is on.*

Note *Shunt calibration does not compensate for changes in the sensor sensitivity over time.*

How to perform a shunt calibration

Shunt calibration is a feature available for DC conditioners. It checks the integrity of the conditioner/sensor combination. It works by shunting a precision resistor across one arm of the sensor's Wheatstone bridge. The resulting imbalance provides a reference value for later use. Shunt calibration also lets you replace DC conditioners without affecting the sensor calibration accuracy.

Note *The following procedure requires that a valid shunt reference value has already been established. Establishing a shunt reference value involves selecting and installing precision shunt resistors, and is a part of detailed calibration instructions included in this manual. For information about establishing shunt reference for force sensors, see* *page 182**, and for strain sensors, see* *page 210**.*

1. Turn on hydraulic power.
2. Zero the DC sensor output.

   Standalone FlexTest SE Controllers:

   Use the **Manual Offset** control (**Setup** > **Force** > **Offset/Zero** > **Manual Offset**) to achieve a 0 kN output.

   Automated Controllers:

   Adjust the **Manual Cmd** slider on the **Manual Command** window to achieve a 0 kN output.

3. If necessary, change the control mode.

   Shunt calibration cannot be performed on a sensor when it is in control of the servo loop.

   Standalone FlexTest SE Controllers:

   Select **Status** > Control Mode > *displacement*.

   Automated Controllers:

   Change **Control mode** on the **Manual Command** window to a **Displacement** control mode.

Note *If you only want to view the current shunt value without changing the shunt reference value, the operator access level is adequate.*

4. Select an access level of Calibration.

5. Select the control mode to which shunt calibration applies.

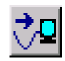
   Standalone FlexTest SE Controllers:

   Select **Setup** > *force or strain*> **Calibration**.

   Automated Controllers:

   A. In the **Station Manager** window's **Display** menu, select **Station Setup**.

   B. In the **Station Setup** window's navigation pane **Channels**, locate and select the control mode needing a shunt calibration (e.g., force or strain).

   C. In the **Station Setup** window, click .

6. Apply the shunt calibration.

   Standalone FlexTest SE Controllers:

   A. Locate the shunt calibration controls toward the bottom of the calibration menu.

   B. Apply the shunt by setting the **Shunt State (+)** control to **On**.

   Automated Controllers:

   A. In the **Inputs** panel, click the **Shunt** tab.

   B. If desired, change units for the **Shunt Reference Value**.

   C. To apply the shunt, click the button with three white bars.

   While the shunt is applied, the bars will turn green .

Note *To apply a shunt calibration to an auxiliary input, select **Auxiliary Inputs** in the navigation pane and click the input signal needing shunt calibration.*

7. Compare the **Current Shunt Value** to the **Shunt Reference Value**.

   Consider recalibrating the sensor/conditioner pair if the values differ by more than 0.2%. For example, if the **Shunt Reference Value** is displayed in Volts, consider recalibrating if the **Current Shunt Value** differs more than 20 mV.

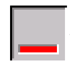
8. Remove the shunt.

   Standalone FlexTest SE Controllers:

   Set the **Shunt State (+)** control to **Off**.

   Automated Controllers:

   In the **Shunt** tab, click the button with one white bar to remove the shunt.

   The bar in the button will turn red .

Displacement Sensor Calibration

A displacement sensor (also called an LVDT) is calibrated with a dial indicator or some other displacement measuring device. The indicator is mounted between the actuator rod and a stationary point.

A typical LVDT has a positive and a negative output. This is usually considered tension and compression.

Displacement is usually calibrated such that the maximum extension and retraction represent ±100% of the full-scale capacity of the LVDT, with mid-displacement set at zero.

Prerequisites

Be sure the items described in “Pre-Calibration Considerations” on page 123 are true.

An LVDT requires AC excitation, which requires either a dedicated AC conditioner or a digital universal conditioner (DUC) configured in the AC mode. You must know which conditioner is connected to the LVDT.

Note *If you are recalibrating a sensor, use the existing calibration values as a starting point.*

Initial calibration

If you are calibrating a sensor for the first time, you may find it necessary to:

- Perform an initial tuning of the sensor channel before calibration.
- Perform the procedure twice.

Recalibration

If you are recalibrating a sensor, use the existing calibration values as a starting point.

Considerations for full-range conditioners

Full-range conditioners allow you to choose Gain/Delta K or Gain/Linearization for calibrating LVDTs. The mV/V Pos Tension and mV/V Pos Comp calibration types are typically not used for controllers equipped with full-range conditioners.

Considerations for Gain/Linearization calibrations

Gain/Linearization calibrations requires specific conditioner zeroing practices, as follows:

- Before and during calibration, ensure the **Manual Offset** and **Electrical Zero** controls on the **Offset/Zero** tab of the **Inputs** panel are set to zero. Also, ensure the **Electrical Zero Lock** box is set.
- After calibration, **do not change the electrical zero adjustment**. Readjustment of electrical zero after calibration will change the point at which linearization takes place, which will disturb other calibration settings.

Range support

Full-range conditioners (e.g. Model 493.25 DUCs) do not require individual ranges.

Ranged conditioners (e.g. Model 493.21/21B DUCs and Model 497.14 AC Conditioners) support up to four ranges for LVDT calibration. Displacement can be calibrated to any range within the full-scale capacity of the sensor. Also, ranges do not have to be centered on zero.

What you will need

You will need a dial indicator gage (or for longer displacements a measuring device such as a long ruler, laser, or optical detector) to calibrate an LVDT.

Note *All calibration tools should be calibrated to an industry standard.*

Note *This calibration procedure calibrates the conditioner for an actuator displacement of ±10 cm. You will need to adjust the procedure to accommodate your actuator displacement.*

Displacement Sensor Calibration: Abbreviated Procedure

The following abbreviated procedure outlines a displacement sensor (LVDT) calibration process. More detailed calibration information is available on the pages listed.

Task 1, “Get things ready,” on page 133

Task 2, “Turn on hydraulic pressure,” on page 136

Task 3, “Verify the conditioner polarity,” on page 137

Task 4, “Set the phase,” on page 137

Task 5, “Set the zero and offset,” on page 138

Task 6, “Gain/Delta K Calibration,” on page 142

Note *The Gain/Linearization Calibration procedure applies only to controllers equipped with full-range conditioners (e.g. Model 493.25 DUCs).*

Task 7, “Gain/Linearization Calibration,” on page 147

Task 8, “Save the calibration,” on page 154

Note *Controllers equipped with full-range conditioners (e.g. Model 493.25 DUCs) do not require multiple ranges.*

Task 9, “Calibrate additional ranges,” on page 155

Displacement Sensor Calibration: Detailed Procedure

Task 1 Get things ready

Perform the following before you start sensor calibration.

1. Locate relevant documentation.

   - You need information about the sensor such as the serial number, model number, excitation voltage, displacement, etc. This information can be found on the appropriate Calibration Data sheet included with your system, or the Final Inspection card included with all MTS sensors.
   - You need calibration identification numbers for any calibration tools that will be used for this calibration procedure (e.g., the dial indicator used for LVDT calibration). The calibration information is usually on a sticker attached to the equipment.
   - You need the appropriate DUC Conditioner serial number.

2. Open a station configuration file.

   You need a station configuration file that includes a control channel with a control mode that uses the sensor you intend to calibrate.

   Also, to monitor the sensor output signal with an external DVM, ensure that you have allocated an analog output resource (readout channel) in the Station Builder program.

3. On the **File** menu, select **Open Station**, and then open the appropriate configuration file on the **Open Station** window.Select the **Calibration** access level.

   Standalone FlexTest SE Controllers: Select **Config** > **Access Level** > **Calibration**

   Automated Controllers: On the **Station Manager** toolbar, select the **Calibration** user level on the **Access Level** list. Type the required password. By default, the password is *Calibration*; however, it can be changed during the software installation procedure.

4. Set up a signal monitor.

   You will be monitoring sensor output when making adjustments throughout this procedure. You can monitor the sensor output in the same units that you are using for the calibration.

   Standalone FlexTest SE Controllers: Use an external DVM to monitor sensor output from a BNC connector located on the front panel, or use the **Meters** panel.

   Automated Controllers:

   - Use an external DVM to monitor encoder output from a BNC connector on the Analog Out panel located on your controller chassis
   - Use the **Meters** window to monitor sensor output.
   - Use the **Station Signals** panel to monitor sensor output. On the Station Manager **Display** menu, select **Station Setup**. In the navigation pane, select **Station Signals** to display the **Station Signals** panel to monitor current values for user-defined signals.

   For more information on using the **Station Signals** panel, refer to "About the Station Signals Panel" in Chapter 2: Station Manager of the *MTS Series 793 Control Software* manual.

5. Select the desired calibration type.

   Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Calibration** > **Cal Type**

   Automated Controllers: On the Station Setup **Inputs** panel **Calibration** tab, use **Cal Type** for your selection

6. On the **Calibration** submenu or tab, set the initial conditioner calibration values. This creates a sensor calibration file and sets up your ranges. A typical complement of ranges could be: 100%, 50%, 20%, and 10% of full scale. You may create ranges for any percentage of full scale.

Note *Some systems do not provide or require multiple ranges, such as those using full-range conditioners (e.g., Model 493.25 DUC module). In this case, only one range is used (typically 100%).*

   See "How to Create a Sensor File" in the *MTS Series 793 Control Software* manual.

Conditioner calibration values

For LVDT calibration, set the following initial conditioner calibration values on the **Calibration** submenu or tab:

CONTROL	SETTING
Polarity	Normal
Pre-Amp Gain	1.0
Post-Amp Gain	1.5
Excitation	10 volts
Phase	45º
Delta K (Gain/Delta K calibration only)	1
Fine Zero	0

Task 2 Turn on hydraulic pressure

This task activates the hydraulic pressure.

WARNING

Do not place any part of your body in the path of a moving actuator.

A crush zone exists between the actuator and any equipment in the path of its movement. Immediate and unexpected actuator response is possible when you apply hydraulic pressure to your system.

Stay clear of the actuators when applying hydraulic pressure.

1. Ensure that displacement control mode is selected.

   Standalone FlexTest SE Controllers: Select **Status** > **Control Mode** > **Disp.**

   Automated Controllers: Check **Control Mode** on the Station Manager **Function Generator** panel.

2. Ensure that the **Span** is set for 100%.

   Standalone FlexTest SE Controllers: Select **Status** > **Span**

   Automated Controllers: Check the **Master Span** setting on the **Station Controls** panel

3. Check hydraulic and program interlock indicators.

   Standalone FlexTest SE Controllers: If the **Hydraulic Interlock** or **Program Interlock** indicator is lit on the front panel, determine the cause, correct it, and then click **Reset**.

   Automated Controllers: If the **Interlock** or **Program** indicator is lit on the **Station Controls** panel, determine the cause, correct it, and then click **Reset** or **Reset/Override**.

   If either interlock indicator lights again, you will need to determine the cause of the interlock and correct it before proceeding.

4. In the power selection box, click the **Low** button, and then **High** for the HPU. If an HPU is not listed, start the HPU at the pump.

Note *The HPU can be configured for “first on”. If this is the case, start the appropriate HSM.*

5. If an HSM is present, click the **Low** button, and then **High** for the HSM.

Task 3 Verify the conditioner polarity

This task checks the polarity of the conditioner. Different types of test systems are configured with different conditioner polarities. The polarity of the conditioner, the polarity of the valve driver, and the orientation of system cabling all play a role in controlling the actuator and determining how signals are displayed. This procedure assumes the servovalve polarity is set to **Normal** on the Station Setup **Drive** panel **Valve** tab.

1. Check the sensor connection.

   Be sure the displacement sensor is properly connected.

2. Apply a positive actuator command.

   Standalone FlexTest SE Controllers: Enable the front panel Dial, and then use the Dial to increase the **Setpoint** adjustment for a positive command.

   Automated Controllers: Open the **Manual Command** window, and then click on the **Enable Manual Command** check box to enable manual command. Increase the **Manual Cmd** adjustment for a positive command.

3. Monitor the displacement feedback.

   If the signal value is positive for actuator extension, the conditioner polarity is correct. If desired, you can change the conditioner polarity to make the signal value negative for actuator extension.

Note *The polarity setting should be the same when calibrating additional ranges for the same sensor.*

Task 4 Set the phase

This task determines the proper phase adjustment. The phase adjustment matches the phase of the AC feedback signal to the 10 kHz demodulation excitation signal.

1. Fully retract the actuator.

   Standalone FlexTest SE Controllers: Using the front panel Dial, adjust the **Setpoint** to fully retract the actuator. Select **Status** > **Setpoint**

   Automated Controllers: Adjust the **Manual Cmd** slider control on the **Manual Command** window to fully retract the actuator.

2. Remove hydraulic pressure.

3. Adjust phase for the maximum conditioner output.

   Monitor the appropriate AC conditioner feedback signal. Adjust **Phase** to achieve a maximum value.

   Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Calibration** > **Phase**

   Automated Controllers: Adjust the **Phase** control on the **Calibration** tab to achieve a maximum value. Use the **Station Signals** panel to monitor the appropriate AC conditioner feedback signal

Note *When adjusting phase, the LVDT feedback may exceed 10 volts. You may need to lower conditioner gain before continuing phase adjustment.*

Task 5 Set the zero and offset

Establishing zero requires the actuator to be set at mid-displacement when you calibrate the LVDT for equal amounts of actuator extension and retraction.

Suppose you have an actuator with ±10 cm displacement—which actually has a 20 cm displacement. Setting zero at mid-displacement produces a displacement of ±10 cm (this is the most common approach). However, you can set zero anywhere within the full scale of the sensor, such as with the actuator fully extended or retracted to produce a displacement range of 0 mm - 20 mm.

Before beginning, ensure the following are true:

- The **Fine Zero** adjustment is set to 0.

  Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Calibration** > **Fine Zero**

  Automated Controllers: Adjust **Fine Zero** on the **Calibration** tab.

- The **Manual Offset** is set to 0.

  Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Offset/Zero** > **Manual Offset**

  Automated Controllers: Adjust **Manual Offset** on the **Offset/Zero** tab.

- The **Electrical Zero** adjustment is set to 0.

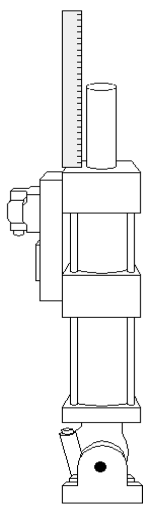
  Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Offset/Zero** > **Electrical Zero**

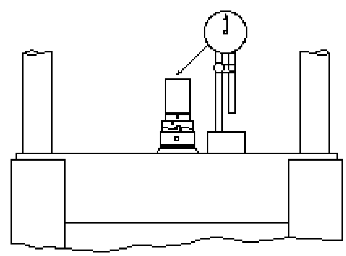
  Automated Controllers: Adjust **Electrical Zero** on the **Offset/Zero** tab

1. Mount the displacement measuring device.

   Mount the measuring device to measure the distance between the end of the actuator's piston rod and a stationary point such as the actuator's upper endcap. There are a variety of ways to measure actuator displacement:

   - Dial Indicator
   - Tape Measure/Ruler
   - Optical Detector
   - Encoder





   - You may need to place the dial indicator on a block to measure the mid-displacement position.
   - Be sure to zero the dial indicator after you position it properly.

2. Ensure that displacement control mode is selected.

   Standalone FlexTest SE Controllers: Select **Status** > **Control Mode** > **Disp.**

   Automated Controllers: In the **Manual Command** window perform the following:

   A. Select the appropriate **Channel** associated with the LVDT signal you are calibrating.

   B. For the **Control Mode**, select **Displacement**.

   C. Click **Enable Manual Command**.

3. Evaluate the mid-displacement position for the actuator.

Standalone FlexTest SE Controllers:

A. Enable the front panel Dial.

B. Use the Dial to increase the **Setpoint** adjustment for a positive command.

Select **Status** > **Setpoint**

C. Adjust the **Setpoint** to fully extend the actuator and note the displacement signal value.

D. Adjust the **Setpoint** to fully retract the actuator and note the displacement signal value.

Automated Controllers:

A. Move the **Manual Cmd** slider to apply a positive command (extend the actuator).

B. Adjust the **Manual Cmd** slider to fully extend the actuator and note the displacement signal value in the **Station Signals** panel.

C. Adjust the **Manual Cmd** slider to fully retract the actuator and note the displacement signal value in the **Station Signals** panel.

The noted displacement signal values should be within 1% of each other.

If these displacement signals are not within 1%, you can evaluate the following procedures to establish the zero reference:

- Use the **Fine Zero** adjustment to shift the sensor conditioner's zero reference position.

  Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Calibration** > **Fine Zero**

  Automated Controllers: Adjust **Fine Zero** on the **Calibration** tab.

Note *Some conditioners have two zero adjustments (coarse and fine). Try to calibrate zero using only the* ***Fine Zero*** *control whenever possible. Using the* ***Coarse Zero*** *control affects the signal before the post amp stage of the conditioner and may require additional* ***Gain*** *adjustments.*

- In some cases, a mechanical adjustment may be necessary to center the LVDT (for instructions, see the actuator product manual).

Task 6 Gain/Delta K Calibration

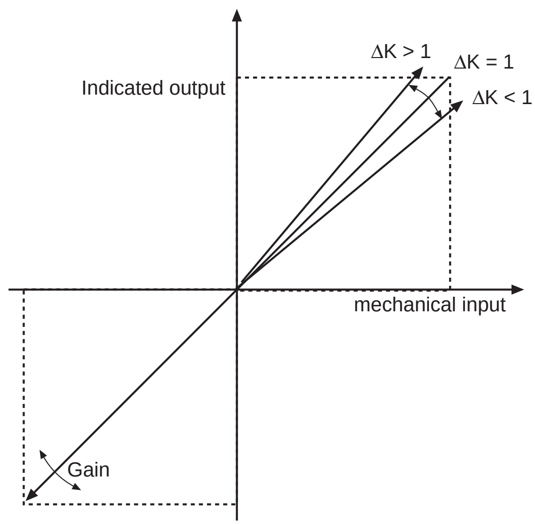
If you using **Gain/Delta-K** for your calibration type, complete the following procedure. If not, complete **Task 7 Gain/Linearization Calibration on page 147**

Calibrate actuator retraction

LVDTs can be calibrated so that a positive output represents actuator extension and a negative output represents actuator retraction, or vice versa.

You calibrate the negative side of the output with gain and the positive side of the output with Delta K.

Delta K compensates for differences in symmetry between the positive and negative outputs.



You should calibrate actuator extension at 80% of the full scale range.

Gain controls

Pre-Amp gain is a selectable gain amplifier with predefined values. Since changes in **Pre-Amp** gain can cause spikes in the feedback signal, **Pre-Amp** gain can only be adjusted when hydraulics are off.

Post-Amp gain is a finer, operator-defined gain control that can be adjusted when hydraulics are on.

The **Total Gain** value is calculated by multiplying the **Pre-Amp** and **Post-Amp** gain values. If the total desired gain amount is known (from a calibration sheet), you can enter the amount in the **Total Gain** box and the software will calculate the **Pre-Amp** and **Post-Amp** gain values automatically.

When you are calibrating an AC conditioner, use the **Post-Amp** gain control to increase gain. If more gain is needed, you must disable hydraulics and increase the **Pre-Amp** gain. You can then turn on hydraulics and continue to adjust the **Post-Amp** gain.

Note *This procedure assumes a positive command extends the actuator and a negative command retracts the actuator. If not, use the opposite polarity for any values given.*

Procedure

1. Select **Gain/Delta-K** for **Cal Type**.

   Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Calibration** > **Cal Type** > **Gain/Delta-K**

   Automated Controllers: Select **Gain/Delta-K** for **Cal Type** on the **Calibration** tab of the **Inputs** panel.

2. Apply a retraction command that is 80% of the full scale range.

   Standalone FlexTest SE Controllers: Standalone FlexTest SE Controllers:

   A. Enable the front panel Dial.

   B. Use the Dial to adjust the **Setpoint** for 80% of the full scale range.

   C. Verify that your LVDT displacement signal equals 80% of the full scale range.

   Automated Controllers:

   A. Open the **Manual Command** window, and then click on the **Enable Manual Command**.

   B. Adjust the **Manual Cmd** slider on the **Manual Command** window for 80% of the full scale range.

   C. Use the **Station Signals** panel to verify that your LVDT displacement signal equals 80% of the full scale range.

   During the initial calibration and tuning of your system, it may take repeated adjustment for the two values to match.

Note *If the actuator response is sluggish and/or the signal value does not match the command, you will need to adjust the tuning of this control mode. Increase the proportional gain (**P Gain** on the **Tuning** menu) to correct sluggish actuator movement. Increase the integration value (**I Gain**) to help the feedback match the command.*

At this point, unless the conditioner is already in calibration, the actuator’s physical retraction will not equal your commanded value. You will adjust gain in the next step so that the actuator’s physical retraction and your commanded retraction match.

Example: Suppose your actuator has a 100% retraction of -10 cm. In this step you would apply a -8 cm command, and even though the station signals would read -8 cm of feedback, the actuator may retract only -4 cm. This shows the conditioner/sensor pair are out of calibration.

3. Adjust gain to retract the actuator until it equals your retraction command.

   Adjust **Post-Amp Gain** until your dial indicator or other readout device shows that the actuator’s physical retraction equals your retraction command.

Note *This procedure assumes a positive command extends the actuator and a negative command retracts the actuator. If not, use the opposite polarity for any values given.*

4. If applicable, repeat steps 1 - 3 for all ranges.

   Example: Suppose you have an actuator with a full-scale capacity of ±10 cm and ranges of ±10 cm, ±5 cm, ±2 cm, and ±1 cm. In this case you would repeat this process and calibrate retraction at 80% of each range (-8 cm, -4 cm, -1.6 cm, and -0.8 cm).

Note *Some systems do not provide or require multiple ranges, such as those using full-range conditioners (e.g., Model 493.25 DUC module). In this case, only one range is used (typically 100%).*

Calibrate actuator extension

Note *This procedure assumes a positive command extends the actuator and a negative command retracts the actuator. If not, use the opposite polarity for any values given.*

5. Apply an extension command that is 80% of the full scale range

   Standalone FlexTest SE Controllers:

   A. Enable the front panel Dial.

   B. Use the Dial to adjust the **Setpoint** for 80% of the full scale range.

C. Verify that your LVDT displacement signal equals 80% of the full scale range.

Automated Controllers:

A. Open the **Manual Command** window, and then click on the **Enable Manual Command**.

B. Adjust the **Manual Cmd** slider on the **Manual Command** window for 80% of the full scale range.

C. Use the **Station Signals** panel to verify that your LVDT displacement signal equals 80% of the full scale range.

During the initial calibration and tuning of your system, it may take a while for the two values to match.

Note *If the actuator response is sluggish and/or the signal value does not match the command, you will need to adjust the tuning of this control mode. Increase the proportional gain (**P Gain** on the **Tuning** menu) to correct sluggish actuator movement. Increase the reset integration value (**I Gain**) to help the feedback match the command.*

At this point, unless the conditioner is already calibrated, the actuator's physical extension will not equal your commanded value. You will adjust Delta K in the next step so that the actuator's physical extension and your commanded extension match.

Example: Suppose your actuator has a 100% extension of 10 cm. In this step you would apply a 8 cm command, and even though the station signals would read 8 cm of feedback, the actuator may extend only 4 cm. This shows the conditioner/sensor pair are out of calibration.

6. Adjust **Delta K** to extend the actuator until it equals your extension command.

   Adjust **Delta K** until the dial indicator or other readout device shows that the actuator's physical extension equals your extension command.

7. If applicable, repeat steps 5 and 6 for all ranges.

   Example: Suppose you have an actuator with a full-scale capacity of ±10 cm and ranges of ±10 cm, ±5 cm, ±2 cm, and ±1 cm. In this case you would repeat this process and calibrate extension at 80% of each range (8 cm, 4 cm, 1.6 cm, and 0.8 cm).

Note *Some systems use full-range conditioners (e.g., Model 493.25 DUC module). In this case, only one range is used (typically 100%).*

Record data points

The accuracy tolerance of your data depends on the manufacturer of your sensor. Your sensor should include a calibration data sheet that shows the data point tolerance. Sensors from MTS include a sensor calibration data sheet that shows the data points as it was calibrated.

1. Record the data points for LVDT extension.

   Standalone FlexTest SE Controllers:

   A. Adjust the **Setpoint** to achieve zero command.

   B. Adjust the dial indicator for a zero reference.

   C. Adjust the **Setpoint** to 20% extension and record the dial indicator reading. Repeat this step for 40%, 60%, 80%, and 100% actuator extension.

   Automated Controllers:

   A. Adjust the **Manual Cmd** slider to achieve zero command.

   B. Adjust the dial indicator for a zero reference.

   C. Adjust the **Manual Cmd** slider to 20% extension and record the dial indicator reading. Repeat this step for 40%, 60%, 80%, and 100% actuator extension.

2. Record the data points for LVDT retraction.

   Standalone FlexTest SE Controllers:

   A. Adjust the **Setpoint** to achieve zero command.

   B. Adjust the dial indicator for a zero reference.

   C. Adjust the **Setpoint** to 20% retraction and record the dial indicator reading. Repeat this step for 40%, 60%, 80%, and 100% actuator retraction.

   Automated Controllers:

   A. Adjust the **Manual Cmd** slider to achieve zero command.

   B. Adjust the dial indicator for a zero reference.

   C. Adjust the **Manual Cmd** slider to 20% retraction and record the dial indicator reading. Repeat this step for 40%, 60%, 80%, and 100% actuator retraction.

Note *The Gain/Linearization Calibration procedure that follows applies only to controllers equipped with full-range conditioners (e.g., Model 493.25 DUC module).*

Task 7 Gain/Linearization Calibration

If you are using **Gain/Linearization** for your calibration type, complete the following procedure. If not, complete **Task 6 Gain/Delta K Calibration on page 142**.

Important *Using linearization data requires specific conditioner zeroing practices. Ensure that **Electrical Zero*** is set to zero and the ***Electrical Zero Lock*** box is set (enabled). *Adjusting electrical zero after calibration may invalidate linearization data.*

Initial LVDT calibration

For initial calibration of an LVDT complete the following procedure:

1. Select **Gain/Linearization** for **Cal Type**.

   Standalone FlexTest SE Controllers: Select **Setup** > **Disp.** > **Calibration** > **Cal Type** > **Gain/Linearization**

   Automated Controllers: Select **Gain/Linearization** for **Cal Type** on the **Calibration** tab of the **Inputs** panel.

2. Apply a retraction command that is 80% of the full scale range.

   Standalone FlexTest SE Controllers:

   A. Enable the front panel Dial.

   B. Use the Dial to adjust the **Setpoint** for 80% of the full scale range.

   C. Verify that your LVDT displacement signal equals 80% of the full scale range.

   Automated Controllers:

   A. Open the **Manual Command** window, and then click on the **Enable Manual Command**.

   B. Adjust the **Manual Cmd** slider on the **Manual Command** window for 80% of the full scale range.

   C. Use the **Station Signals** panel to verify that your LVDT displacement signal equals 80% of the full scale range. During the initial calibration and tuning of your system, it may take repeated adjustment for the two values to match.

Note *If the actuator response is sluggish and/or the signal value does not match the command, you will need to adjust the tuning of this control mode. Increase the proportional gain (**P Gain** on the **Calibration** submenu or tab) to correct sluggish actuator movement. Increase the reset integration value (**I Gain**) to help the feedback match the command.*

At this point, unless the conditioner is already in calibration, the actuator's physical retraction will not equal your commanded value. You will adjust gain in the next step so that the actuator's physical retraction and your commanded retraction match.

Example: Suppose your actuator has a 100% retraction of -10 cm. In this step you would apply a -8 cm command, and even though the station signals would read -8 cm of feedback, the actuator may retract only -4 cm. This shows the conditioner/sensor pair are out of calibration.

3. Adjust gain to retract the actuator until it equals your retraction command.

Standalone FlexTest SE Controllers:

Select **Setup** > **Disp.** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Post-Amp Gain**

Automated Controllers:

Adjust **Post-Amp Gain** on the **Calibration** submenu or tab until your dial indicator or other readout device shows that the actuator's physical retraction equals your retraction command.

4. Record dial indicator and conditioner feedback readings at predetermined retraction command points.

Note *After shutting down system hydraulics, you will enter these recorded readings on the Linearization Data window.*

Standalone FlexTest SE Controllers:

A. Use the Dial to adjust the **Setpoint** for a 0% command.

B. Record the dial indicator value for the 0% command.

C. Enter the corresponding conditioner feedback reading.

D. Use the Dial to adjust the **Setpoint** for a -2% retraction command.

E. Record the dial indicator value and conditioner feedback at the -2% row of your record sheet.

F. Repeat steps D and E for other retraction commands (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

Automated Controllers:

A. Adjust the **Manual Cmd** slider for a 0% command.

B. Record the dial indicator value for the 0% command.

C. Enter the corresponding conditioner feedback reading in the **Conditioner** column at the appropriate row in the window.

D. Adjust the **Manual Cmd** slider for a -2% retraction command.

E. Record dial indicator value and conditioner feedback at the -2% row of your record sheet.

F. Repeat steps D and E for other retraction commands (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

5. Record dial indicator and conditioner feedback readings at predetermined extension command points.

Standalone FlexTest SE Controllers:

A. Use the Dial to adjust the **Setpoint** for a +2% extension command.

B. Record the dial indicator and conditioner feedback values at the +2% row of your record sheet.

C. Repeat steps A and B for other extension commands (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale).

Automated Controllers:

A. Adjust the **Manual Cmd** slider for a +2% extension command.

B. Record the dial indicator value and conditioner feedback at the +2% row of your record sheet.

C. Repeat steps A and B for other extension commands (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale)

6. Turn off system hydraulics.

7. On the Linearization Data window, enter the dial indicator and conditioner feedback readings for all command points previously recorded.

   Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Linearization Data**

   Automated Controllers: Click **Linearization Data** on the **Calibration** tab to open the Linearization Data window.

8. Turn on system hydraulics.

LVDT recalibration

If the LVDT has been previously calibrated, use the following procedure:

1. Locate the calibration data sheet for the appropriate conditioner.
2. Ensure that system hydraulics is off.
3. Open the **Linearization Data** window.

   Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Linearization Data**

   Automated Controllers: Click **Linearization Data** on the **Calibration** tab to open the Linearization Data window.

4. Transfer **Standard** and **Conditioner** data from the conditioner's calibration data sheet to corresponding data entries on the Linearization Data window.
5. Turn on system hydraulics.
6. Verify the linearization data.

   Standalone FlexTest SE Controllers:

   A. Using the front panel Dial, adjust the **Setpoint** for each retraction and extension command point on the Linearization Data window.

   B. At each command point, verify both the dial indicator value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**) with the corresponding values on the Calibration Data sheet.

   Automated Controllers:

   A. Adjust the **Manual Cmd** slider for each retraction and extension command point on the Linearization Data window.

B. At each command point, verify both the dial indicator value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**) with the corresponding values on the Calibration Data sheet

If the data is valid: **Stop** this procedure.

If the data is not valid: **Proceed** to the next step.

7. Reset Linearization Data window to default values.

Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Calibration** > **Cal Type** > **Gain/Linearization** > **<<Reset>>**

Automated Controllers: Click **Reset** on the Linearization Data window.

8. Apply a retraction command that is 80% of the full scale range.

Standalone FlexTest SE Controllers:

A. Use the front panel Dial to adjust the **Setpoint** for 80% of the full scale range. Select **Status** > **Setpoint**

B. Verify that your LVDT displacement signal equals 80% of the full scale range.

Automated Controllers:

A. Adjust the **Manual Cmd** slider on the **Manual Command** window for 80% of the full scale range.

B. Use the **Station Signals** panel to verify that your LVDT displacement signal equals 80% of the full scale range.

During the initial calibration and tuning of your system, it may take repeated adjustment for the two values to match.

Note *If the actuator response is sluggish and/or the signal value does not match the command, you will need to adjust the tuning of this control mode. Increase the proportional gain (**P Gain** on the **Tuning** menu) to correct sluggish actuator movement. Increase the reset integration value (**I Gain**) to help the feedback match the command.*

At this point, unless the conditioner is already in calibration, the actuator's physical retraction will not equal your commanded value. You will adjust gain in the next step so that the actuator's physical retraction and your commanded retraction match.

Example: Suppose your actuator has a 100% retraction of -10 cm. In this step you would apply a -8 cm command, and even though the station signals would read -8 cm of feedback, the actuator may retract only -4 cm. This shows the conditioner/sensor pair are out of calibration.

9. Adjust gain to retract the actuator until it equals your retraction command.

   Standalone FlexTest SE Controllers: Select **Setup** > **Disp** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Post-Amp Gain**

   Automated Controllers: Adjust the **Post-Amp Gain** slider control on the **Calibration** tab

   Adjust **Post-Amp Gain** until your dial indicator or other readout device shows that the actuator's physical retraction equals your retraction command.

10. Record dial indicator and conditioner feedback readings at predetermined retraction command points.

Note *After shutting down system hydraulics, you will enter these recorded readings on the Linearization Data window.*

Standalone FlexTest SE Controllers:

A. Use the front panel Dial to adjust the **Setpoint** for a 0% command.

B. Record the dial indicator value at 0% command.

C. Record the corresponding conditioner feedback reading on your record sheet.

D. Use the Dial to adjust the **Setpoint** for a -2% retraction command.

E. Record the dial indicator value and conditioner feedback at the -2% row of your sheet.

F. Repeat steps D and E for other retraction commands (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

Automated Controllers:

A. Adjust the **Manual Cmd** slider for a 0% command.

B. Record the dial indicator value at 0% command.

C. Record the corresponding conditioner feedback reading at the 0% row of your record sheet.

D. Adjust the **Manual Cmd** slider for a -2% retraction command.

E. Record the dial indicator and conditioner feedback values at the -2% row of your record sheet.

F. Repeat steps D and E for other retraction commands (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

11. Record dial indicator and conditioner feedback readings at predetermined extension command points.

Standalone FlexTest SE Controllers:

A. Use the front panel Dial to adjust the **Setpoint** for a +2% extension command.

B. Record the dial indicator value and conditioner feedback at the +2% row of your record sheet.

C. Repeat steps A and B for other extension commands (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale).

Automated Controllers:

A. Adjust the **Manual Cmd** slider for a +2% extension command.

B. Record the dial indicator value and conditioner feedback at the -2% row of your record sheet.

C. Repeat steps A and B for other extension commands (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale).

12. Turn off system hydraulics.

13. On the Linearization Data window, enter the dial indicator and conditioner feedback readings for all command points previously recorded on a separate sheet.

14. Turn on system hydraulics.

15. Verify linearization data.

Standalone FlexTest SE Controllers:

A. Using the front panel Dial, adjust the **Setpoint** for each retraction and extension command point on the Linearization Data window.

B. At each command point, verify both the dial indicator value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**).

C. Check validity before entering each pair of values on a new Calibration Data Sheet.

Automated Controllers:

A. Adjust the **Manual Cmd** slider for each retraction and extension command point on the Linearization Data window.

B. At each command point, verify both the dial indicator value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**).

C. Check validity before entering each pair of values on a new Calibration Data Sheet.

Task 8 Save the calibration

It is important that you save your sensor calibration values.

Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters** > **<<Save>>**

Automated Controllers: Click **Save** on the **Calibration** tab to save the current calibration values to the sensor calibration file.

Note *Systems equipped with full range conditioners (e.g., Model 493.25 DUC module) do not require or support multiple ranges. They use one range that is typically set to 100%.*

Task 9 Calibrate additional ranges

Each sensor calibration file can have calibration data for four ranges. If you have a need for additional ranges, simply create another sensor calibration range.

- Use the calibration values from the previous range as a starting point.
- If you adjust the zero reference, it may affect the other ranges.

Adding a range

If the sensor calibration file must have additional ranges defined, perform the following:

1. On the **Tools** menu, select **Sensor File Editor**.
2. Open the sensor file for the sensor you have just calibrated.
3. Click **Add** under **Range Definition**.
4. Select the units for the range, and then enter the absolute value of the range.
5. Save the new range to the calibration file.
6. Calibrate the added range

Note *Ranges can also be added on the **Sensor** tab and calibrated on the **Calibration** tab.*

Force Sensor Calibration

A force sensor (also called a load cell) is calibrated with a load standard. A load standard can be a special calibrated force sensor with its own electronics or a set of calibrated dead weights. A force sensor is calibrated such that the maximum compression and tension represent ±100% of the full-scale capacity of the sensor, with zero force set at midcapacity.

Prerequisites

Be sure the items described in "Pre-Calibration Considerations" on page 123 are true.

A force sensor requires DC excitation, which requires either a dedicated DC conditioner or a digital universal conditioner (DUC) configured in the DC mode.

You must know which conditioner is connected to the force sensor.

Initial calibration

If you are calibrating a sensor for the first time, you may find it necessary to:

- Perform an initial tuning of the sensor channel before calibration.
- Perform the procedure twice.

Recalibration

If you are recalibrating a sensor, use the existing calibration values as a starting point.

Considerations for full-range conditioners

Full-range conditioners allow you to choose Gain/Delta K or Gain/Linearization for calibrating force conditioners. The mV/V Pos Tension and mV/V Pos Comp calibration types are typically not used for controllers equipped with full-range conditioners.

- During calibration, **Manual Offset** should always be set to zero.
- During calibration, ensure that **Electrical Zero Lock** is checked on the **Offset/Zero** tab of the **Inputs** panel.
- After calibration, **do not change the electrical zero adjustment**. Readjustment of electrical zero after calibration will change the point at which linearization takes place, disturbing other calibration settings (especially Delta K).

Range support

Full-range conditioners (e.g. Model 493.25 DUCs) do not require individual ranges.

Ranged conditioners (e.g. Model 493.21/21B DUCs and Model 497.22 DC Conditioners) support up to four ranges for force sensor calibration. Force can be calibrated to any range within the full-scale capacity of the sensor. Also, ranges do not have to be centered on zero.

What you will need

You will need the following items to calibrate a a force sensor.

- A load standard can be a calibrated force sensor with its own electronics or it can be a calibrated set of dead weights.
- A DVM to monitor the output of the load standard.

Note *All calibration tools should be calibrated to an industry standard.*

Note *This calibration procedure calibrates the DC conditioner for a force sensor of ±10 kN. You will need to adjust the procedure to accommodate your force sensor.*

Force Sensor Calibration: Abbreviated Procedure

The following abbreviated procedure outlines a force sensor (load cell) calibration process. More detailed calibration information is available on the pages listed.

Task 1, "Get things ready," on page 159

Task 2, "Turn on hydraulic pressure," on page 162

Task 3, "Verify the conditioner polarity," on page 162

Task 4, "Set the zero and offset," on page 163

Task 5, "Gain/Delta K Calibration," on page 163

Note *The Gain/Linearization Calibration procedure applies only to controllers equipped with full-range conditioners (e.g., Model 493.25 DUC module).*

Task 6, "Gain/Linearization Calibration," on page 170

Task 7, "Millivolt/Volt Calibration," on page 179

Task 8, "Establish the shunt calibration reference," on page 182

Task 9, "Save the calibration," on page 186

Note *Controllers equipped with full-range conditioners (e.g., Model 493.25 DUC module) do not provide or require multiple ranges.*

Task 10, "Calibrate additional ranges," on page 187

Force Sensor Calibration: Detailed Procedure

Task 1 Get things ready

Perform the following before you start sensor calibration.

1. Locate relevant documentation.
   - You need information about the force sensor such as the serial number, model number, excitation voltage, capacity, etc. The information can be found on the Force Transducer Calibration Data sheet included with a calibrated force sensor, or the Final Inspection card included with all MTS sensors.
   - You need calibration identification numbers for the force standard (or any other calibration equipment) that will be used for this calibration procedure. The calibration information is usually on a sticker attached to the equipment.
   - You need the serial number of the Digital Universal Conditioner.
   - You will need shunt calibration resistors.
2. Set up to monitor load standard output.

   Typically, you should monitor the load standard output signal with a digital volt meter (DVM) when you calibrate a force sensor.
3. Open a station configuration file.

   You need a station configuration file that includes a control channel with a control mode that uses the sensor you intend to calibrate.

   Also, to monitor the force sensor signal with an external DVM, ensure that you have allocated an analog output resource (readout channel) in the Station Builder program.

   On the **File** menu, select **Open Station** to open the appropriate configuration file on the **Open Station** window.

4. Select the **Calibration** access level.

   Standalone FlexTest SE Controllers: Select **Config** > **Access Level** > **Calibration**

   Automated Controllers: In the **Station Manager** window toolbar, select **Calibration**

5. Set up a signal monitor.

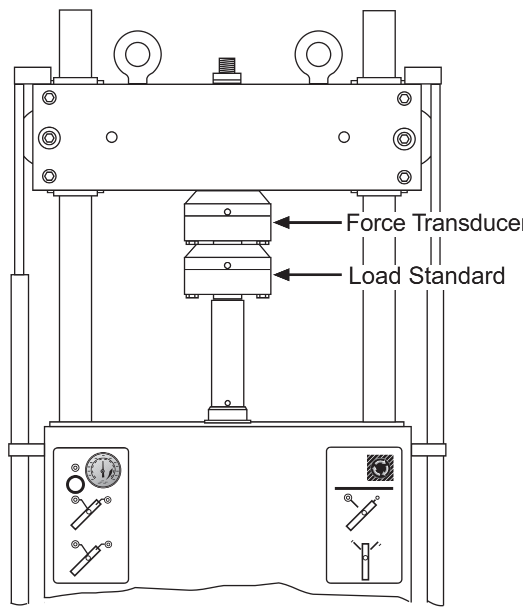
   See page 134 for more information.

6. Mount the force standard.

The illustration shows a load standard in-line with the force train coupled with the force sensor.

The load standard reacts like a stiff specimen. Be sure the gain settings (PID) for the control mode are appropriate.

If the control mode has not been tuned yet, use some default values. Then recalibrate the sensor after the initial tuning.



7. If you are using Gain/Delta K or Gain/Linearization for calibration, set initial conditioner calibration values on the Calibration submenu. A typical complement of ranges could be: 100%, 50%, 20%, and 10% of full scale. You can create ranges for any percentage of full scale. This creates a sensor calibration file and sets up any ranges you may want.

   Example: Suppose you have an actuator with a full-scale capacity of ±10 kN. You might create ranges for ±10 kN, ±5 kN, ±2.0 kN, and ±1.0 kN.

Note *Some systems do not provide or require multiple ranges, such as those using full-range conditioners (e.g., Model 493.25 DUC module). In this case, only one range is used (typically 100%).*

Note *Sensor calibration and range information can be edited on the* ***Sensor*** *tab, located on the* ***Station Setup*** *window* ***Inputs*** *panel.*

See “How to Create a Sensor File” in Chapter 2: Station Manager of the *MTS Series 793 Control Software* manual.

Conditioner calibration values

For force sensor calibration, set the following initial conditioner calibration values.

CONTROL	SETTING
Polarity	Normal
Pre-amp Gain	250 480 (for Model 493.25 conditioner)
Post-amp Gain	2 1 (for Model 493.25 conditioner)
Total Gain	500
Excitation	10 volts
Fine Zero	0
Zero/Balance	0
Delta K (Gain/Delta K calibration only)	1

Task 2 Turn on hydraulic pressure

WARNING

Do not place any part of your body in the path of a moving actuator.

A crush zone exists between the actuator and any equipment in the path of its movement. Immediate and unexpected actuator response is possible when you apply hydraulic pressure to your system.

Stay clear of the actuators when applying hydraulic pressure.

See "Turn on hydraulic pressure" on page 136 for a detailed procedure.

Task 3 Verify the conditioner polarity

This task checks the polarity of the conditioner. Different types of test systems are configured with different conditioner polarities. The polarity of the conditioner, the polarity of the valve driver, and the connection positions of system cabling all play a role in controlling the actuator and determining how signals are displayed.

This procedure assumes the servovalve polarity is set to **Normal** on the Station Setup **Drive** panel **Valve** tab.

1. Check the sensor connection.

   Be sure the force sensor is properly connected to the controller.

2. Apply a load to the force sensor.

   Push on the force sensor (with your hand) and note the signal value on the DVM, front panel meter (Standalone), or **Station Signals** (automated).

   If the signal value is positive for actuator compression, the conditioner polarity is correct. If desired, you can change the conditioner polarity to make the signal value negative for actuator compression.

Note *The polarity setting should be the same when calibrating additional ranges for the same sensor.*

Task 4 Set the zero and offset

This task records the load standard readout as the zero reference.

Using a load standard

Standalone FlexTest SE Controllers: Adjust the **Setpoint** for 0 kN. Then zero the load standard readout. Select **Status** > **Setpoint**

Automated Controllers: Adjust the **Manual Cmd** slider on the **Manual Command window** for 0 kN. Then zero the load standard readout.

Using dead weights

Standalone FlexTest SE Controllers: Remove all dead weights, and then click **Auto Offset** on the **Offset/Zero** menu. Select **Setup** > **Force** > **Offset/Zero** > **<<Auto Offset>>**

Automated Controllers: Remove all dead weights, and then click **Auto Offset** on the **Offset/Zero** tab (**Inputs** panel).

Task 5 Gain/Delta K Calibration

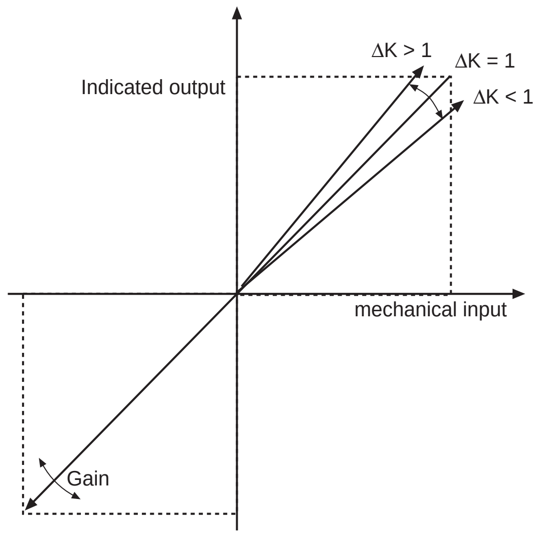
If you using **Gain/Delta-K** for your calibration type, complete the following procedure. If not, complete "Gain/Linearization Calibration" **on page 170** or "Millivolt/Volt Calibration" on page 179.

Calibrate tension

Force sensors can be calibrated so that a positive output represents actuator compression and a negative output represents actuator tension, and vice versa.

You calibrate the negative side of the output with gain and the positive side of the output with Delta K.

Delta K compensates for differences in symmetry between positive and negative outputs.



Calibrate compression at 80% full scale for each range.

Note *This procedure assumes a positive command extends the actuator and a negative command retracts the actuator. If not, use the opposite polarity for any values given.*

Gain controls

Pre-Amp gain is a selectable gain amplifier with predefined values. Since changes in **Pre-Amp** gain can cause spikes in the feedback signal, **Pre-Amp** gain can only be adjusted when hydraulics are off.

Post-Amp gain is a finer, operator-defined gain control that can be adjusted when hydraulics are on.

The **Total** gain value is calculated by multiplying the **Pre-Amp** and **Post-Amp** gain values. If the total desired gain amount is known (from a calibration sheet), you can enter the amount in the **Total** gain box and the software will calculate the **Pre-Amp** and **Post-Amp** gain values automatically.

When you are calibrating a DC conditioner, use the **Post-Amp** gain control to increase gain. If more gain is needed, you must disable hydraulics and increase the **Pre-Amp** gain. You can then turn on hydraulics and continue to adjust the **Post-Amp** gain.

1. Select **Gain/Delta-K** for **Cal Type**.

   Standalone FlexTest SE Controllers: Select **Setup** > **Force** > **Calibration** > **Cal Type** > **Gain/Delta-K**

   Automated Controllers: Select **Gain/Delta-K** for **Cal Type** on the **Calibration** tab of the **Inputs** panel.

2. Exercise the force standard.

   Standalone FlexTest SE Controllers: After enabling the front panel Dial, adjust the **Setpoint** to cycle the load standard readout between zero and full tension three times. This removes sensor hysteresis. Select **Status** > **Setpoint**

   Automated Controllers: Use the **Manual Cmd** slider on the **Manual Command** window to cycle the load standard readout between zero and full tension three times. This removes sensor hysteresis.

   Example: When calibrating a ±10 kN range, exercise the actuator between 0 and -10 volts. To calibrate the same force sensor for a different range such as ±5 kN, exercise the load standard between 0 and -5 volts.

3. Apply a tensile force command that is 80% of the full scale range.

   Standalone FlexTest SE Controllers:

   A. Using the Dial, adjust the **Setpoint** for a tensile force command that is 80% of the full scale range.

   B. Verify that your force transducer feedback signal is 80% of the full scale range.

   Automated Controllers:

   A. Open the **Manual Command** window, and then click on the **Enable Manual Command**.

   B. Adjust the **Manual Cmd** slider on the **Manual Command** window for 80% of the full scale range.

   C. Use the **Station Signals** panel to verify that your force transducer signal equals 80% of the full scale range.

   During the initial calibration and tuning of your system, it may require repeated adjustment for the tensile force command and feedback values to match.

Note *If the actuator response is sluggish and/or the signal value does not match the command, you will need to adjust the tuning of this control mode. Increase the proportional gain (**P Gain** on the **Tuning** menu) to correct sluggish actuator movement. Increase the reset integration value (**I Gain**) to help the feedback match the command.*

At this point, unless the conditioner is already in calibration, the tensile force applied to the force transducer will not equal your commanded value. You will adjust gain in the next step so that the actual tensile force (as measured by the load standard) and your commanded tensile force match.

Example: Suppose your actuator has a 100% tensile force rating of -10 kN. In this step you would apply -8 kN of command, and even though the station signals would read -8 kN of feedback, the force standard may only read -4 kN. This shows the conditioner/sensor pair are out of calibration.

4. Adjust **Post-amp Gain** on the **Calibration** submenu or tab to increase the tensile force reading on the load standard until it equals your tensile force command.

5. If applicable, repeat steps 2 through 4 for all ranges.

   Example: Suppose you have an actuator with a full-scale capacity of ±10 kN and ranges of ±10 kN, ±5 kN, ±2 kN, and ±1 kN. In this case you would repeat this process and calibrate tension at 80% of each range (-8 kN, -4 kN, -1.6 kN, and -0.8 kN).

Note *Some systems do not provide or require multiple ranges, such as those using full-range conditioners (e.g., Model 493.25 DUC module). In this case, only one range is used (typically 100%).*

Calibrate compression

Note *This procedure assumes a positive command extends the actuator and a negative command retracts the actuator. If not, use the opposite polarity for any values given.*

1. Exercise the force sensor.

   Standalone FlexTest SE Controllers: After enabling the front panel Dial, adjust the **Setpoint** to cycle the load standard readout between zero and full tension three times. This removes sensor hysteresis. Select **Status** > **Setpoint**

   Automated Controllers: Use the **Manual Cmd** slider on the **Manual Command** window to cycle the load standard readout between zero and full tension three times. This removes sensor hysteresis.

   Example: When calibrating a ±10 kN range, exercise the load standard between 0 and 10 kN.

2. Apply a compressive force command that is 80% of the range's full scale.

   Standalone FlexTest SE Controllers:

   A. Enable the front panel Dial.

   B. Using the Dial, adjust the **Setpoint** for a compressive force command that is 80% of the full scale range.

   C. Verify that your force transducer feedback signal is 80% of the full scale range.

   Automated Controllers:

   A. Open the **Manual Command** window, and then click on the **Enable Manual Command**.

   B. Adjust the **Manual Cmd** slider on the **Manual Command** window for a compressive force command that is 80% of the full scale range.

   C. Use the **Station Signals** panel to verify that your force transducer signal equals 80% of the full scale range.

   During the initial calibration and tuning of your system, it may require repeated adjustment for the compressive force command and feedback values to match.

Note *If the actuator response is sluggish and/or the signal value does not match the command, you will need to adjust the tuning of this control mode. Increase the proportional gain (**P Gain** on the **Tuning** menu) to correct sluggish actuator movement. Increase the reset integration value (**I Gain**) to help the feedback match the command.*

   At this point, unless the conditioner is already in calibration, the compressive force applied to the force transducer will not equal your commanded value. You will adjust Delta K in the next step so that the actual compressive force and your commanded compressive force match.

   Example: Suppose your actuator has a 100% compressive force rating of 10 kN. In this step you would apply 8 kN of command, and even though the station signals would read 8 kN of feedback, the force standard may only read 4 kN. This shows the conditioner/sensor pair are out of calibration.

3. Adjust Delta K until the actual compressive force equals your compressive force command.

   Adjust **Delta K** on the **Calibration** submenu or tab to increase the compressive force reading on the load standard until it equals your compressive force command.

4. Repeat steps 2 and 3 for all ranges.

   Example: Suppose you have an actuator with a full-scale capacity of ±10 kN and ranges of ±10 kN, ±5 kN, ±2 kN, and ±1 kN. In this case you would repeat this process and calibrate compression at 80% of each range (8 kN, 4 kN, 1.6 kN, and 0.8 kN).

Note *Some systems do not provide or require multiple ranges, such as those using full-range conditioners (e.g., Model 493.25 DUC module). In this case, only one range is used (typically 100%).*

Record data points

The accuracy tolerance of your data depends on the manufacturer of your sensor. Your sensor should include a calibration data sheet that shows the data point tolerance. Sensors from MTS include a sensor calibration data sheet that shows the data points as it was calibrated.

1. Record the data points for compression.

   Standalone FlexTest SE Controllers:

   A. Adjust the **Setpoint** to achieve a load standard readout of zero.

   B. Adjust the **Setpoint** between zero and full compression three times. This exercises the force sensor to remove hysteresis.

   C. Establish the zero reference.

   Using a load standard

   - Adjust **Setpoint** for 0 kN. Then zero the load standard readout.

   Using dead weights

   - Remove all dead weights.
   - Adjust the **Manual Offset** for a signal value of 0 kN on the DVM or other monitoring device.

     Select **Setup** > **Force** > **Offset/Zero** > **Manual Offset**

   D. Adjust the **Setpoint** to achieve a load standard reading of 20% compression and record the meter reading. Repeat this step for 40%, 60%, 80%, and 100% compression.

   Automated Controllers:

   A. Adjust the **Manual Cmd** slider on the **Manual Command** window to achieve a load standard readout of zero.

   B. Adjust the **Manual Cmd** slider between zero and full compression three times. This exercises the force sensor to remove hysteresis.

   C. Establish the zero reference.

Using a load standard

- Adjust **Manual Cmd** slider for 0 kN. Then zero the load standard readout.

Using dead weights

- Remove all dead weights. On the **Inputs** panel, click on the **Offset/ Zero** tab, and then adjust **Manual Offset** for a signal value of 0 kN on the DVM or **Station Signals** panel.

D. Adjust the **Manual Cmd** slider to achieve a load standard reading of 20% compression and record the meter reading. Repeat this step for 40%, 60%, 80%, and 100% compression.

2. Record the data points for the tension.

Standalone FlexTest SE Controllers:

A. Adjust the **Setpoint** to achieve a load standard readout of zero.

B. Adjust the **Setpoint** between zero and full tension three times. This exercises the force sensor to remove hysteresis.

C. Establish the zero reference.

Using a load standard

- Adjust the **Setpoint** for 0 kN. Then zero the load standard readout.

Using dead weights

- Remove all dead weights.
- Adjust **Manual Offset** for a signal value of 0 kN on the DVM or other monitoring device.

  Select **Setup** > **Force** > **Offset/Zero** > **Manual Offset**

D. Adjust the **Setpoint** to achieve a force standard reading of 20% tension and record the meter reading. Repeat this step for 40%, 60%, 80%, and 100% compression.

Automated Controllers:

A. Adjust the **Manual Cmd** slider to achieve a load standard readout of zero.

B. Adjust the **Manual Cmd** slider between zero and full tension three times. This exercises the force sensor to remove hysteresis.

C. Establish the zero reference.

Using a load standard

- Adjust the **Manual Cmd** slider for 0 kN. Then zero the load standard readout.

Using dead weights

- Remove all dead weights. Then adjust the **Offset** control for a **Signal Value** of 0 kN on the **Input Signals** window.

D. Adjust the **Manual Cmd** slider to achieve a force standard reading of 20% tension and record the meter reading. Repeat this step for 40%, 60%, 80%, and 100% compression.

Note *The Gain/Linearization Calibration procedure that follows applies only to controllers equipped with full-range conditioners (e.g., Model 493.25 DUC module).*

Task 6 Gain/Linearization Calibration

If you are using **Gain/Linearization** for your calibration type, complete the following procedure. If not, complete **Task 5 Gain/Delta K Calibration on page 163** or **Task 7 Millivolt/Volt Calibration on page 179**.

Important *Using linearization data requires specific conditioner zeroing practices. Ensure that **Electrical Zero Lock** on the **Offset/Zero** menu is set to **Locked**. Adjusting electrical zero after calibration may invalidate linearization data.*

Important *Changing conditioner polarity after calibration may invalidate linearization data. If you need to change conditioner polarity (for example, when moving a sensor to a different test system), the sensor may need to be recalibrated.*

Initial force sensor calibration

For initial calibration of a force sensor, complete the following procedure:

1. Select **Gain/Linearization** for **Cal Type**.

   Standalone FlexTest SE Controllers: Select **Setup** > **Force** > **Calibration** > **Cal Type** > **Gain/Linearization**

   Automated Controllers: Select **Gain/Linearization** for **Cal Type** on the **Calibration** tab of the **Inputs** panel.

2. Exercise the force standard.

   Standalone FlexTest SE Controllers: Enable the front panel Dial, then adjust the **Setpoint** to cycle the load standard readout between zero and full tension three times. This removes sensor hysteresis. Select **Status** > **Setpoint**

   Automated Controllers: Use the **Manual Cmd** slider on the **Manual Command** window to cycle the load standard readout between zero and full tension three times. This removes sensor hysteresis.

   Example: When calibrating a ±10 kN range, exercise the actuator between 0 and -10 volts. To calibrate the same force sensor for a different range such as ±5 kN, exercise the load standard between 0 and -5 volts.

3. Apply a tensile force command that is 80% of the range’s full scale.

   Standalone FlexTest SE Controllers:

   A. Enable the front panel Dial.

   B. Using the Dial, adjust the **Setpoint** for a tensile force command that is 80% of the full scale range.

   C. Verify that your force transducer feedback signal is 80% of the full scale range.

   Automated Controllers:

   A. Open the **Manual Command** window, and then click on the **Enable Manual Command**.

   B. Adjust the **Manual Cmd** slider on the **Manual Command** window for a tensile force command that is 80% of the full scale range.

   C. Use the **Station Signals** panel to verify that your force transducer signal equals 80% of the full scale range.

   During the initial calibration and tuning of your system, it may require repeated adjustment for the tensile force command and feedback values to match.

Note *If the actuator response is sluggish and/or the signal value does not match the command, you will need to adjust the tuning of this control mode. Increase the proportional gain (**P Gain** on the **Tuning** menu) to correct sluggish actuator movement. Increase the integration value (**I Gain**) to help the feedback match the command.*

At this point, unless the conditioner is already in calibration, the tensile force applied to the force transducer will not equal your commanded value. You will adjust gain in the next step so that the actual tensile force and your commanded tensile force match.

Example: Suppose your actuator has a 100% tensile force rating of -10 kN. In this step you would apply -8 kN of command, and even though the station signals would read -8 kN of feedback, the force standard may only read -4 kN. This shows the conditioner/sensor pair are out of calibration.

4. Adjust the **Post-amp Gain** control to increase the tensile force reading on the load standard until it equals your tensile force command.

   Standalone FlexTest SE Controllers: Select **Setup** > **Force** > **Calibration** > **Cal Type > Gain/Linearization** < **Post-Amp Gain**

   Automated Controllers: Adjust the **Post-amp Gain** control on the **Calibration** tab of the **Inputs** panel.

5. Apply a compressive force command that is 80% of the full scale range.

   Standalone FlexTest SE Controllers:

   A. Using the front panel Dial, adjust the **Setpoint** for a compressive force command that is 80% of the full scale range.

   B. Verify that your force transducer feedback signal is 80% of the full scale range.

   Automated Controllers:

   A. Adjust the **Manual Command** slider for a compressive force command that is 80% of the full scale range.

   B. Use the **Station Signals** panel to verify that the compressive force signal is approximately equal to 80% of the full scale range.

6. Record force standard and conditioner feedback readings at predetermined tensile force command points.

Note *After shutting down system hydraulics, you will enter these recorded readings on the Linearization Data window.*

Standalone FlexTest SE Controllers:

A. Use the Dial to adjust the **Setpoint** for a 0% command.

B. Record the force standard's readout value in the 0% row of your record sheet.

C. Enter the corresponding conditioner feedback reading.

D. Use the Dial to adjust the **Setpoint** for a -2% tensile force command.

E. Record the force standard's readout value and its corresponding conditioner feedback reading in the -2% row of your record sheet.

F. Repeat steps D and E for other tensile force commands (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

Automated Controllers:

A. Adjust the **Manual Cmd** slider for a 0% command.

B. Record the force standard's readout value and corresponding conditioner feedback reading at 0% command.

C. Adjust the **Manual Cmd** slider for a -2% tensile force command.

D. Record the force standard's readout value and its corresponding conditioner feedback reading in the -2% row of your record sheet.

E. Repeat steps E-G for other tensile force commands (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

7. Record conditioner feedback readings at predetermined compressive force command points.

Standalone FlexTest SE Controllers:

A. Use the Dial to adjust the **Setpoint** for a +2% compressive force command.

B. Record the force standard's readout value in the +2% row of your record sheet.

C. Enter the corresponding conditioner feedback reading.

D. Repeat steps A-C for other compressive force commands (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale).

Automated Controllers:

A. Adjust the **Manual Cmd** slider for a +2% compressive force command.

B. Record the standard's readout signal and corresponding conditioner feedback reading in the +2% row of your record sheet.

C. Repeat steps A and B for other compressive force commands (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale).

8. Turn off system hydraulics

9. On the Linearization Data window, enter the force standard values and corresponding conditioner feedback readings for all command points previously recorded on a separate sheet.

   Standalone FlexTest SE Controllers: Select **Setup** > **Force** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Linearization Data**

   Automated Controllers: Click **Linearization Data** on the **Calibration** tab to open the Linearization Data window.

Force transducer recalibration

If the force transducer has been previously calibrated, use the following procedure:

1. Locate the calibration data sheet for the appropriate conditioner.

2. Turn off system hydraulics.

3. Click **Linearization Data** to open the Linearization Data window.

   Standalone FlexTest SE Controllers: Select **Setup** > **Force** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Linearization Data**

   Automated Controllers: Click **Linearization Data** on the **Calibration** tab of the **Inputs** panel.

4. Transfer **Standard** and **Conditioner** data from the conditioner's calibration data sheet to corresponding data entries on the Linearization Data window.

5. Turn on system hydraulics.

6. Verify linearization data.

   Standalone FlexTest SE Controllers:

   A. Using the Dial, adjust the **Setpoint** for each tensile and compressive force command point on the Linearization Data window.

B. At each command point, verify both the dial indicator value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**) by comparing them with the corresponding values on the Calibration Data sheet.

Automated Controllers:

A. Adjust the **Manual Cmd** slider for each tensile and compressive force command point on the Linearization Data window.

B. At each command point, verify both the dial indicator value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**) by comparing them with the corresponding values on the Calibration Data sheet

If the data is <u>valid</u>: **Stop** this procedure.

If the data is <u>not valid</u>: **Proceed** to the next step.

7. Reset Linearization Data window to default values.

Standalone FlexTest SE Controllers: Select **Setup** > **Force** > **Calibration** > **Cal Type** > **Gain/Linearization** > **<<Reset>>**

Automated Controllers: Click **Reset** on the Linearization Data window to return to default values.

8. Exercise the force standard.

Standalone FlexTest SE Controllers: Enable the front panel Dial, then adjust the **Setpoint** to cycle the load standard readout between zero and full tension three times. This removes sensor hysteresis. Select **Status** > **Setpoint**

Automated Controllers: Use the **Manual Cmd** slider on the **Manual Command** window to cycle the load standard readout between zero and full tension three times. This removes sensor hysteresis.

Example: When calibrating a ±10 kN range, exercise the actuator between 0 and -10 volts. To calibrate the same force sensor for a different range such as ±5 kN, exercise the load standard between 0 and -5 volts.

9. Apply a tensile force command that is 80% of the range's full scale.

Standalone FlexTest SE Controllers:

A. Using the Dial, adjust the **Setpoint** for a tensile force command that is 80% of the full scale range.

B. Verify that your force transducer feedback signal is 80% of the full scale range.

Automated Controllers:

A. Adjust the **Manual Cmd** slider for a tensile force command that is 80% of the full scale range.

B. Verify that your force transducer feedback signal is 80% of the full scale range.

During the initial calibration and tuning of your system, it may require repeated adjustment for the tensile force command and feedback values to match.

Note *If the actuator response is sluggish and/or the signal value does not match the command, you will need to adjust the tuning of this control mode. Increase the proportional gain (**P Gain** on the **Tuning** menu) to correct sluggish actuator movement. Increase the integration value (**I Gain**) to help the feedback match the command.*

At this point, unless the conditioner is already in calibration, the tensile force applied to the force transducer will not equal your commanded value. You will adjust gain in the next step so that the actual tensile force and your commanded tensile force match.

Example: Suppose your actuator has a 100% tensile force rating of -10 kN. In this step you would apply -8 kN of command, and even though the station signals would read -8 kN of feedback, the force standard may only read -4 kN. This shows the conditioner/sensor pair are out of calibration.

10. Adjust the **Post-amp Gain** control to increase the tensile force reading on the load standard until it equals your tensile force command.

    Standalone FlexTest SE Controllers: Select **Setup** > **Force** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Post-Amp Gain**

    Automated Controllers: Adjust the **Post-amp Gain** control on the **Calibration** tab of the **Inputs** panel.

11. Apply a compressive force command that is 80% of the full scale range.

    Standalone FlexTest SE Controllers:

    A. Using the Dial, adjust the **Setpoint** for a compressive force command that is 80% of the full scale range.

B. Verify that your force transducer feedback signal is 80% of the full scale range.

Automated Controllers:

A. Adjust the **Manual Command** slider for a compressive force command that is 80% of the full scale range.

B. Use the **Station Signals** panel to verify that the compressive force signal is approximately equal to 80% of the full scale range.

12. Record conditioner feedback readings at predetermined tensile force command points.

Note *After shutting down system hydraulics, you will enter these recorded readings on the Linearization Data window.*

Standalone FlexTest SE Controllers:

A. Use the Dial to adjust the **Setpoint** for a 0% command.

B. Record the force standard's readout value and corresponding conditioner feedback reading in the 0% row of your record sheet.

C. Use the Dial to adjust the **Setpoint** for a -2% tensile force command.

D. Record the force standard's readout signal and corresponding conditioner feedback reading in the -2% row of your record sheet.

E. Repeat steps C and D for other tensile force commands (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

Automated Controllers:

A. Adjust the **Manual Cmd** slider for a 0% command.

B. Record the force standard readout signal and corresponding conditioner feedback reading at the 0% command line of your record sheet.

C. Adjust the **Manual Cmd** slider for a -2% tensile force command.

D. Record the force standard readout signal and corresponding conditioner feedback reading at the -2% command line of your record sheet.

E. Repeat steps C and D for other tensile force commands (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

13. Record conditioner feedback readings at predetermined compressive force command points.

    Standalone FlexTest SE Controllers:

    A. Use the Dial to adjust the **Setpoint** for a +2% compressive force command.

    B. Record the force standard's readout value and corresponding conditioner feedback reading in the +2% row of your record sheet.

    C. Repeat steps A and B for other compressive force commands (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale).

    Automated Controllers:

    A. Adjust the **Manual Cmd** slider for a +2% compressive force command.

    B. Record the force standard readout signal and corresponding conditioner feedback reading at the +2% command line of your record sheet.

    C. Repeat steps A and B for other compressive force commands (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale).

14. Turn off system hydraulics.

15. On the Linearization Data window, enter the force standard values and corresponding conditioner feedback readings for all command points previously recorded on a separate sheet.

16. Turn on system hydraulics.

17. Verify linearization data.

    Standalone FlexTest SE Controllers:

    A. Using the Dial, adjust the **Setpoint** for each tensile and compressive force command point on the Linearization Data window.

    B. At each command point, verify both the force standard value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**).

    C. Check validity before entering each pair of values on a new Calibration Data Sheet.

    Automated Controllers:

A. Adjust the **Manual Cmd** slider for each retraction and extension command point on the Linearization Data window.

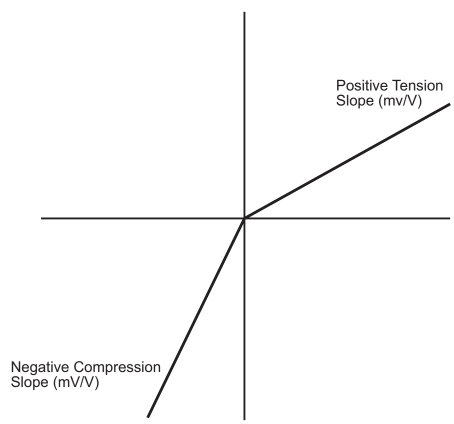
B. At each command point, verify both the force standard value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**).

C. Check validity before entering each pair of values on a new Calibration Data Sheet.

Task 7 Millivolt/Volt Calibration

If you are using **mV/V Calibration** for your calibration type, complete the following procedure. If not, complete **Task 5 Gain/Delta K Calibration on page 163** or **Task 6 Gain/Linearization Calibration on page 170**.

Millivolt/volt calibration is used for transducers that have two different slopes (positive and negative).



In this calibration process, system software calculates conditioner Delta K Gain and Gain values from previously measured mV/V values under both tension and compression.

The slope and gain values are derived from, and are relative to, the output of the load cell transducer as follows:

$$\text{Delta K Gain} = \frac{\text{Compression mV/V}}{\text{Tension mV/V}}$$

Where:

Compression is specified using the **Neg Compression** or **Pos Compressive** entry box on the Calibration submenu or tab.

Tension is specified using the **Neg Tension** or **Pos Tension** entry box on the Calibration submenu or tab.

$$\text{Gain} = \frac{\text{Conditioner Output Voltage}}{\text{Excitation Voltage} \times \text{Compression mV/V}}$$

Where:

Conditioner Output Voltage is typically 10 Vdc.

Excitation Voltage is specified using the **Excitation** entry box on the **Calibration** submenu or tab.

Compression is specified using the **Negative Compression** or **Positive Compressive** entry box on the Calibration submenu or tab.

mV/V Positive Tension Calibration

Use the following procedure if your force transducer is set up so that a positive output represents actuator retraction (tension).

1. Select **mV/V Pos Tension** for your calibration type.

   Standalone FlexTest SE Controllers: Select **Setup** > **Force** > **Calibration** > **Cal Type** > **mV/V Pos Tension**

   Automated Controllers: Select **mV/V Pos Tension** for **Cal Type** on the **Calibration** tab of the **Inputs** panel.

2. From the Calibration Data sheet for your force transducer enter the following values on the **Calibration** submenu or tab:

   Standalone FlexTest SE Controllers:

   A. Enter the full scale force values in the **Minimum** and **Maximum** entry boxes.

B. Enter the tension sensitivity value (+mV/V) in the **Pos Tension** entry box.

C. Enter the compression sensitivity value (-mV/V) in the **Neg Compression** entry box.

D. Enter the calibration excitation value (Vdc) in the **Excitation** entry box.

Automated Controllers:

A. On the **Inputs** panel, enter the full scale force values in the **Fullscale Min/Max** entry boxes.

B. Adjust **Pos Tension** for the required tension sensitivity value (+mV/V).

C. Adjust **Neg Compression** for the required compression sensitivity value (-mV/V).

D. Adjust **Excitation** for the required calibration excitation value (Vdc).

mV/V Positive Compression Calibration

Use the following procedure if your force transducer is set up so that a positive output represents actuator extension (compression).

1. Select **mV/V Pos Comp** for your calibration type.

   Standalone FlexTest SE Controllers: Select **Setup** > **Force** > **Calibration** > **Cal Type** > **mV/V Pos Comp**

   Automated Controllers: Select **mV/V Pos Compression** for **Cal Type** on the **Calibration** tab of the **Inputs** panel

2. From the Calibration Data sheet for your force transducer enter the following values on the **Calibration** submenu or tab:

   Standalone FlexTest SE Controllers:

   A. Enter the full scale force values in the **Minimum** and **Maximum** entry boxes.

   B. Enter the tension sensitivity value (-mV/V) in the **Neg Tension** entry box.

   C. Enter the compression sensitivity value (+mV/V) in the **Pos Compression** entry box.

   D. Enter the calibration excitation value (Vdc) in the **Excitation** entry box.

   Automated Controllers:

A. Enter the full scale force values in the **Fullscale Min/Max** entry boxes.

B. Adjust **Neg Tension** for the required tension sensitivity value (+mV/V).

C. Adjust **Pos Compression** for the required compression sensitivity value (-mV/V).

D. Adjust **Excitation** for the required calibration excitation value (DC).

Task 8 Establish the shunt calibration reference

Each resistive bridge type transducer (DC sensor) uses a shunt resistor to check the calibration accuracy of the sensor/conditioner combination. Each DC conditioner supports a shunt resistor.

1. Turn off hydraulic power.
2. Remove the load standard.
3. Turn on hydraulic power.
4. Zero the force sensor output.

   Standalone FlexTest SE Controllers:

   Adjust the **Setpoint** for a 0 kN output. The sensor output must be 0.000 kN for a proper shunt calibration. If not, return to “Set the zero and offset” on page 163.

   Automated Controllers:

   Adjust the **Manual Cmd** slider on the **Manual Command** window for a 0 kN output. The sensor output must be 0.000 kN for a proper shunt calibration. If not, return to “Set the zero and offset” on page 163.

5. Change the control mode to displacement.

   Standalone FlexTest SE Controllers: Select **Status** > **Control Mode** > **Disp.**

   Automated Controllers: On the **Manual Command** window, change **Control Mode** to **Displacement**.

   Shunt calibration cannot be performed on a sensor when it is in control of the servo loop.

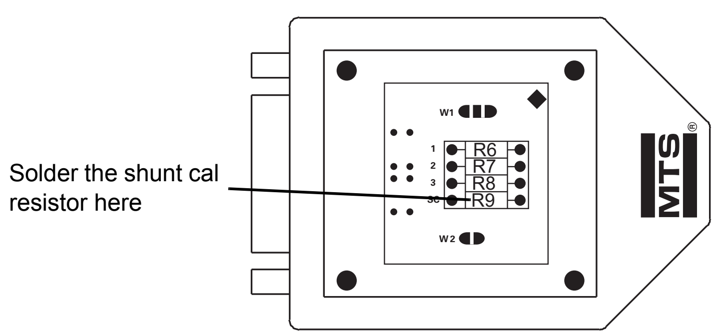
6. Determine the shunt calibration resistor from the following table:

Bridge Resistance	Sensitivity	Range (% Full Scale)	Resistor Value
350 Ω	2 mV/V	100% 50% 20% 10%	49.9 k 100 k 249 k 499 k
350 Ω	1 mV/V	100% 50% 20% 10%	100 k 200 k 499 k 1000 k
700 Ω	2 mV/V	100% 50% 20% 10%	100 k 200 k 499 k 1000 k
700 Ω	1 mV/V	100% 50% 20% 10%	200 k 402 k 1000 k 2000 k

Note *If you are calibrating a FlexTest IIm/CTC Controller, skip to step 9.*

7. If you have sensor cables with optional transducer ID modules complete the following procedure. If not, proceed to Step 8.

   Install the shunt calibration resistor into the **R9** location of the sensor ID module. The sensor identification cartridge is molded into the sensor cable.



8. *FlexTest SE/LE, FlexTest GT, TestStar IIm Controllers only:* If you do not have transducer ID modules on your sensor cables, install the shunt calibration resistor as follows:

   A. Select the appropriate shunt calibration resistor.

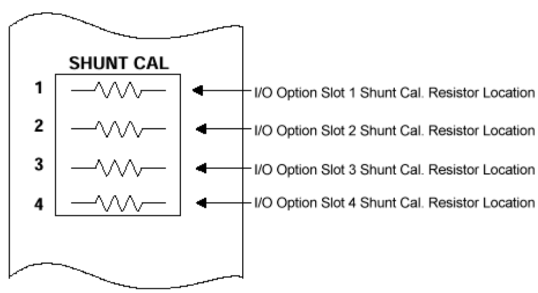
   B. Bend the resistor leads 90º for a 0.3 inch separation.

   C. Cut the resistor leads 0.12 inch from the bend.

   D. Insert the resistor into the connector solder cups and solder.

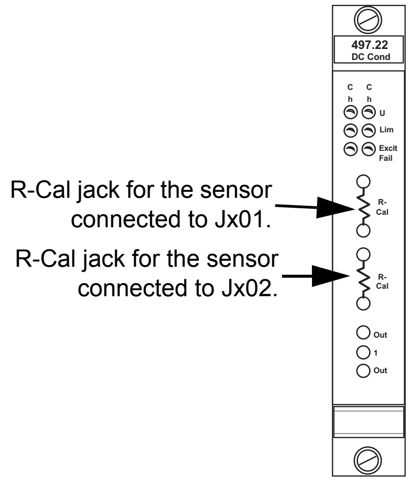
   E. Complete and attach a shunt calibration label as specified on the 493.40/41 Carrier I/O Shunt Calibration Kit (MTS PN 100-028-185).

   F. Install the shunt cal resistor/connector assembly into the appropriate slot of the **SHUNT CAL** connector on the front panel of the appropriate I/O Carrier Module.



9. *FlexTest IIm/CTC Controllers only:* Install the shunt calibration resistor into the **R-Cal** jacks in the appropriate DC conditioner.

   You must know which DC conditioner is associated with the force sensor.



   You also need to know which of the two DC conditioners on the module is used by your load cell.

   The shunt resistors for the Model 497.22 DC Conditioner are packaged in a thumb-nail sized module. It makes it easier to install and remove the shunt calibration resistor.

10. Verify that force is still zero.

    While it is unlikely, it is possible for the force signal to change when the control mode changes. If it does:

    Standalone FlexTest SE Controllers: Click **Auto Offset** on the **Offset/Zero** submenu to zero the force output. Select **Setup** > **Force** > **Offset/Zero** > **Auto Offset**

    Automated Controllers: Click **Auto Offset** on the **Offset/Zero** tab (**Inputs** panel) to zero the force output.

11. Perform shunt calibration.

    Standalone FlexTest SE Controllers:

    Select **Setup** > **Force** > **Calibration** > Select Cal Type

    A. Select required **Shunt Display** units.

B. Ensure that **Shunt State (+)** is set to **On**. Polarity is always positive.

Note the **Shunt Ref (+)** value, it should be 60%–90% (80% is ideal) of the calibrated range of the sensor.

C. Click **Update** to copy the current shunt reference value into the **Shunt Reference** box.

D. Set **Shunt State (+)** to **Off**.

Automated Controllers:

A. In **Station Setup** select the appropriate force channel on the navigation panel**.,** click the **Channel Input Signals** icon, and then click the **Shunt** tab.

B. Select the shunt type. Use (+) polarity if you are not sure what to select.

C. In the **Current Shunt Value** box, click the **On** button. Note the **Current Shunt Value**, it should be 60%–90% (80% is ideal) of the calibrated range of the sensor.

D. Click **Update** to copy the **Current Shunt Value** into the **Shunt Reference Value** box, and then click **Off**.

Task 9 Save the calibration

It is important that you save your sensor calibration values.

Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters** > **<<Save>>**

Automated Controllers: On the **Station Setup** window **Inputs** panel, click the **Calibration** tab, and then **Save**. This saves current calibration values on the **Calibration**, **Sensor**, and **Shunt** tabs to the sensor calibration file.

Note *Systems equipped with full range conditioners (e.g., Model 493.25 DUCs) do not require or support multiple ranges. They use one range that is typically set to 100%.*

Task 10 Calibrate additional ranges

This task describes how to calibrate additional ranges. Each sensor calibration file can have calibration data for four ranges. If you have a need for additional ranges, simply create another sensor calibration range.

- Use the calibration values from the previous range as a starting point, as
- For a starting point, set additional range values using the following guideline:
  - For a 50% range, multiply the 100% (full scale) value by 2.
  - For a 20% range, multiply the 100% (full scale) value by 5.
  - For a 10% range, multiply the 100% (full scale) value by 10.
- If you adjust the zero reference, it may affect the other ranges.

Adding a range

If the sensor calibration file must have additional ranges defined, perform the following:

1. On the **Tools** menu, select **Sensor File Editor**.
2. Open the sensor file for the sensor you just calibrated.
3. Click **Add** under **Range Definition**.
4. By default, **Range 2** is entered. Highlight the name **Range 2** and change it to something meaningful.

   Example: Suppose you are setting up a calibration file for a ±5 kN range. You may want to name the full-scale range “5 kN”.
5. Select the units for the range, and then enter the absolute value of the range.
6. Save the new range to the calibration file.

Note *Ranges can also be added on the **Sensor** tab and calibrated on the **Calibration** tab.*

7. Repeat as necessary for calibrating additional ranges.

How to Install a Shunt-Calibration Resistor on an I/O Carrier Board

The Model 494.40 I/O Carrier board has a front-panel socket where you can insert shunt-calibration plug assembly for use with DUC cards. Each socket is associated with one of the eight RJ-50 connectors on the front panel.

1. Determine the RJ-50 connector(s) used by the transducer(s).

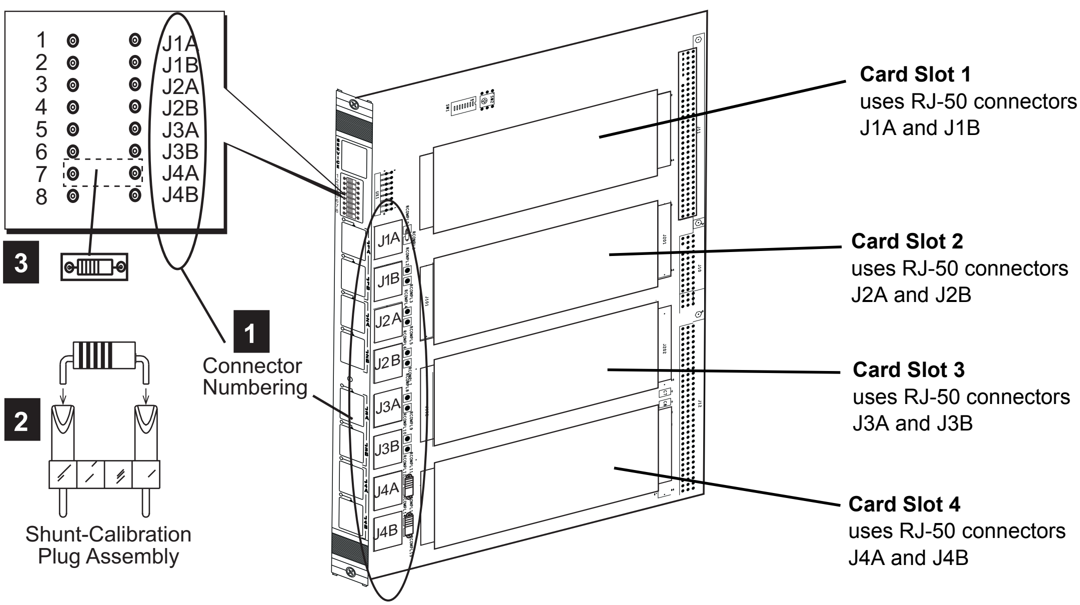
Note *Each mezzanine-card slot on the I/O carrier board connects to two RJ-50 connectors on the front of the I/O carrier board.*

2. Solder the shunt-calibration resistors to an MTS shunt-calibration plug assembly (MTS 11-433-826).

Note *The shunt-calibration plug assembly includes plug assemblies for eight shunt resistors. Each resistor should be labeled with its resistance value and transducer serial number.*

3. Insert the shunt-calibration plug assemblies into the front-panel sockets.

Note *If you use MTS TEDS modules or MTS transducers with integrated shunt-calibration resistors, you must insert a jumper plug (MTS 100-188-097) into the socket for each transducer input where you will use the integrated shunt-calibration resistor.*



Encoder and Temposonics Calibration

Encoders

Linear encoders measure the position change of the actuator's piston rod by digitizing, sensing, and resolving actuator movement.

Temposonics transducers

MTS Temposonics™ linear displacement sensors measure the position change of the actuator's piston rod by sensing the position an attached permanent magnet.

The calibration procedure for both types of devices are similar.

Daughter board support

For FlexTest SE/LE, FlexTest GT, and TestStar IIm, encoders and Temposonics sensors require a Model 493.47 Encoder Interface daughter board to be installed in a Model 493.40 Carrier I/O board. The Carrier I/O connector (J4 - J7) used depends on the installed location of the daughter board on the Carrier I/O module.

For FlexTest IIm/CTC, encoders and Temposonics sensors require an optional daughter board installed in the 498 ADDA plug-in module.

Determine installed location

For Automated Controllers, determine the installed location of the sensor's daughter board by using the **Hardware** tab on the **Station Signals** window. Access **Station Signals** on the **Station Setup** window navigation pane.

For Standalone FlexTest SE Controllers, use the Edit > Config menu to do the same.

For encoders, feedback resources labeled "Encoder Input #" or "Heidenhain 417/425 Input #" indicate that the controller is equipped with an optional encoder interface daughter board.

For Temposonics sensors, feedback resources labeled "Temposonics Input#" or "Temposonics III Input #" indicate that the controller is equipped with an optional Temposonics interface daughter board.

Zeroing

For Automated Controllers, the sensor signal is defined in the Station Setup **Inputs** panel.

For Standalone FlexTest SE Controllers, the encoder signal is defined in the Edit > Config menu.

Note *You cannot zero an encoder or Temposonics sensor if it is selected for the active control mode.*

Range support

Encoder and Temposonics sensors do not support multiple ranges.

Encoder Calibration: Abbreviated Procedure

The following abbreviated procedure outlines an encoder calibration process. More detailed calibration information is available on the pages listed.

Task 1, "Get things ready," on page 191

Task 2, "Create a calibration file," on page 192

Task 4, "Turn on hydraulic pressure," on page 192

Task 5, "Set the zero position," on page 193

Task 6, "Save the calibration," on page 194

Encoder Calibration: Detailed Procedure

Task 1 Get things ready

Perform the following before you start the calibration.

1. Locate relevant documentation.

   When calibrating an encoder or Temposonics sensor, you will need information about the device such as the serial number, model number, and a specification called measuring step (resolution).

2. Open a station configuration file.

   You need a station configuration file that includes a control channel and a control mode that uses the sensor you intend to calibrate.

   Standalone FlexTest SE Controllers: Select **Config** > **Edit Config** > **Configuration File**

   Automated Controllers: On the **File** menu, select **Open Station** to open the appropriate configuration file.

3. Select the **Calibration** access level.

   You must select the Calibration user access level before you can perform any of the calibration procedures. You may need to enter a password.

   Standalone FlexTest SE Controllers: Select **Config** > **Access Level** > **Calibration**

   Automated Controllers: In the **Station Manager** window toolbar, select **Calibration**

4. Set up a signal monitor.

   See page 134 for more information.

Note *If you already have a sensor calibration file, skip Task 2.*

Note *Tasks 2 and 3 do not apply to Standalone FlexTest SE Controllers.*

Task 2 Create a calibration file

This task creates a sensor calibration file.

Note *Encoder and Temposonics sensors do not require ranges, their resolution is constant.*

See "How to Create a Sensor File" in the *MTS Series 793 Control Software* manual.

Setting device resolution

In the **Resolution** box, enter the resolution supplied in the device's documentation.

Note *If you want to use units different than those supplied in the sensor documentation, enter the full scale and resolution in the supplied units first, and then switch to the desired full-scale units. The units conversion will be calculated automatically.*

Task 3 Assign a calibration file

This task links a sensor calibration file to a hardware resource. The purpose for this is to select one of the sensor ranges for the input signal definition.

See "How to Assign a Sensor File" in the *MTS Series 793 Control Software* manual.

Task 4 Turn on hydraulic pressure

This task sets up the **Control Panel** so you can turn on the hydraulic pressure.

WARNING

Do not place any part of your body in the path of a moving actuator.

A crush zone exists between the actuator and any equipment in the path of its movement. Immediate and unexpected actuator response is possible when you apply hydraulic pressure to your system.

Stay clear of the actuators when applying hydraulic pressure.

See "Turn on hydraulic pressure" on page 136 for a detailed procedure.

Task 5 Set the zero position

The zero position can be set anywhere within the full-scale range of the device.

Standalone FlexTest SE Controllers:

A. Using the front panel Dial, adjust the **Setpoint** to move the actuator to the position you want to assign as zero.

B. Select any control mode that does not use the encoder.

Select **Status** > **Control Mode**

Note *If the actuator should move after making the change in control modes, you will need to reposition the actuator, then change to a more stable control mode.*

C. With the actuator in the desired zero position, click **<<Auto Zero>>** button on the **Offset/Zero** submenu.

Select **Setup** > **Disp.** > **Offset/Zero** > **<<Auto Zero>>**

Automated Controllers:

A. Adjust the **Manual Cmd** slider on the **Manual Command** window to move the actuator to the position you want to assign as zero.

B. Use **Control Mode** on the Change control modes on the **Control Panel**. Select any control mode that does not use the encoder or Temposonics sensor.

Note *If the actuator should move after making the change in control modes, you will need to reposition the actuator, then change to a more stable control mode.*

C. With the actuator in the desired zero position, click the **Auto Zero** button on the **Offset/Zero** tab (**Inputs** panel).

Note *When you change the device resolution on the **Calibration** tab, it immediately changes the resolution of signal values displayed on the **Station Signals**, **Meters**, and **Scope** windows.*

Task 6 Save the calibration

It is important that you save your sensor calibration values.

Standalone FlexTest SE Controllers: Select **Setup** > **Open/Save Parameters** > **<<Save>>**

Automated Controllers: On the **Station Setup** window **Inputs** panel, click the **Calibration** tab, and then **Save**. This saves current calibration values on the **Calibration**, **Sensor**, and **Shunt** tabs to the sensor calibration file.

Extensometer Calibration

An extensometer is a sensor attached to a specimen that measures a dimensional change (gage length or strain) that occurs in the specimen during testing. It works by means of precision resistance-type strain gages bonded to a metallic element to form a Wheatstone bridge circuit.

Extensometers require special test fixtures to aid in calibration.

Prerequisites

Be sure the items described in "Pre-Calibration Considerations" on page 123 are true.

An extensometer requires DC excitation, which requires either a dedicated DC conditioner or a digital universal conditioner (DUC) configured in the DC mode. You must know which conditioner is connected to the extensometer.

Note *If you are recalibrating a sensor, use the existing calibration values as a starting point.*

Initial calibration

If you are calibrating a sensor for the first time, you may find it necessary to:

- Perform an initial tuning of the sensor channel before calibration.
- Perform the procedure twice.

Recalibration

If you are recalibrating a sensor, use the existing calibration values as a starting point.

Considerations for full-range conditioners

Full-range conditioners allow you to choose Gain/Delta K or Gain/Linearization for calibrating extensometers. The mV/V Pos Tension and mV/V Pos Comp calibration types are typically not used for controllers equipped with full-range conditioners.

- During calibration, **Manual Offset** should always be set to zero.
- During calibration, ensure that **Electrical Zero Lock** is checked on the **Offset/Zero** tab of the **Inputs** panel.
- After calibration, **do not change the electrical zero adjustment**. Readjustment of electrical zero after calibration will change the point at which linearization takes place, disturbing other calibration settings (especially Delta K).

What you will need

To calibrate an extensometer, you will need:

- An extensometer calibrator (such as an MTS Model 650.03-01 Extensometer Calibrator)
- A digital voltmeter (DVM)

Range support

Extensometers are typically calibrated such that the maximum strain represents ±100% of the full-scale capacity of the extensometer.

Extensometer Calibration: Abbreviated Procedure

Task 1, “Get things ready,” on page 198.

Task 2, “Create a sensor calibration file,” on page 199

Task 3, “Adjust offset,” on page 200.

Task 4, “Gain/Delta K Calibration,” on page 201.

Note *The Gain/Linearization Calibration procedure applies only to controllers equipped with full-range conditioners (e.g., Model 493.25 DUC module).*

Task 5, “Gain/Linearization Calibration,” on page 204.

Task 6, “Establish the shunt calibration reference,” on page 210.

Task 7, “Save the calibration settings,” on page 212.

Extensometer Calibration: Detailed Procedure

Task 1 Get things ready

1. Review "Pre-Calibration Considerations" on page 123.
2. Locate all relevant documentation including information about the extensometer such as the serial number, model number, etc.
3. For Automated Controllers, open a station configuration file.

   You need a station configuration file that has a defined input signal, such as an auxiliary input.

   On the **File** menu, click **Open Station** to open the appropriate configuration file.
4. Select **Calibration** for Access Level.

   Select **Config** > **Access Level** > **Calibration**
5. Set up to monitor strain feedback.

   You will be monitoring strain feedback when making adjustments throughout this procedure. You should monitor strain feedback in the same units that you are using for the calibration.

   Alternatively, you can use an external DVM to monitor strain feedback from a BNC connector located on the FlexTest SE Controller front panel (FlexTest SE Controllers) or Analog Out panel (all other controllers).

   You can also use the **Meters** window to monitor strain feedback.

   For Automated Controllers, you can also use the **Station Signals** panel to monitor strain feedback. On the Station Manager **Display** menu, select **Station Setup**. In the navigation pane, select **Station Signals** to display the **Station Signals** panel to monitor current values for user-defined signals.

   For more information on using the **Station Signals** panel, refer to "About the Station Signals Panel" in the *MTS Series 793 Control Software* manual.
6. Mount the extensometer to the calibrator.

   A. Review the extensometer product manual for mounting information and calibrator requirements.

   B. Ensure that the extensometer is cabled to an appropriate conditioner.

7. Turn on electrical power to your system and allow thirty minutes for warm-up.

Note *If you already have a sensor calibration file, skip Task 2.*

Note *Tasks 2 and 3 do not apply to Standalone FlexTest SE Controllers.*

Task 2 Create a sensor calibration file

This task creates a sensor calibration file and sets up any ranges you may want. If you already have a sensor calibration file, skip this task.

The following steps provide an overview of sensor file creation. For a more detailed description of this procedure, refer to "How to Create a Sensor File" in the *MTS Series 793 Control Software* manual.

1. On Station Manager **Tools** menu, select **Sensor File Editor**.
2. On the **Sensor File Editor** toolbar, click the **Open** button, and then **New**.
3. From the **Conditioner Type** list, select the type (Model #) of conditioner that is connected to the extensometer you are calibrating.

Note *Until you select conditioner type, all conditioner entries are disabled.*

4. Enter a sensor name or model number, and then the serial number.
5. Specify either **Strain** or **Length** for the signal **Dimension**.
6. Enter any additional information.
7. Under **Range Definition**, define a range, including the **Name** of the range.
8. Set the sensor fullscale min/max and unit.

   Set the units and enter the full-scale minimum and maximum for the range. The system software supports non-symmetrical full scales.

Note *If you want to use units different than those supplied in the sensor documentation, enter the full scale in the supplied units first, and then switch to the desired full-scale units. The units conversion will be calculated automatically.*

9. Enter initial calibration values.

Note *Do not use default values. Enter actual calibration values.*

10. Save your sensor file and close the **Sensor File Editor**.

Task 3 Adjust offset

This task verifies the sensor's zero position and offsets any imbalance due to specimen size, forces from test components, cable length, and so forth. The zero position can be set anywhere within the full-scale range of the strain sensor.

Note *The arms of the extensometer must be in the zero reference position. Depending on the extensometer, this can be accomplished using the zero pin, stop block, or a special fixture.*

Standalone FlexTest SE Controllers:

1. Monitor the current strain output to ensure that it is zero.
2. If it is not zero, click Auto Offset.

   Select **Setup** > **Strain** > **Offset/Zero** > **<<Auto Offset>>**

Automated Controllers:

1. Click Auto Offset icon on the **Station Controls** panel to display the **Signal Auto Offset** window.
2. If the current strain output is not zero, click the Auto Offset icon next to the signal value to offset it. automatically.

Note *You can also click the* ***Auto Zero*** *button on the* ***Calibration*** *tab of the* ***Station Setup*** *panel to automatically offset the current strain output.*

Note *For calibration purposes, it is desirable to use Auto Zero. However, you must ensure that any other offsets, such as those occurring through the use of the Auto Offset, are eliminated first.*

Task 4 Gain/Delta K Calibration

If you are using **Gain/Delta K** for your calibration type, complete the following procedure. If not, complete **Task 5 Gain/Linearization Calibration on page 204**.

Calibration setup

1. Ensure that the extensometer is properly attached to the calibrator frame using the associated installation drawings and calibrator fixtures.
2. Set an initial transducer excitation voltage.

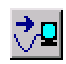
   Standalone FlexTest SE Controllers:

   Select **Setup** > **Strain** > **Calibration** > **Cal Type > Gain/Delta K > Excitation (peak)**

   Set the **Excitation (peak)** voltage value (typically 5-8 volts).

   Automated Controllers:

   A. In the **Station Setup** window's navigation pane, locate and select the **Channels** resource providing the strain feedback signal.

   B. In the **Station Setup** window, click .

   C. In the **Inputs** panel, click the **Calibration** tab.

   D. Set **Type** to **Gain/Delta-K**.

   E. Set **Excitation (peak)** voltage value (typically 5-8 volts).
3. If the extensometer uses a zero pin, remove the zero pin now.
4. Monitor the extensometer's amplified output (strain).

Note *Before clicking **Auto Zero**, ensure that any offsets due to Auto Offset and Manual Offset actions are eliminated.*

5. Use **Auto Zero** to zero transducer output.

   Standalone FlexTest SE Controllers:

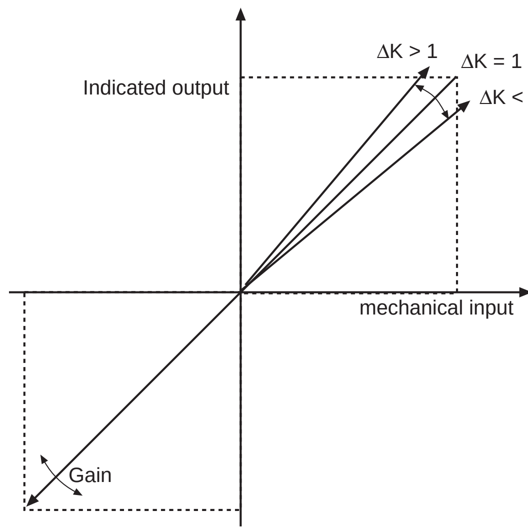
   Select **Setup** > **Strain** > **Offset/Zero** > **<<Auto Zero>>**

   Automated Controllers:

   Click **Auto Zero** on the **Calibration** tab to set transducer's amplified output to 0.000 V DC.

Calibrate the negative output (tension)

This task calibrates the extensometer negative output using the calibration **Gain** controls. Since the **Gain** setting will affect your **Delta K** setting, you should always calibrate the negative side first.



To calibrate the negative extensometer output:

1. Set an initial nominal **Gain** setting of **500**.
2. Adjust the calibrator between zero and -100% of the extensometer's full-scale range three times. This exercises the extensometer to remove any hysteresis.
3. Use **Auto Zero** to zero transducer output.

   Standalone FlexTest SE Controllers: Select **Setup > Strain > Offset/Zero > <<Auto Zero>>**

   Automated Controllers: Click **Auto Zero** on the **Calibration** tab to set transducer's amplified output to 0.000 V DC.

4. Set the calibrator micrometer head for 80% of the negative full-scale value.

5. Note the monitored strain signal value.

6. If the signal value does not match the set value, adjust the transducer excitation voltage to achieve an 80% value (–8 V DC). Record your final strain signal value for the 80% output.

Note *After determining an approximate excitation value, round it to convenient value (e.g., 8.00 V DC). Use **Post-amp Gain** to make fine adjustments of calibration.*

Calibrate the positive output (compression)

To calibrate the positive extensometer output:

1. Adjust the calibrator between zero and 100% of the extensometer's full-scale range three times. This exercises the extensometer to remove any hysteresis.

Note *Before clicking **Auto Zero**, ensure that any offsets due to Auto Offset and Manual Offset actions are eliminated*

2. Use **Auto Zero** to zero transducer output.

   Standalone FlexTest SE Controllers: Select **Setup > Strain > Offset/Zero > <<Auto Zero>>**

   Automated Controllers: Click **Auto Zero** on the **Calibration** tab to set transducer's amplified output to 0.000 V DC.

3. Set the calibrator micrometer to 80% of the positive full scale value.

4. Note the monitored strain signal value.

5. Adjust **Delta K** to achieve an 80% value (+8 V DC).

Note *The Delta K value can be adjusted above or below 1.000. This means it will correct for an error above or below 8 volts.*

Compare recorded data points to calibration sheet

Your sensor should include a calibration data sheet that shows the data point tolerance.

1. Record the negative and positive outputs values at the 20%, 40%, 60%, and 100% data points.

2. Compare your recorded output values to the calibration data sheet that accompanied your sensor.

3. Make sure your current values fall within the permissible variation.

Note *It is up to the user to establish whether the recorded data points meet the required accuracy. Typically, 1% of a reading is the normal accuracy specification.*

If they do not, you must go back to recalibrate the extensometer negative and positive outputs.

Note *The Gain/Linearization Calibration procedure that follows applies only to controllers equipped with full-range conditioners (e.g., Model 493.25 DUC module).*

Task 5 Gain/Linearization Calibration

If you are using **Gain/Linearization** for your calibration type, complete the following procedure. If not, complete **Task 4 Gain/Delta K Calibration on page 201**.

Important *Using linearization data requires specific conditioner zeroing practices. Ensure that **Electrical Zero Lock** on the **Offset/Zero** menu is set to **Locked**. Adjusting electrical zero after calibration may invalidate linearization data.*

Calibration setup

1. Ensure that the extensometer is properly attached to the calibrator frame using the associated installation drawings and calibrator fixtures.

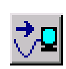
2. Set an initial transducer excitation voltage.

   Standalone FlexTest SE Controllers: Select **Setup** > **Strain** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Excitation (peak)**

   Set the **Excitation (peak)** voltage value (typically 5- 8 volts).

   Automated Controllers:

   A. In the **Station Setup** window's navigation pane, locate and select the **Channels** resource providing the strain feedback signal.

   B. In the **Station Setup** window, click .

   C. In the **Inputs** panel, click the **Calibration** tab.

   D. Set **Type** to **Gain/Linearization**.

   E. Set **Excitation (peak)** voltage value (typically 5- 8 volts).

3. If the extensometer uses a zero pin, remove the zero pin now.

4. Monitor the extensometer's amplified output (strain).

Note *Before using **Auto Zero**, ensure that any offsets due to Auto Offset and Manual Offset actions are eliminated.*

5. Use **Auto Zero** to zero transducer output.

   Standalone FlexTest SE Controllers: Select **Setup > Strain > Offset/Zero > <<Auto Zero>>**

   Automated Controllers: Click **Auto Zero** on the **Calibration** tab to set transducer's amplified output to 0.000 V DC.

Initial extensometer calibration

If you have previously calibrated this extensometer, see "Extensometer recalibration" on page 207. If this is a first-time calibration, use the following procedure:

1. Adjust the calibrator between zero and -100% of the extensometer's full-scale range three times. This exercises the extensometer to remove any hysteresis.
2. Set the calibrator micrometer to a value that is 80% of the negative full scale range.
3. Verify that your extensometer feedback signal is -80% of the full scale range.

   During the initial calibration of your system, it may require repeated adjustment for the negative strain calibrator setting and feedback values to match.

   At this point, unless the conditioner is already in calibration, the negative strain reading will not equal the value set on your calibrator micrometer. You will adjust gain in the next step so that the actual strain and your calibrator strain setting match.
4. Set an initial gain of 500.
5. Adjust **Excitation** so that the strain signal approaches the target value. As the target value is approached, determine an appropriate integer or half-integer value (e.g., 6.5 V). Then, make finer adjustments to the sensor output using **Post-amp Gain**.
6. Set the calibrator micrometer to a value that is 80% of the positive full scale range.

Note *Since you are using a Model 493.25 conditioner, with no Delta K adjustment, you can only adjust **Post-amp Gain** at one point, either the +80% point, or -80% point. The other point (+80% or -80%) simply becomes a data point value for the linearization table.*

7. Verify that your extensometer feedback signal is 80% of the full scale range.

8. Record conditioner feedback readings at predetermined negative strain settings.

    A. Set the calibrator micrometer to a value that is 0% of the extensometer's full scale range.

    B. Record the calibrator's readout value and the corresponding conditioner feedback reading in the 0% row of your record sheet.

    C. Set the calibrator micrometer to a value that is -2% of the extensometer's full scale range

    D. Record the calibrator's readout value and corresponding conditioner feedback reading in the -2**%** row of your record sheet.

    E. Repeat steps C and D for other negative strain settings (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

    F. Reset the calibrator micrometer to a value that is 0% of the extensometer's full scale range. Ensure that the conditioner feedback reading is zero. If necessary, use Auto Zero to achieve this zero reading

9. Record conditioner feedback readings at predetermined positive strain settings.

    A. Set the calibrator micrometer to a value that is +2% of the extensometer's full scale range

    B. Record the calibrator's readout value and corresponding conditioner feedback reading in the +2**%** row of your record sheet.

    C. Repeat steps A and B for other positive strain settings (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale).

10. On the Linearization Data window, enter the calibrator readout values and corresponding conditioner feedback readings for all command points previously recorded on a separate sheet.

    Standalone FlexTest SE Controllers: Select **Setup** > **Strain** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Linearization Data**

    Automated Controllers: Click **Linearization Data** on the **Calibration** tab.

11. Save the sensor file

12. Reassign the sensor file to ensure that the new sensor settings take effect.

13. Repeat steps 8 and 9.

14. Verify Linearization Data.

    Make sure your current values fall within the permissible variation.

Note *It is up to the user to establish whether the recorded data points meet the required accuracy. Typically, 1% of a reading is the normal accuracy specification.*

    If they do not, you must go back to recalibrate the extensometer negative and positive outputs.

Extensometer recalibration

If the extensometer has been previously calibrated, use the following procedure:

1. Locate the calibration data sheet for the appropriate Model 493.25 conditioner.
2. Click **Linearization Data** to open the Linearization Data window.

   Standalone FlexTest SE Controllers: Select **Setup** > **Strain** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Linearization Data**

   Automated Controllers: Click **Linearization Data** on the **Calibration** tab.
3. Verify linearization data.
4. Verify linearization data.

   A. Adjust the calibrator micrometer for each strain setting on the Linearization Data window.

   B. At each micrometer setting, verify both the calibrator readout value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**) by comparing them with the corresponding values on the Calibration Data sheet

   If the data is valid: **Stop** this procedure.

   If the data is not valid: **Proceed** to the next step.
5. Reset Linearization Data window to default values.

   Standalone FlexTest SE Controllers: Select **Setup** > **Strain** > **Calibration** > **Cal Type** > **Gain/Linearization** > **<<Reset>>**

   Automated Controllers: Click **Reset** on the Linearization Data window to return to default values.
6. Adjust the calibrator between zero and -100% of the extensometer's full-scale range three times. This exercises the extensometer to remove any hysteresis.

7. Apply a negative strain command that is 80% of the negative full scale range.

   A. Set the calibrator micrometer to a negative strain value that is 80% of the full scale range.

   B. Verify that your extensometer feedback signal is 80% of the full scale range.

   At this point, unless the conditioner is still in calibration, the negative strain applied to the extensometer will not equal your calibrator setting. You will adjust gain in the next step so that the actual strain and the strain set on the calibrator match.

8. Adjust gain until the actual strain equals your strain command.

   Standalone FlexTest SE Controllers:

   Adjust the **Post-amp Gain** control on the **Calibration** submenu to increase the negative strain reading on the calibrator until it equals your negative strain command.

   Select **Setup** > **Strain** > **Calibration** > **Cal Type** > **Gain/Linearization** > **Post-Amp Gain**

   Automated Controllers:

   Adjust the **Post-amp Gain** control on the **Calibration** tab to increase the negative strain reading on the calibrator until it equals your negative strain command.

9. Apply a positive strain command that is 80% of the positive full scale range.

Note *Since you are using a Model 493.25 conditioner, with no Delta K adjustment, you can only adjust **Post-amp Gain** at one point, either the +80% point, or -80% point. The other point (+80% or -80%) simply becomes a data point value for the linearization table.*

   A. Adjust the **Setpoint** (Standalone) or **Manual Cmd** slider (Automated) for a positive strain command that is 80% of the full scale range.

   B. Verify that your extensometer feedback signal is 80% of the full scale range.

10. Record conditioner feedback readings at predetermined negative strain settings.

Note *You will enter these recorded readings on the Linearization Data window.*

A. Set the calibrator micrometer to a value that is 0% of the extensometer's full scale range.

B. Record the calibrator's readout value and the corresponding conditioner feedback reading in the 0% row of your record sheet.

C. Set the calibrator micrometer to a value that is -2% of the extensometer's full scale range

D. Record the calibrator's readout value and corresponding conditioner feedback reading in the -2**%** row of your record sheet.

E. Repeat steps C and D for other negative strain settings (typically at -4, -6, -8, -10, -20, -40, -70, and -100 percent of full scale).

11. Record conditioner feedback readings at predetermined positive strain calibrator settings.

    A. Set the calibrator micrometer to a value that is +2% of the extensometer's full scale range

    B. Record the calibrator's readout value and corresponding conditioner feedback reading in the +2**%** row of your record sheet.

    C. Repeat steps A and B for other positive strain settings (typically at +4, +6, +8, +10, +20, +40, +70, and +100 percent of full scale).

12. On the Linearization Data window, enter the calibrator values (**Standard**) and its corresponding conditioner feedback readings (**Conditioner**) for all command points previously recorded on a separate sheet.

13. Verify linearization data.

    A. Set the calibrator micrometer for each strain setting on the Linearization Data window.

    B. At each setting, verify both the calibrator readout value (**Standard**) and its corresponding conditioner feedback value (**Conditioner**).

    C. Check validity before entering each pair of values on a new Calibration Data sheet.

Task 6 Establish the shunt calibration reference

Each DC conditioner supports a shunt resistor. To establish the shunt reference value, perform the following tasks.

1. Depending on your extensometer type, install a zero pin, gage block, or special fixturing to mechanically hold the extensometer at its zero position.

2. Determine the shunt calibration resistor from the following table:

Bridge Resistance	Sensitivity	Range (% Full Scale)	Resistor Value
350 Ω	2 mV/V	100% 50% 20% 10%	49.9 k 100 k 249 k 499 k
350 Ω	1 mV/V	100% 50% 20% 10%	100 k 200 k 499 k 1000 k
700 Ω	2 mV/V	100% 50% 20% 10%	100 k 200 k 499 k 1000 k
700 Ω	1 mV/V	100% 50% 20% 10%	200 k 402 k 1000 k 2000 k

3. *FlexTest SE/LE, FlexTest GT, TestStar IIm Controllers only:* If you do not have transducer ID modules on your sensor cables, install the shunt calibration resistor as follows:

   A. Select the appropriate shunt calibration resistor.

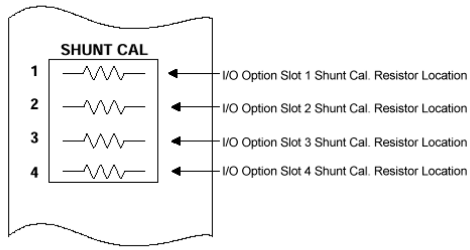
   B. Bend the resistor leads 90º for a 0.3 inch separation.

   C. Cut the resistor leads 0.12 inch from the bend.

   D. Insert the resistor into the connector solder cups and solder.

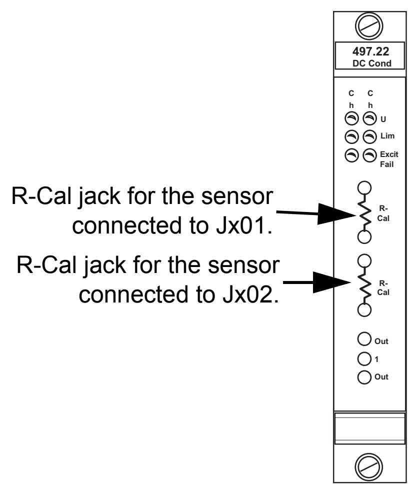
   E. Complete and attach a shunt calibration label as specified on the 493.40/41 Carrier I/O Shunt Calibration Kit (MTS PN 100-028-185).

F. Install the shunt cal resistor/connector assembly into the appropriate slot of the **SHUNT CAL** connector on the front panel of the appropriate I/O Carrier Module.



4. *FlexTest IIm/CTC Controllers only:* Install the shunt calibration resistor into the **R-Cal** jacks in the appropriate DC conditioner.

   You must know which DC conditioner is associated with the strain sensor.



   You also need to know which of the two DC conditioners on the module is used by your extensometer.

   The shunt resistors for the Model 497.22 DC Conditioner are packaged in a thumb-nail sized module. It makes it easier to install and remove the shunt calibration resistor.

5. Perform shunt calibration.

   Standalone FlexTest SE Controllers:

   Select **Setup** > **Strain** > **Calibration** > Select Cal Type >

   A. Select required **Shunt Display** units.

   B. Ensure that **Shunt State (+)** is set to **On**. Polarity is always positive.

      Note the **Shunt Reference (+)** value, it should be 60%–90% (80% is ideal) of the calibrated range of the sensor.

   C. Click **Update** to copy the current shunt reference value into the **Shunt Reference** box.

   D. Set **Shunt State (+)** to **Off**.

   Automated Controllers:

   A. In **Station Setup** select the appropriate strain channel on the navigation panel.**,** click the **Channel Input Signals** icon, and then click the **Shunt** tab.

   B. Select the shunt type. Use (+) polarity if you are not sure what to select.

   C. In the **Current Shunt Value** box, click the **On** button. Note the **Current Shunt Value**, it should be 60%–90% (80% is ideal) of the calibrated range of the sensor.

   D. Click **Update** to copy the **Current Shunt Value** into the **Shunt Reference Value** box, and then click **Off**.

Task 7 Save the calibration settings

It is important that you save your sensor calibration values.

Standalone FlexTest SE Controllers: Select **Setup > Open/Save Parameters > <<Save>>**

Automated Controllers: Click **Update File** on the **Calibration** tab

This saves the current calibration values to your current sensor calibration file.

Index

A

B

C

D

E

F

G

H

I

L

M

O

P

R

S

T

U

V

W

Z

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, Minnesota 55344-2290 USA
Toll Free Phone: 800-328-2255
(within the U.S. or Canada)
Phone: 952-937-4000
(outside the U.S. or Canada)
Fax: 952-937-4515
E-mail: info@mts.com
Internet: www.mts.com

ISO 9001:2000 Certified QMS