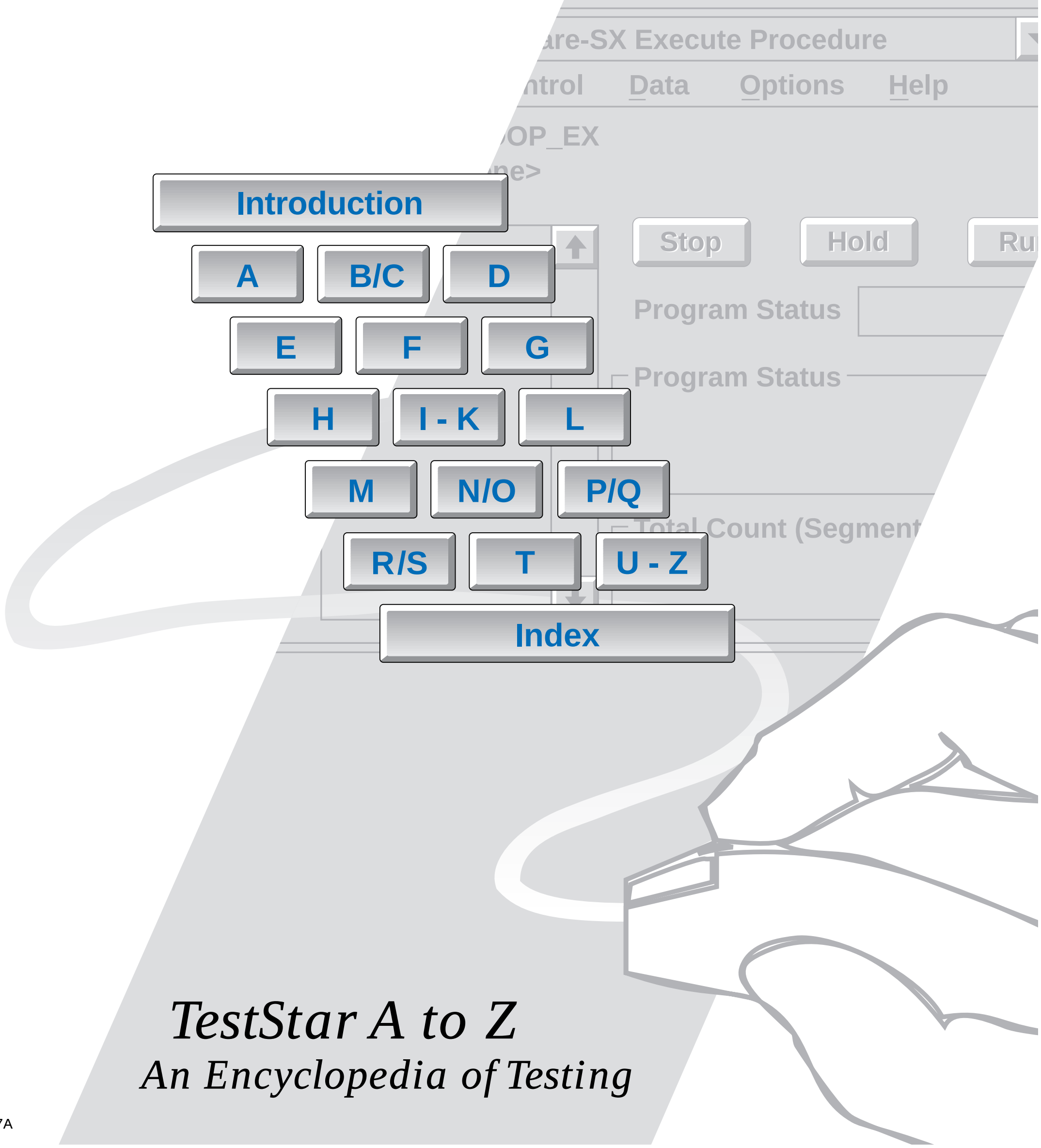
MTS®

TestStar™ II

Control System



TestStar A to Z

An Encyclopedia of Testing

150371-07A

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Acknowledgments

This manual was a collaborative (and often combative) effort by the cantankerous writers in MTS' Educational Products and Services Department.

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How to Use this Manual

This manual is available as:

- An on-line document
- A printed manual

Print Conventions

Cross References

This manual has numerous cross references (with page numbers) so you can easily navigate the manual. If your topic is not listed alphabetically, use the index. Alternate terminology is listed in the index.

Where is the Table of Contents?

In this manual, as in any standard encyclopedia, the various subjects are arranged in alphabetical order. The first several pages of the manual give a broad overview of closed-loop servohydraulic systems, both from the mechanical and from the conceptual viewpoints.

From then on, read just what you want and need. This manual is not meant to be read at one sitting. Look up what you want, and then go about your business elsewhere.

On-Line Conventions

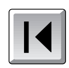
This manual is available as an on-line document in the Portable Document File (PDF) format. It can be viewed on any computer that has an Acrobat reader.

The on-line document has many hypertext links displayed in a blue typeface. All blue words in the body text, blue letters in the footer, blue letters in the buttons on the cover, and index page numbers are hypertext links.

When you click on hypertext link the application jumps to a corresponding topic in another part of the document.

For example, suppose you click the letter "*D*" on the title page. The application automatically jumps to the page that displays topics beginning with the letter D. Then clicking the blue word "*Dither*" causes the application to display the page on which dither is described. Next, if you click the double left-arrow button, the application returns you to the last page you visited, which lists topics that begin with D.

Acrobat includes a button strip that displays these navigation buttons: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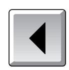
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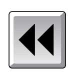
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Lists a table of contents and two levels of sub-topics along the left edge of the window

Acrobat includes other tools too, and we encourage you to explore them. For instance, you can use the magnification tool to magnify the illustration in the *Hydraulic Power Supply* topic until you can read the gages and the text on the warning label. Try it!

Technical Information

Tech Stuff

This icon identifies information of a technical nature. They are provided for engineers, technicians, and other curious people. It's OK if you skip these parts.

Customer Feedback

You can help improve future editions. What subjects should be added? Which subject descriptions need to be improved? We want and need your comments. Please send your comments and corrections to:

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Why this Manual was Created

The materials testing field is rather esoteric. You certainly won't find any information about it in the romance novels section of the local bookstore. Go to a technical library and you're into differential equations by page 10. Manufacturers' manuals sometimes seem to assume that you have multiple postgraduate degrees.

That leaves a big hole. You may be an expert on operating or maintaining complex equipment, but be inexperienced in materials testing systems. Or you may have a lot of theoretical knowledge, but feel uncomfortable in actually undertaking a test.

What You Should Know

You'll be comfortable with this manual if you can handle basic algebra, know enough about electricity and electronics to understand the difference between ac and dc current, and have at least a smattering of knowledge about hydraulics.

The TestStar application program covered in this manual uses OS/2 Version 2.1 or higher. You should have a reasonable knowledge of this operating system before actually running a test.

The TestStar Reference Manual provides a brief review of the OS/2 windows, especially as they pertain to the TestStar system.

Before You Use Your System

Before you attempt to use your system you should get proper training. Do not attempt to use your system based solely on reading this manual.

The power provided by servohydraulic testing systems makes them adaptable to your testing needs, but also presents potential hazards. You should be able to anticipate your system's response before you issue commands from the Load Unit Control Panel, keyboard, or menu. If you cannot, you probably need additional training.

We have experienced and dedicated instructors who can provide you with the skills needed to operate your system efficiently and safely. Again, do not operate the system without proper training.

For information about menus and windows, refer to the *TestStar Reference Manual*.

Primary Components

The components shown below are the primary components in a test system equipped with a TestStar controller. Your system may have a different load unit or a completely different type of test frame. (See *Types of Test Systems* for examples.)

In addition to these primary components, your system may also be equipped with special test fixtures and accessories to accommodate specific test requirements.

Personal Computer

The personal computer provides the primary operator interface to the system. The TestStar software resides on the computer's hard disk.

Digital Controller

The digital controller provides the interface between the computer and the rest of the system. Plug-in modules supply machine control, sensor conditioning, and connections for external equipment

Load Unit Control Panel

The LUCP provides the operator with control of this test station's hydraulics. It is particularly useful when installing a specimen.

Load Unit

This is a typical load unit. Load units apply mechanical forces to the specimen in response to commands from the digital controller.

Types of Test Systems

TestStar's flexibility permits it to control many different types of testing systems, including:

- Component test systems
- Material test systems
- Biomechanical test systems
- Elastomer test systems
- Geomechanical test systems
- Structural test systems

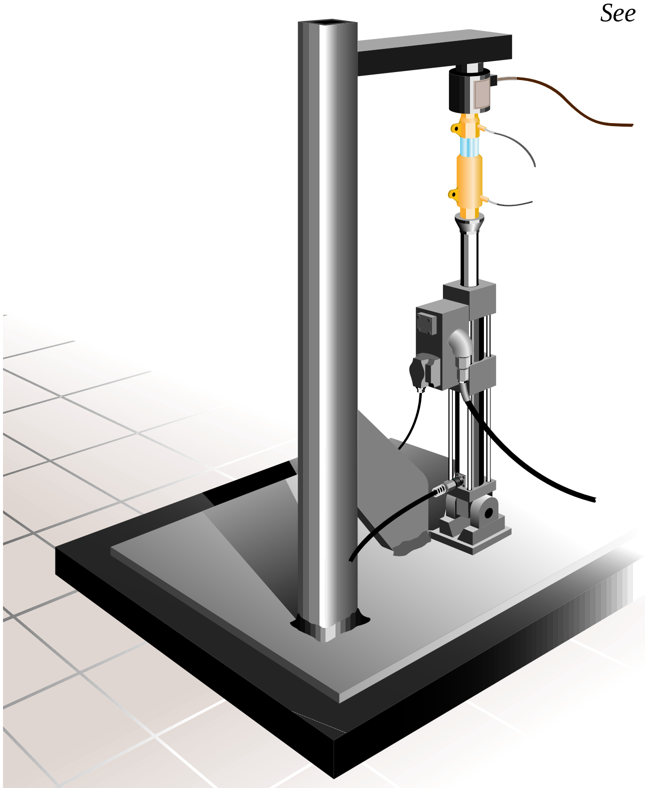
Each type of system uses a unique test frame design. A system's test frame must be suited to the types of forces and environmental conditions required by the test.

As you will see in the following pages, many test systems use a load unit as a test frame. A load unit can accommodate different specimens with an adjustable crosshead and different types of grips. It also houses many of the components needed for testing.

Component Test Systems

Component test systems often use custom test frames designed to test specific specimens (such as engine mount brackets, suspension components, and mechanical assemblies).

See also: *Load Unit 99*
Test Frames 141



Custom Test Frame

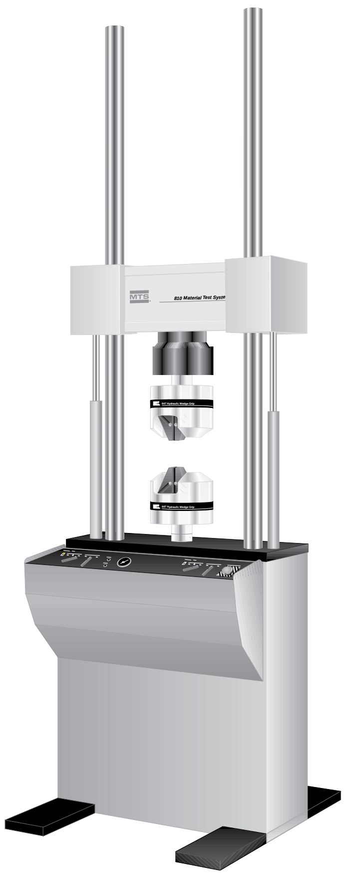
This is an example of a custom test frame used to test components, such as the shock absorber shown.

The actuator is mounted to the base of a reaction mass with a fixed arm. The specimen is mounted to the load cell and joined to the load train with a compression platen.

The actuator's piston rod is positioned to accommodate varying specimen lengths.

Material Test Systems

Material test systems perform general purpose testing of basic material samples (such as plastic, steel, composite, etc.). Test specimens are often cut to standard geometries—such as such as “dog-bone” specimens.



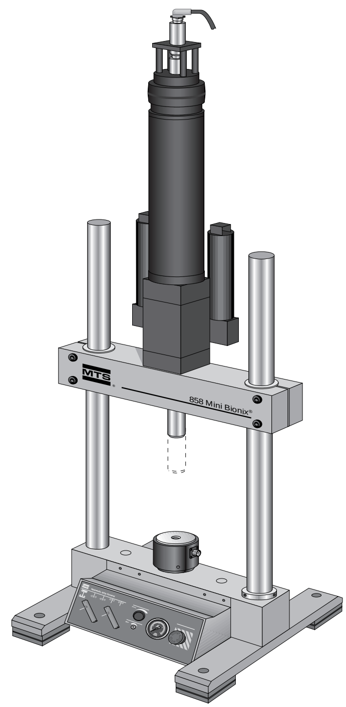
Series 318 Load Unit

This style of test frame is used to test basic engineering materials.

Biomedical Test Systems

Biomedical test systems perform precision, low-force testing of biomaterials and biomechanical devices.

Biomedical applications include fatigue certification studies, bone, joint, and soft tissue studies, implantable devices, and other medical and dental devices where material and structural properties must be determined.



Series 358 Load Unit

This style of test frame is used to test biological materials and biomechanical devices at relatively low forces.

Elastomer Test Systems

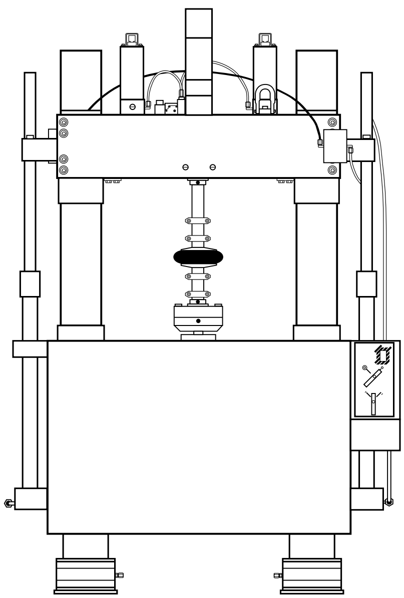
Elastomer test systems perform a variety of specialized tests on elastomeric materials, such as dynamic characterization, static deflection, resonant search, and tearing energy. Each test reveals a different property of the material.

Elastomer tests that require high-frequency loading use Series 331 Load Units. The Model 331.02 Load Unit (shown below) can perform tests up to 300Hz. The Model 331.05 Load Unit. can perform tests up to 1000Hz. Series318 and 358 Load Units can be used to perform low frequency elastomer testing.

Geomechanical Test Systems

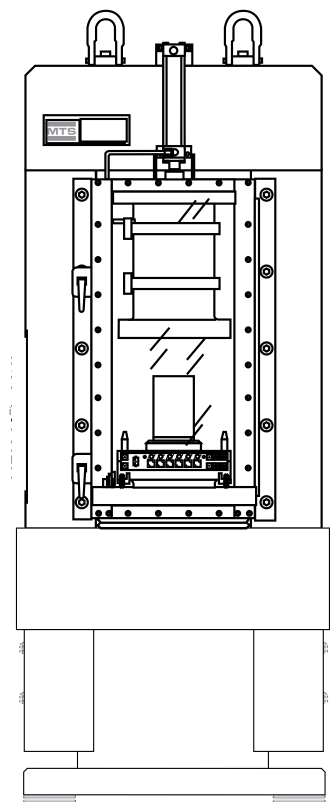
Geomechanical systems perform fundamental rock, concrete, and asphalt mechanics research. These systems often include accessories such as temperature controllers, pressure intensifiers, and a triaxial cells to supply confining pressure, pore pressure, permeable pressure, high and low temperatures, and other environmental simulations.

The load unit used with a rock mechanics system is the Model 315 Load Frame. It can handle the high loads and special fixtures required for geomechanical testing.



Series 331 Load Unit

This style of test frame is used to test elastomeric materials at high frequencies.



Series 315 Load Units

This style of test frame is used to test geologic materials at high forces. Accessories provide special environmental conditions.

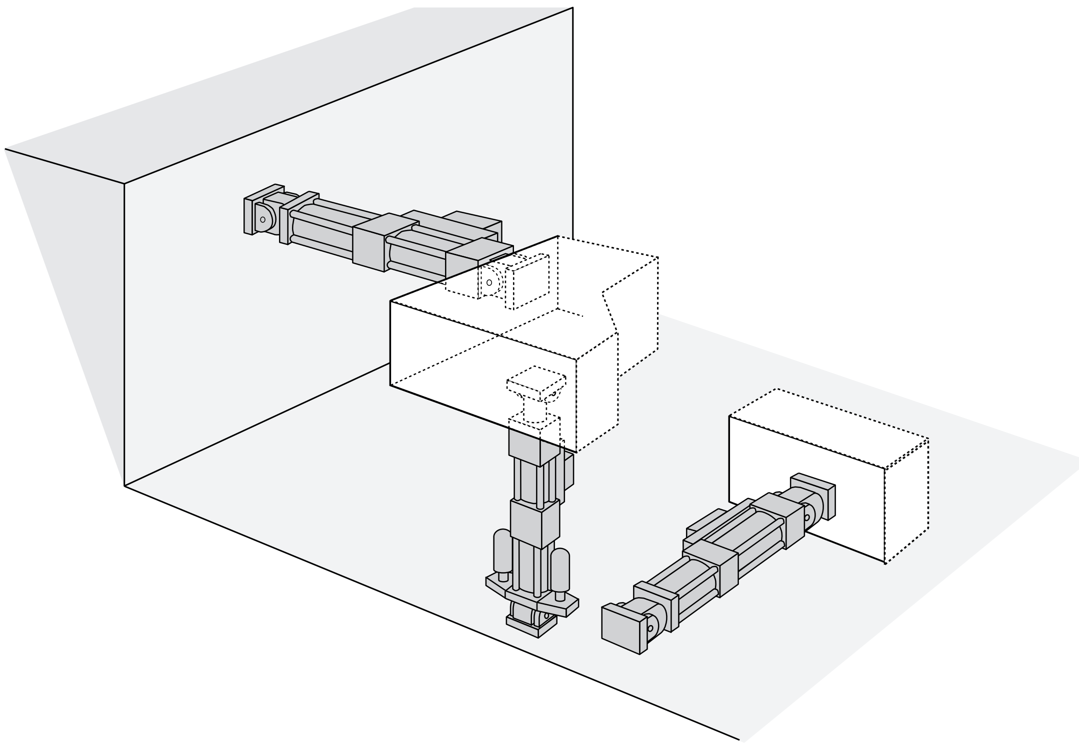
Structural Test Systems

Structural systems perform tests on building structures, such as bridge spans, large trusses, and sometimes entire buildings.

Structural test systems do not use test frames. Instead, the actuators are typically mounted directly to the specimen, and the system control electronics are housed in a separate room.

Structural applications include earth quake simulators and structural beam testing.

The illustration below shows a simplified view of a structural test system. Structural systems may have eight (or more) actuators.



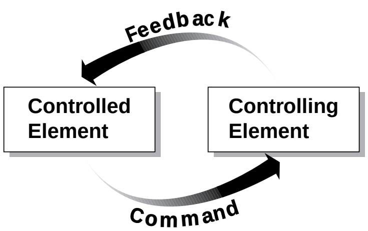
Structural Actuators

Structural test systems typically attach actuators directly to the structures being tested.

Closed-Loop Control

All systems equipped with a TestStar controller use closed-loop control, and understanding it lays a foundation for many of the topics in this document.

Closed-loop control is a basic servomechanism concept of controlling a test, in which a controlling element controls a controlled element.



In a TestStar system, the controlling element is the computer, the digital controller and the TestStar/TestWare-SX software. The controlling element produces a control signal (*Command*) that represents the direction and amount of force the actuator should apply to the specimen.

The controlled element usually comprises the servovalve, the hydraulic actuator, and the specimen itself. The controlled element applies the required forces (command) to the specimen and the specimen reacts to it.

The *Feedback* is the response from one of various sensors that indicates how the controlled element has responded.

See also: *Command 29*
Control Channel 32
Control Loop 35
Control Modes 34
Feedback 66

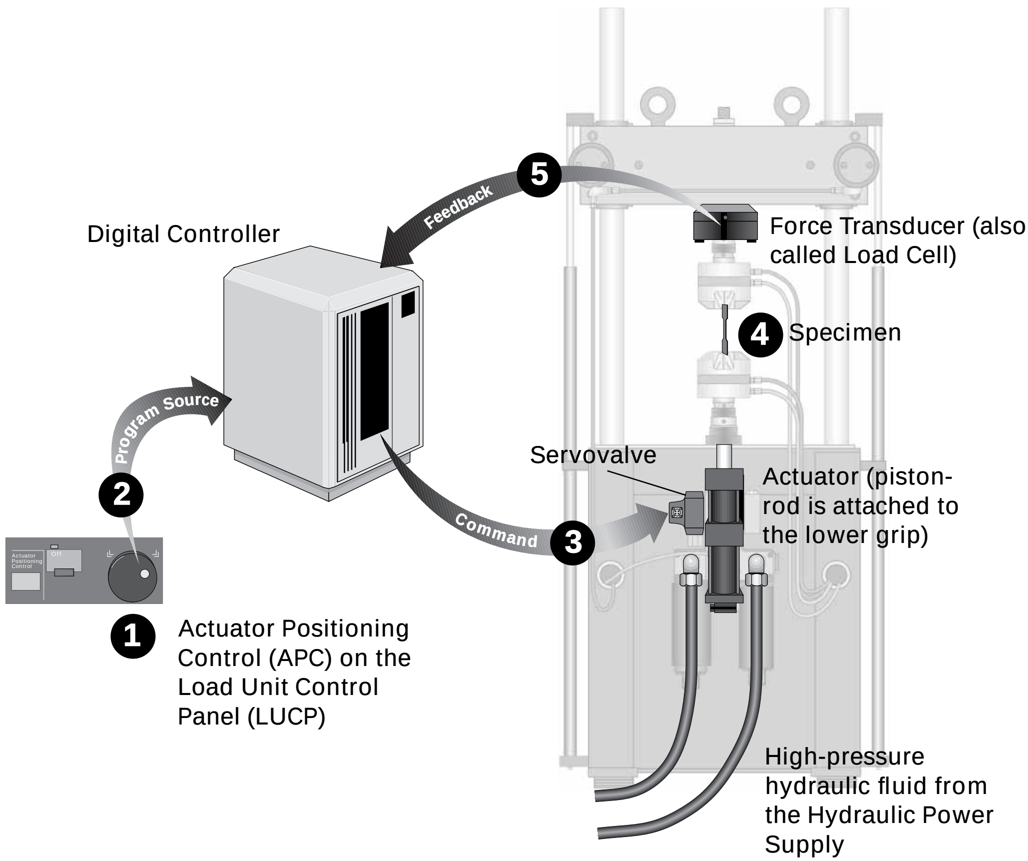
Closed-loop control step-by-step

Refer to the closed-loop illustration on the following page. Assume that the system is in *Force Control*. (It could just as well be controlling another variable, such as displacement or strain.)

Now image that you want to compress the specimen by using the actuator positioning control on the system's LUCP.

1. You input a command by rotating the Actuator Positioning Control.
2. The TestStar application instructs the digital controller to generate a signal that represents the direction and amount of force the actuator needs to apply to the specimen to accommodate your command.
3. The digital controller generates this command and sends it to the servovalve, which opens the servovalve spool and allows more high-pressure hydraulic fluid to push on the actuator.
4. The actuator moves and compresses the specimen.
5. The force transducer senses the amount of compression and sends this feedback to the digital controller, where it is compared with your command.

The system automatically repeats steps 2 through 5 until the desired command is achieved. The digital controller continues to generate commands to the servovalve to maintain the commanded force on the specimen.



Closed-loop Sequence

When you rotate the Actuator Positioning Control the actuator compresses the specimen.

A

Acceleration Compensation

Acceleration compensation minimizes unwanted feedback from vibration caused by the acceleration of any fixture and specimen mass attached to the force sensor. The acceleration compensation signal is applied to the force input signal.

Acceleration compensation is common in the following:

- Moving load cells, where the force sensor is mounted to the end of an actuator
- Load units that operate at high frequencies with massive grips

AC Conditioner

AC conditioners provide a 10 kHz excitation signal to reactive devices (such as an LVDT). The conditioner demodulates the sensor's feedback to produce a proportional signal that represents the sensor's physical state.

See also: Conditioner 31

Accumulator

Accumulators are like a hydraulic version of a capacitor. These are hydro-pneumatic devices located at strategic points in a hydraulic system (usually near the HSM). They may be connected to the pressure line and to the return line.

Accumulators can reduce fluctuations due to sudden changes in flow rate. They also act a short term energy source for high-rate tests by providing additional hydraulic flow for short periods to meet irregular peak demands. Like a capacitor, accumulators filter out pulses in the hydraulic fluid to provide steady hydraulic pressure.

Accumulators are precharged with pressure. Precharge pressure is the pressure of the compressed gas (usually nitrogen) before hydraulic fluid is introduced

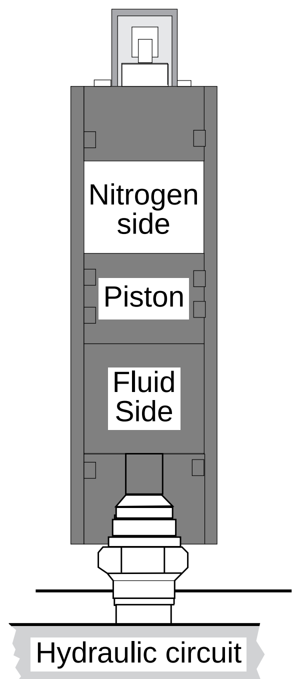
Inserting accumulators into the hydraulic lines permits some fluid to be stored under pressure a short distance from the servovalve and actuator. This has the effect of keeping fluid in the lines in motion and reducing the inertia and line restriction considerations. When the servovalve opens and line pressure begins to drop, the accumulator in the HSM immediately supplies part of the fluid volume and maintains the line pressure. Then, when the servovalve closes, the HPS recharges the accumulator, causing fluid in the lines to remain in motion.

The pattern and frequency of the signal that drives the servovalve will have considerable effect on the HSM accumulator efficiency. Square wave signals, for example, cause a greater demand than sine wave signals or ramp signals.

At some frequencies, fluid flow in the lines may stop completely, and overcoming the fluid inertia may become a more significant operational factor.

An accumulator in the return line damps the pulsing effect caused by “slugs” of fluid being injected into the line as the actuator moves. Movement of hoses and/or hammering of hard lines is thus reduced.

See also: *Hydraulic Service Manifold 87*



Accumulator

Cross section of a typical piston-type, nitrogen gas-charged accumulator.

Actuator

An actuator is a hydraulically powered device that provides displacement of (or force into) a specimen or structure for testing. There are two types of actuators:

- Linear actuators
- Rotary actuators

See also: *Force Train 71*
Differential Pressure Cell 48
Hydraulic Power Supply 83
Hydraulic Service Manifold 87
LVDT 104
Load Unit 99
Test Frames 141
Servovalve 125

Linear Actuators

A linear actuator is used to push on a specimen to cause it to crush or compress (compression testing), or to pull it apart causing it to stretch (tensile testing).

A linear actuator consists of a cylinder that contains a piston. When high pressure fluid is applied to one side of the piston, the piston moves. If the piston rod contacts some external reaction point, then a force is applied to that point equal to the effective piston area times the actuating pressure. The main criteria for selecting an actuator are the force and stroke (displacement) required for the job.

Linear actuators are typically associated with axial control channels which usually include an LVDT (to measure displacement) and a force sensor.

MTS linear hydraulic actuators are available in force ratings from 1,100 to 600,000 pounds (5 to 2669 kN). Certain double-ended actuators can go as high as 4,500,000 pounds (20,000 kN).

The different models of actuators offer a range of features and options that allow you to pick the right actuator for your application.

Selecting an actuator is simple for low-rate or low-frequency tests. At higher frequencies, you must account for factors such as servovalve response, fluid compressibility, oil column resonance, and even the inertia of the piston (and the mass attached to the piston).

Rotary Actuators

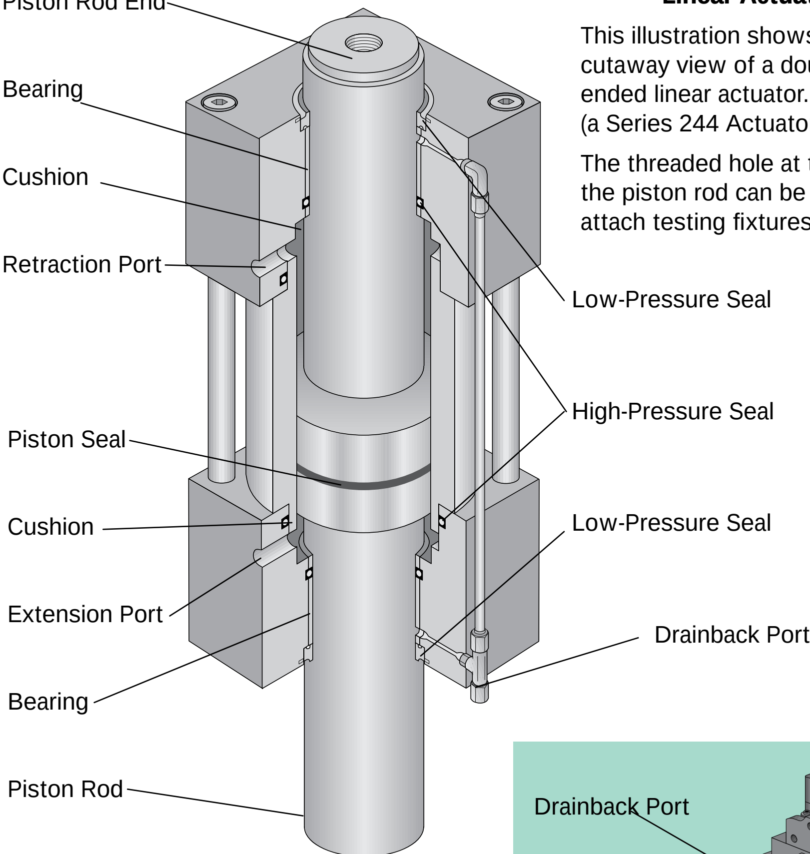
A rotary actuator is used to twist a specimen (torsional testing).

MTS rotary actuators are designed for fatigue and durability testing of materials, axles, couplings, driveshafts, and other components involving limited rotation. These are fatigue-rated, heavy-duty, torque-generating actuators that twist a specimen, and operate under precise servovalve control in MTS closed-loop testing systems.

They are available with a complete line of fixtures and transducer options. MTS rotary hydraulic actuators are available in force ratings from 2000 to 730,000 lbf.in (226 to 82 479 N.m).

Rotary actuators are typically associated with torsional control channels which usually include an ATD (to measure angle) and a torque sensor.

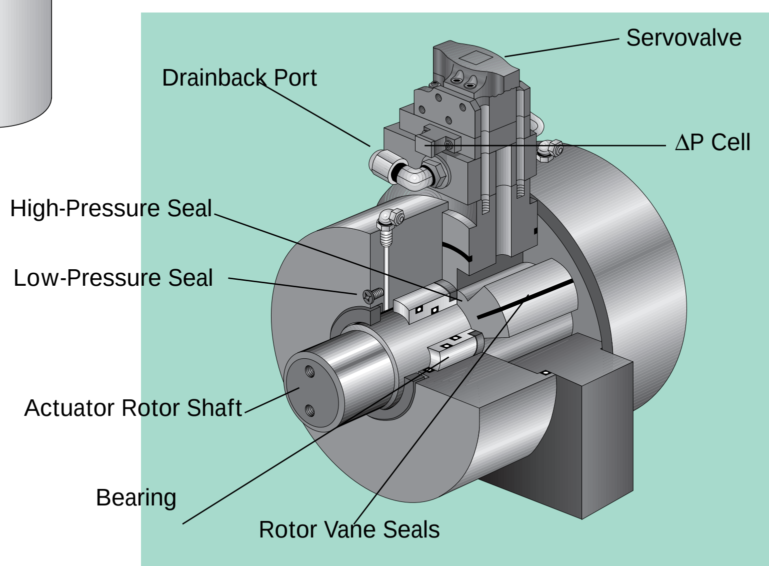
Actuator Components



Linear Actuator

This illustration shows a cutaway view of a double-ended linear actuator. (a Series 244 Actuator.)

The threaded hole at the top of the piston rod can be used to attach testing fixtures.



Rotary Actuator

This illustration shows a cutaway view of a Series 216 rotary actuator. The ΔP (differential pressure) cell senses the force applied to the specimen. It replaces the force sensor (load cell) used in the axial actuators.

Actuator Component Descriptions

Actuator Parts	Description
Bearing	These are nonmetallic bearings bonded directly to the end caps.
Cushion	The cushions protect the actuator from the effects of high-speed and high-mass forces.
Drainback Port	The drainback port allows fluid that manages to leak past the seals to be routed out of the actuator which prevents pressure pockets from interfering actuator performance.
Extension Port/ Retraction Port	High-pressure hydraulic fluid enters the cylinder through one of these control ports. As pressure is applied to one port, the other port is opened to a return line. Fluid flow through these ports is controlled by the servovalve.
High-Pressure Seals	A small amount of hydraulic fluid is allowed to leak past this seal for continuous bearing lubrication. The fluid is returned to the system HPS through a drainback port. High-pressure seals are not normally on actuators with force ratings less than 22 kip (100 kN).
Low-Pressure Seals	The outer part of this seal acts as a scraper ring to minimize external contamination of the seals and bearings. The inner part provides a hydraulic seal. When a high-pressure seal is present, the inner part of the low-pressure seal wipes hydraulic fluid that has leaked past the high-pressure seal from the piston rod. This fluid is then guided to the drainback port.
Piston Rod	The illustration shows an actuator that is equipped with a double-ended piston rod. This type has equal areas on both sides for balanced performance. The piston rod is machined from a single piece of heat-treated alloy steel. In addition, the rod is hollow to allow installing and accurately aligning an LVDT (if used).
Piston Rod End	The piston rod end has a hardened steel insert that provides an internal thread for mounting force cells, swivels, fixtures, grips, etc.
Piston Seal	The piston seal provides a positive seal and reduces friction. Grooves on the piston (not shown here) lubricate the piston surface during short-stroke, side-loaded tests.
Rotor Shaft	One end of the rotor shaft connects to an angular displacement transducer (ATD not shown). The other end of the rotor connects to a specimen where it applies torque forces to the specimen.
Rotor Vane Seals	The rotor vane seals keep fluid from passing from between rotor chambers.
Servovalve	The servovalve controls the hydraulic pressure to the actuator which in turn controls the actuator's movement and velocity.

MTS Linear Actuators

Series	Features	Typical Applications
242	Low force, double-ended, fatigue rated actuator with very low friction operation. High sideload tolerance. Integral Servovalve mounting manifold.	✦ Low force structural fatigue ✦ High velocity, short stroke component tests ✦ Low friction, low signal distortion vibration testing ✦ Structural resonance searching and modal analysis
243	Medium to very high force, single-ended, non-fatigue rated actuator. Easy maintenance. Low cost general purpose static force. Swivel or pivot mounting.	✦ Static testing of space and aviation components ✦ Low frequency cyclic testing of civil engineering structures ✦ Quasi-static vehicle durability tests
244	Medium to high force, double-ended, fatigue rated actuator. Many configuration options. High side load tolerance. Excellent force to weight ratio.	✦ Structural fatigue testing ✦ Highly dynamic fatigue testing of structures and components ✦ Car and truck durability testing
248	Low to medium force, double-ended, fatigue rated actuator with hydrostatic bearings. Very high side load tolerance. High frequency, low harmonic distortion performance. No suction pump required.	✦ High frequency, low amplitude vibration testing ✦ Resonant frequency analysis requiring low harmonic distortion ✦ Applications in which a heavy specimen requires static support ✦ Tests that may cause high sideload forces on the actuator

MTS Rotary Actuators

Series	Features	Typical Applications
215	Low to medium torque, fatigue-rated, two-vane rotary actuator. High strength thrust bearings and non-metallic rotor vane seals. Self-lubricating seals.	Fatigue testing of drive train components for cars, trucks, and aircraft.
216	High to very high torque, fatigue-rated, two-vane rotary actuator. Modular construction with replaceable rotor vanes. Heavy duty radial and axial force tolerance.	✦ Heavy-duty fatigue testing of truck, power plant, and ship derivatives ✦ Military vehicle testing

Actuator Manifold

An actuator manifold is the same as a hydraulic service manifold except it is mounted to an actuator. It is commonly used in load units.

See also: *Hydraulic Service Manifold 87*

Actuator Positioning Control

A control knob on the load unit control panel that permits manual control of the actuator position.

See also: *Load Unit Control Panel 101*

Amplitude Control

TestStar and TestWare-SX applications provide several compensation features that automatically control the amplitude of the command to ensure that the test reaches its desired levels. These are additional features—they are not intended to be a crutch to replace tuning. The following are some of the compensation methods available:

- Peak/valley compensation (also called amplitude control in older versions of the TestStar and TestWare-SX)
- Spectrum amplitude control (SAC)
- Phase amplitude control (PAC)
- Frequency based iterative technique (FIT)

Compensation methods compare the sensor feedback to the test command to determine if the command signal is producing the required physical effect on the specimen. Each type of compensator uses a different method to obtain a programmed correction that ensures the command is properly applied to the specimen.

This is sometimes called overprogramming.

.

Overprogramming is a jargon word that some old timers use. It dates back to the dawn of history when the operator had to set up the system to go too much in order to get it to go anywhere. Go ahead and use the word if you want, but “programming” is just fine and a little more accurate.

See also: *Frequency Iterative Technique 69*
Peak/Valley 112
Phase and Amplitude Control 113
Spectrum Amplitude Control 136

Analog Signals

TestStar converts analog signals into digital signals using analog-to-digital converters. TestStar also converts digital signal back into analog signals using digital-to-analog converters. Each converter is calibrated to accurately reflect original signals with the *System Calibration* program.

See also: *Output Signals 111*

Analog Bus

The analog bus allows you to monitor true analog signals before they are digitized for use within TestStar. Some signals are never digitized (such as *Inner Loop* signals) and the only way to monitor those signals is with an analog output defined to show the analog bus. The analog bus can only be accessed through the rear panel connectors J71 and J72.

Analog Output

Rear panel connectors (J41, J71 - J76) on the digital controller provide analog output signals. An analog output allows you to monitor any signal related to TestStar including digital signals converted into analog signals and true analog signals (see analog bus).

Angular Displacement Transducer

The ADT is a sensor connected to the shaft of a rotary actuator that produces a precise electrical signal proportional to the angular position of the actuator.

See also: *Actuator 15*
Sensor 121

APC

An acronym for the Actuator Positioning Control on the load unit control panel.

See also: *Load Unit Control Panel 101*

ASCII

Acronym for American National Standard Code for Information Exchange. It is a text format. TestStar and TestWare-SX use this format for printed and electronic copies of configuration files, data files, and test template files.

See also: *Files and Directories 67*

Axial

Axial is usually associated with the name of a linear control channel or a type of test using a linear actuator.

See also: *Actuator 15*
Control Channel 32

Auto Tuning

This feature automatically tunes PIDF control modes for a moderate level of tuning. Auto tuning exercises the actuator while monitoring the feedback of the control mode being tuned. This determines the response of the control mode and appropriate settings for the tuning parameters are calculated.

See also: *Auto Tuning 157*

Auto Zero

This is the process of electronic offset to set the output of a sensor to zero without regard to the physical position of the sensed component.

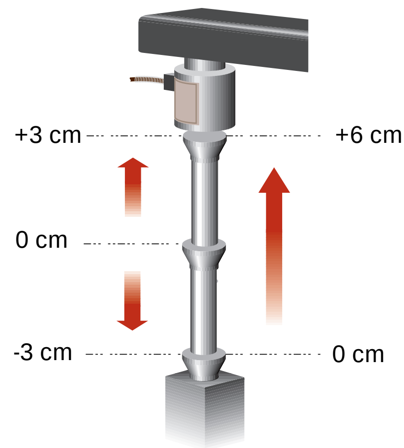
You can auto zero either from the computer or the LUCP. You cannot accomplish this when the sensor is acting as the control mode.

Auto Zero Example

Auto Zero removes the concern about the actual voltage output from a sensor. In other words, you need not be concerned with physically zeroing the sensor—the system electronics adjusts its output electronically.

For example, a system performing compression-only tests. When installing the specimen, you can retract the actuator fully and press the Auto Zero pushbutton either on the screen or on the LUCP display.

Without any physical change in the system, the -3-centimeter position (from the center) appears to be at zero, and the +3-centimeter position appears to be a compression of 6 centimeters.



See also: *Input Signals 94*
Offset 109
Sensor 121

Auxiliary Interlock

An interlock caused when the crosshead is unlocked or by an external device connected to the digital controller rear panel connector J43.

See also: *Crosshead 37*
Interlocks 96
Load Unit 99

B/C

Biaxial Test

A test where two forces are applied at different angles to a specimen.

For example, an axial/torsional test can apply compressive (and/or tensile) forces along with torsional forces to a specimen. The two axis are crushing and twisting.

See also: *Actuator 15*
Axial 21
Control Channel 32
Torsional Test 147

Bridge Completion

Strain gages are sometimes bonded directly to a specimen to measure its deformation under stress. The gages are usually connected in a Wheatstone bridge configuration. One or more arms are bonded to the specimen while the remaining arms are installed in a bridge completion circuit located in the sensor cartridge.

Tech Stuff

This configuration incorporates the resistance of the cable wires(R1) into the bridge to minimize errors. Resistor R10 is a bridge balance adjustment. Resistor R9 sets the bias of the balance adjustment.

See also: *Sensor Cartridge 122*

Calibration

As used in TestStar, 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 calibration procedures are located in the Installation Manual.

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

All sensors require calibration to ensure that their outputs accurately represent the physical condition they sense (such as displacement, force, etc.). 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

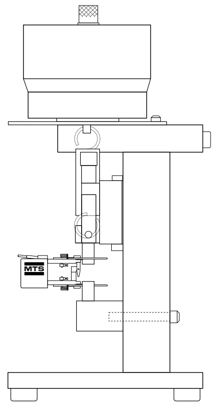
Calibrating a force sensor requires a load standard. A load standard can be a special calibrated force sensor with its own electronics or a set of calibrated dead weights.

Extensometer Calibration

Extensometers require special test fixtures to aid in calibration.

Extensometer Calibration

This illustration shows a typical calibrator with an extensometer mounted to it.



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's 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.

Whenever a dc sensor is connected to the digital controller, be sure that the sensor cartridge associated with the sensor is installed in the corresponding dc conditioner module.

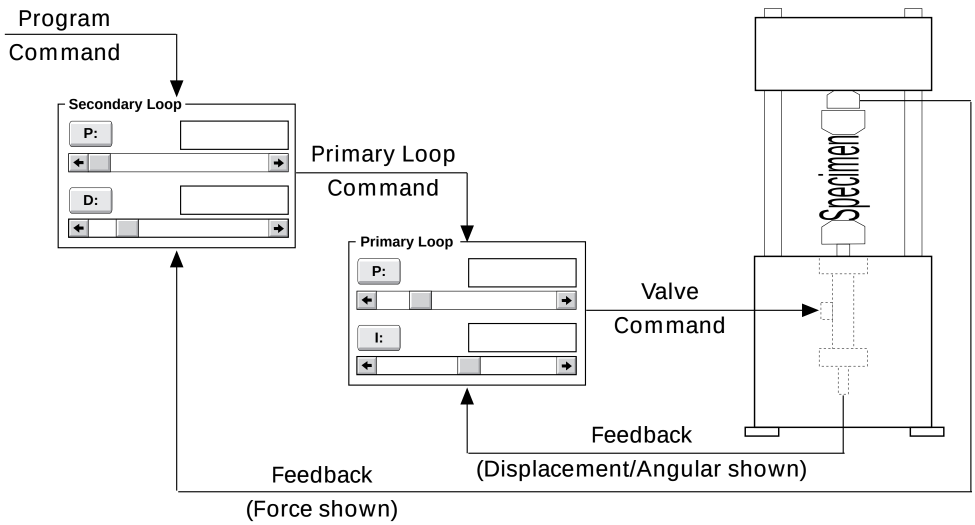
Shunt calibration also lets you swap dc conditioner modules without affecting the sensor calibration accuracy.

See also: *Conditioner 31*
Delta K 45
Extensometers 61
Force Sensor 70
Sensor Cartridge 122
Sensor Range 124
Shunt Calibration 131

Cascade Control

This is a control mode used for specimen testing that requires a high degree of stability under dynamic conditions. This mode uses two sensor feedback signals.

See also: *Control Modes 34*



Cascade Control Diagram

Channel

As used in this manual, Channel is a generic word meaning an electrical path for control signals or data, such as a control channel.

See also: *Axial 21*
Control Channel 32
Torsional Test 147

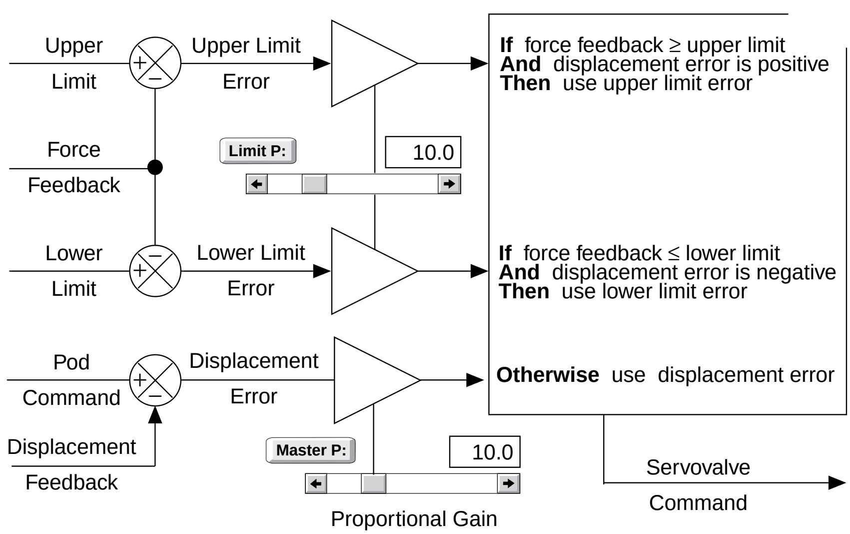
Channel Limited Channel

The channel limited channel control mode (also called CLC) is associated with the load unit control panel, and is involved with installing specimens. The CLC control mode uses two sensor signals.

One input signal (called the *master channel*) controls the servovalve. If the master feedback is displacement, for example, turning the load unit control panel's Positioning control moves the actuator's piston rod so that the grips move closer or farther apart.

A second input signal (called the *limiting channel*) receives an input from another sensor. It oversees the master channel, and ensures that the master channel cannot produce a command that exceeds a limit from the other sensor.

For example, suppose the limiting channel is force. When setting up for a test, you could set a force limit to a low value to prevent damage if the grips accidentally touch each other. If the force limit is reached, the limiting channel prevents further actuator motion no matter how much you continue to rotate the Actuator Positioning Control.



Channel LImited Channel Diagram

See also: *Control Modes 34*
PIDF 113
Tuning 151

Clip-On Gage

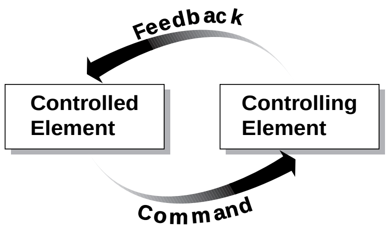
A sensor that clips onto a specimen and monitors the specimen deformation while performing a crack opening test.

See also: *Extensometers 61*

Closed-Loop Control

The test system uses the principle of closed-loop control to apply forces to the test specimen.

Basically, closed-loop control consists of a basic loop where a controlling element provides a control or command signal to the controlled element. The response, or feedback, indicates how the controlled element has responded.

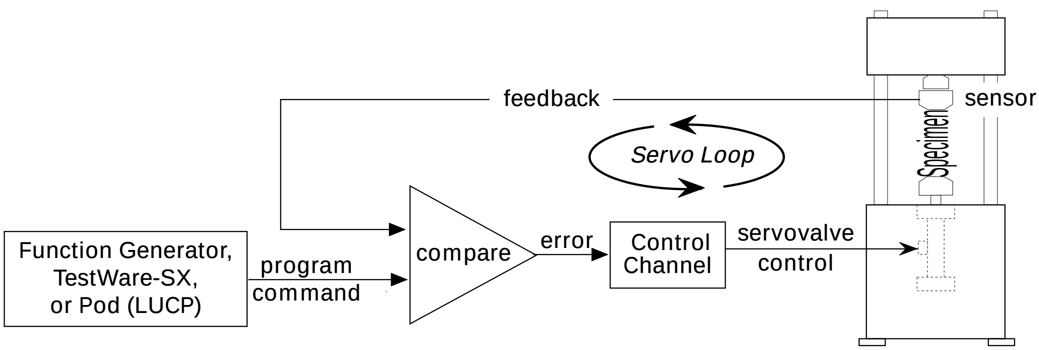


The Fundamental Principal

A simple example of this closed-loop principle is the control over your home heating system. You set the thermostat to a desired temperature. When the room cools off enough, the thermostat closes to turn on the furnace. The thermostat provides the *control* signal. As the furnace operates, it raises the air temperature. The warmer air is the *feedback*. Finally, the thermostat determines that the feedback (the air temperature) and the control (please make the air warmer) are equal. The closed-loop is "satisfied," and the thermostat turns off the control signal to turn off the furnace.

The Servomechanism

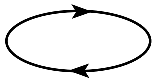
When there is continuous closed-loop control, you have a *servo loop*. There are many examples of this in electronics, such as automatic control of frequency and volume in radio and television receivers. A *servomechanism* is a servo where a mechanical device is part of the loop. Common examples of these are autopilots (aircraft and boat) and controls inside a personal computer's disk drive.



Closed-Loop Control

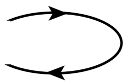
This is the basic closed-loop as used in TestStar.

Closing the Loop



The digital controller reacts to the relative difference between the control and feedback signals (both polarity and magnitude), and adjusts the control signal to correct the difference. This continuous control permits TestStar systems to maintain delicate control of large hydraulic forces. We now have closed-loop control.

Opening the Loop



An open loop is a condition where on of the control/ feedback elements is missing. The loop is open. This is almost always a very bad situation, because there is no longer any control.

An example of this would if somebody were to disconnect the active feedback sensor while a test is in progress. The feedback that limits actuator movement is gone; therefore, the system wants to move at its maximum rate forever. This is impossible, of course, but it's obvious that this type of incident could cause a lot of damage quicker than any human could react to stop it.

For this reason, the TestStar design team has included standard features to monitor the loop and to turn off hydraulic pressure if potentially unsafe conditions occur. You need to learn about these features and how to use them. (Start at the *Interlocks* discussion.) Also, since safety features and written precautions cannot possibly cover every possible situation, please make sure to read the safety precautions information that comes with your system.

Command

This is the signal applied to a closed-loop system or channel to cause the controlled variable to vary in a desired manner. A command is sometimes called a program command, a test command, or a test program. The command source in TestStar is identified as follows:

- SG (segment generator) is generated by the *Function Generator* or *TestWare-SX*
- POD is generated by the *Actuator Positioning Control*
- EXT is generated by an *External Command Source*

Compensators

Compensators are methods that ensure a programmed command is reached. Most of the compensators available to TestStar are designed for specific TestWare-SX processes or specific types of command signals.

See also: *Amplitude Control 19*
Frequency Iterative Technique 69
Peak/Valley 112
Phase and Amplitude Control 113
Spectrum Amplitude Control 136

Compliance

The ability of a specimen to yield elastically when a force is applied.

See also: *Force Train 71*
Load Unit 99

Compression

A force applied to a test specimen that is applied inward from the ends, tending to squeeze the specimen.

Compression Test

Method for determining behavior of materials under crushing loads. When a specimen is compressed, deformation at various loads is recorded. Compressive stress and strain are calculated and plotted as a stress-strain diagram that is used to determine proportional limit, elastic limit, yield point, yield strength, and (for some materials) compressive strength. Standard compression tests are given in ASTM C-528 (high strength ceramics), ASTM E-9 (metals), ASTM E-209 (metals at elevated temperatures), ASTM D-759 (plastics at high and low temperatures).

Compressive Deformation

Compressive deformation is a measurement of the extent to which a material deforms under a crushing load.

Compressive Strength

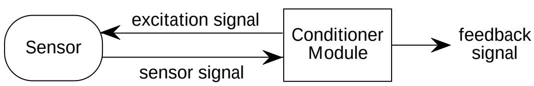
This is the maximum stress a material can sustain under crush loading. The compressive strength of a material that fails by shattering fracture can be defined within fairly narrow limits as an independent property. The compressive strength of materials that do not shatter in compression must be defined as the amount of stress required to distort the material an arbitrary amount. Compressive strength is calculated by dividing the maximum load by the original cross-sectional area of a specimen in a compression test.

Compressive Yield Strength

This is stress that causes a material to exhibit a specified deformation. This is usually determined from the stress-strain diagram obtained in a compression test.

Conditioner

Each type of sensor requires a conditioner module to provide either an ac or dc excitation signal to a sensor. The sensor modifies the excitation signal according to the physical property it measures. The conditioner module processes the signal to extract the feedback signal.



For example, in a force sensor, its voltage output is proportional to the amount of force detected; the polarity indicates the direction of force (compression or tension).

The conditioner also defines the maximum amplified signal. MTS uses a ±10 volt standard.

- AC conditioners provide an ac excitation (10 kHz) for reactive devices. The most common of these is the linear variable differential transformer (LVDT).
- DC conditioners provide a dc excitation +10 vdc) for resistive devices, such as force sensors, extensometers, and strain gages.

Note: *The convention used on TestStar systems is that the sensor's output is negative (the normal output) if it is sensing compression. Although this is the standard for these systems, it can be changed as explained in the Installation Manual. Changing it requires you to recalibrate all of the sensors in the system.*

See also: *Conditioner 31*
Input Signals 94
Output Signals 111

Configuration File

Every user name has a configuration file associated with it. A TestStar configuration is a computer data file that contains operator-defined settings that are customized for each type of test. A configuration file includes all of the TestStar window settings such as: sensor limits and range settings, interlock actions, and tuning values, etc.

Why Have Configuration Files?

Although the flexibility of TestStar permits setting up a wide variety of tests, many users need to perform repetitive testing of similar specimens, or else have tests performed by persons relatively inexperienced in materials testing. In either event, these files permit you to store almost all of a specific test's parameters for recall later.

Using Them to Your Advantage

Each type of test should have its own configuration file. This allows you to recall previous parameter settings so that you don't have to enter them again.

If your system has both experienced operators and trainees, consider setting up separate files for the trainees. Doing so can neutralize the possibility of their corrupting existing carefully adjusted files.

Although one normally associates log-on user names with people's names, consider making "user names" the same as test names if your workstation runs different tests.

This allows TestStar to automatically match the correct configuration file with a specific test.

Configuration files have the extension **.TCC** or **.CFG**. The information in the files can be displayed or printed out as history files.

See also: *Files and Directories 67*

Control Channel

A control channel commands an axis of actuator movement. Normally, there is one actuator per control channel. The channel provides a valve driver signal to a servovalve. The servovalve causes an actuator to move, so that it applies forces to a specimen.

TestStar is capable of operating up to four control channels.

The following diagram shows a typical biaxial test system, where one control channel provides linear motion (usually called the axial channel) and the other control channel provides rotary motion (usually called the torsional channel).

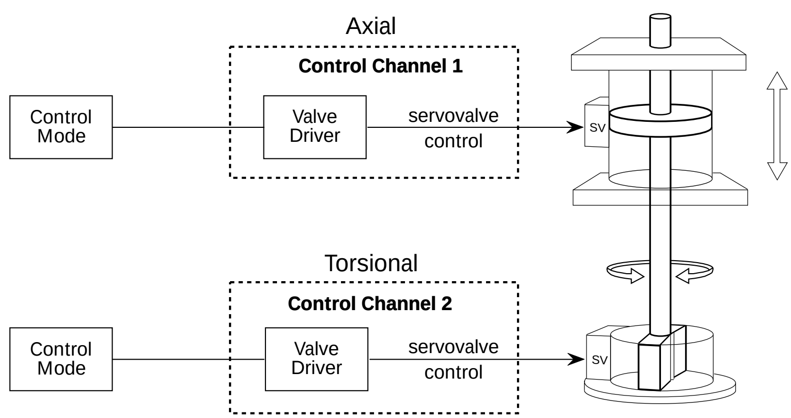
TestStar supports four types of control channels: Axial, Torsional, Pressure, and Generic.

Control Channels on an Axial/Torsional System

This illustration shows the two control channels required for an axial/torsional actuator.

One channel controls the axial movement of the actuator.

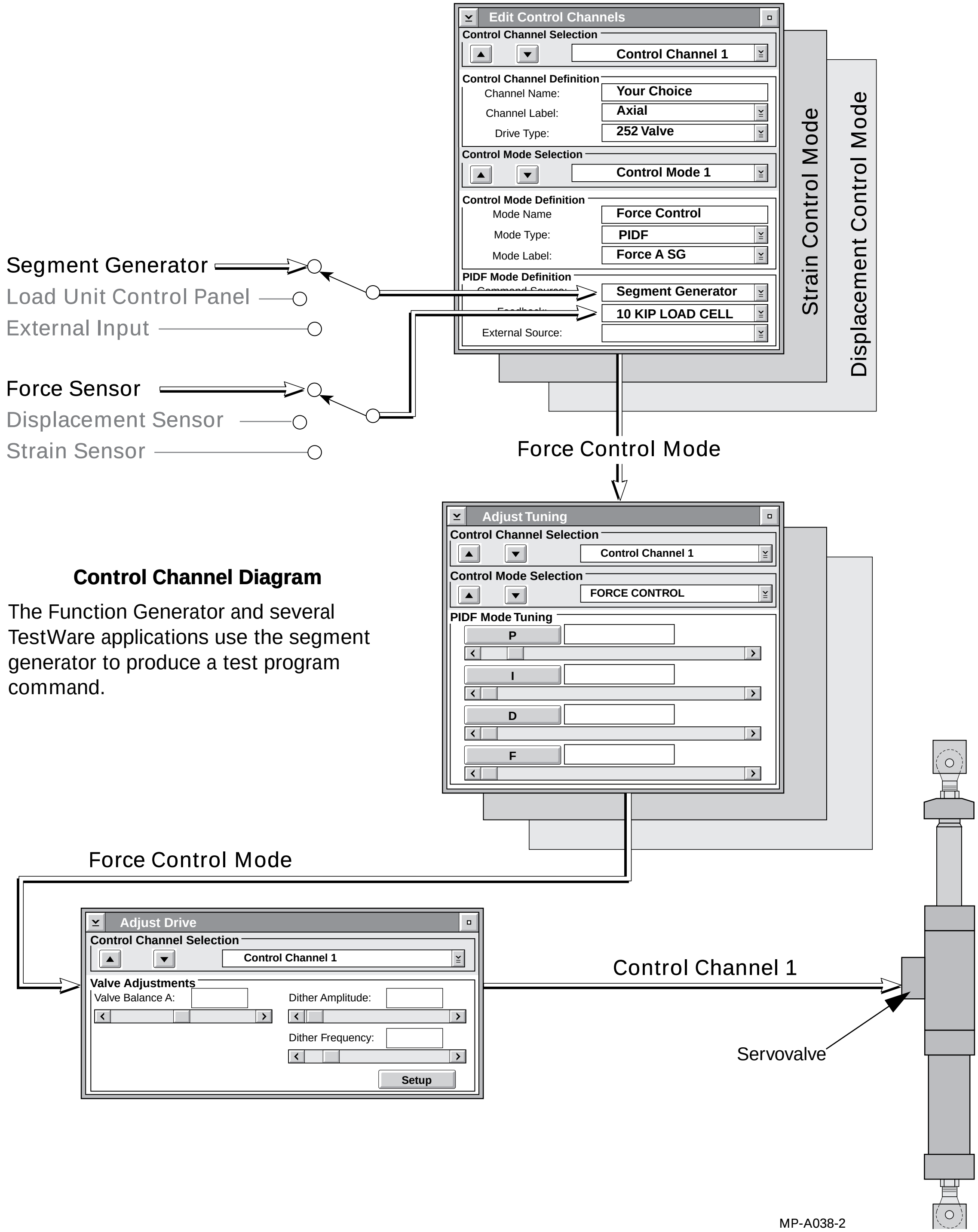
The other channel controls the torsional movement of the actuator.



To define a control channel you need the following:

- A type of control mode
- A source of a feedback for the control mode
- A source that generates a test command

See also: *Control Modes 34*
Command 29
Control Loop



Control Channel Diagram

The Function Generator and several TestWare applications use the segment generator to produce a test program command.

Control Modes

Each control channel can define up to ten control modes. A control mode consists of the sensor signal, command source, and mode type.

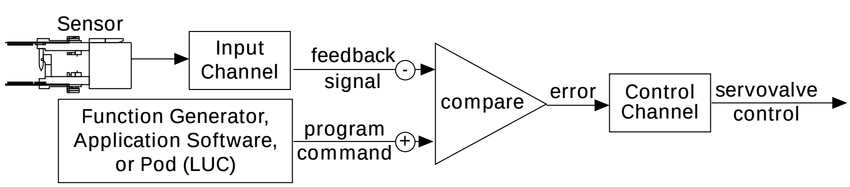
The conditioned feedback signal from any sensor input (internal, external or calculated signal) can be selected for a control mode.

The command source can be from the segment generator, an external dives, or the manual control of the LUCP.

For example, suppose you want to apply a compressive force to your specimen. If you select force control, the test system will apply a compressive force to your specimen in terms of newtons (or pounds) of force. If you select displacement control, the test system will move the actuator in terms of millimeters (or inches) of displacement.

The control mode compares these two signals. Any difference between the signals creates an error signal that causes the control channel to drive the actuator in the direction necessary to remove the difference. When the sensor feedback equals the program command, they cancel each other—the loop is nulled and motion stops.

Only one control mode can be active at a time per control channel.



Control Mode Diagram

This diagram shows the functions involved in one control mode.

Control Mode Types

TestStar uses three types of control modes:

- **PIDF** stands for *Proportional, Integral, Derivative, and Feed Forward*. These are a group of gain adjustments that tune the servo loop response. This is the most widely used control mode. You typically use the PUDF mode for specimen testing.
- **CLC** stands for *Channel Limited Channel*. It is associated with the load unit control panel. When using this mode, one input controls the actuator; a second input limits the effect of the master. You can use the CLC mode for specimen installation.
- **CASC** stands for *Cascade Control*. This mode uses two feedback signals. The output of the secondary loop is the input to the primary control loop. This control mode is used primarily for dynamic testing with force control.

See also: *Cascade Control 26*
Channel Limited Channel 27
PIDF 113
Sensor
Tuning 151

Control Loop

Another term for closed loop control.

See also: *Closed-Loop Control 28*

Controlled Variable

The variable (for example: force, strain, or displacement) that is controlled in a system.

See also: *Closed-Loop Control 28*

Controller Interlock

An interlock caused by any software detector (sensor limit, error detector, or underpeak detector) or any digital controller module (fault or error indicator lights).

See also: *Detector Actions 47*
Interlocks 96

Control Module

Some load units come with an optional control module to aid with specimen installation.

Emergency Stop

This button immediately turns off the hydraulic pressure.

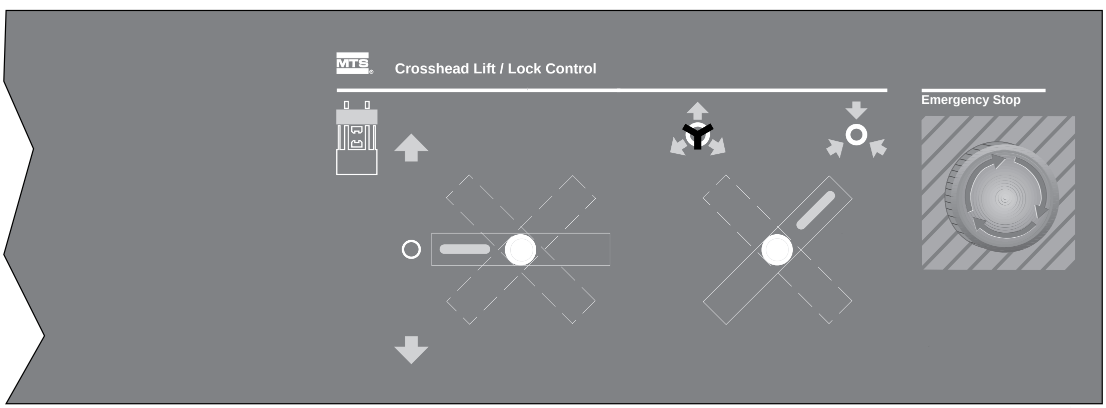
Lock Control

This control locks and unlocks the crosshead so it can be repositioned for a specific specimen.

Lift Control

This control raises and lowers the crosshead using hydraulic lifts. This module needs an external 3000-psi (21-MPa) hydraulic power supply to operate locks and lifts.

See also: *Crosshead 37*
Hydraulic Power Supply 83
Interlocks 96
Load Unit 99



Control Module

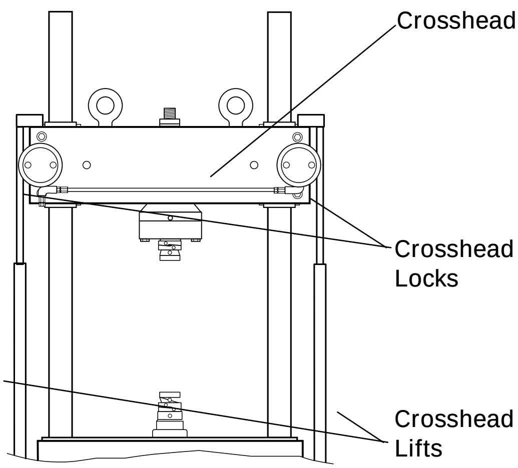
This shows half the control module mounted on the load unit. The other half includes hydraulic grip controls (See also *Grips 79*).

Crosshead

One of the two strong load-bearing structural cross members separating the columns of a load unit. Usually, one of these two members is fixed to the columns while the other is movable to accommodate various-sized specimens.

Crosshead Lifts

Crosshead lifts move the crosshead up and down the columns to achieve a desirable position. Hydraulic crosshead lifts are controlled from the control module. The large eye bolts on the top of the crosshead are used on load units without hydraulic lifts.



Crosshead Lifts and Locks

Crosshead Locks

These locks clamp the crosshead to the columns. Hydraulic crosshead locks are controlled from the control module. Crosshead locking bolts are used on load units without hydraulic crosshead locks.

Auxiliary Interlock

If the crosshead is not locked when hydraulic pressure is turned on, an auxiliary interlock is generated. Once the locks are locked, the interlock automatically clears itself (without Resetting the interlocks)

See also: *Control Module 36*
Interlocks 96
Load Unit 99

Cyclic Command

A cyclic command process uses the segment command to produce a repeating waveform to control a servovalve. A cyclic command creates a waveform by assembling two single segments (monotonic commands) and repeating them continuously or for a predefined number of cycles. It can produce sine, square, and triangle waveforms.

See also: *Function Generator 76*
Processes 116
TestWare-SX 143

D

Data Acquisition

This is a TestWare-SX process that acquires data from any sensor connected to the controller. The data is stored in ASCII format so that it may be used by your choice of programs.

A data acquisition process is sequenced in parallel with a command (function generation) process, that is, data is acquired only while the control channel is actually doing something.

Master Channel

The master channel can be either a sensor signal or else time. It controls the operation by starting data acquisition when it detects the condition you have selected. There can be only one master channel.

Slave Channel

The slave channels acquire data at the same time that the master channel does. There can be as many slave channels as there are defined inputs. Each channel of data can have different units assigned to it.

Tech Stuff

Data Reduction Process

When the program enables data acquisition, it starts an operation called a Data Reduction Process (DRP). You'll get deep into that kind of stuff if you do custom programming using the 790 Application Programming Interface. Fortunately, you don't need to know how DRP works to make full use of TestWare-SX. But an interesting aspect of the DRP is that it includes programming "Calls" that control both the type of data acquisition and which buffer is to be used. When the program issues a call, the digital controller gathers the data and continually returns it to the computer in chunks of 64 data elements. The data is stored within the computer until the end of the call; at that time, it is transferred to the disk drive.

If you wish you can set up one data acquisition process to trigger another data acquisition process.

See also: *Interlocks 96*

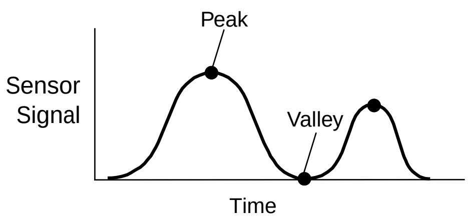
Data Modes

The type of mode you select determines what kind of data is recorded. Each of the following modes can be used to acquire data.

Peak/Valley and Valley/Peak

Either of these modes records data when the master channel signal detects a peak or valley. These modes are the same, except:

- The peak/valley mode looks for a peak first.
- The valley/peak mode looks for a valley first.



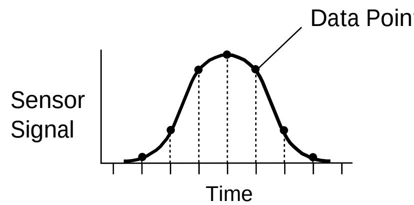
For example, you could set up the test to acquire data each time a peak or valley is detected on a force channel and, at the same time, take data on the strain and displacement channels. Another way to use this mode is to count cycles to trigger another event.

Setting a sensitivity value allows you to specify the amount of reversal that is necessary to define a peak or valley.

See also: *Sensitivity 121*

Timed Data

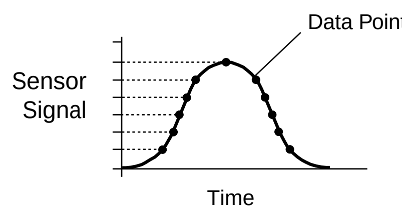
Data is recorded at equal time intervals.



For example, data could be acquired once each second on all selected data channels.

Level Crossing

This operation records data when the master input signal changes a specific amount. In this case, data samples are taken on all desired channels each time the master signal acquires data.



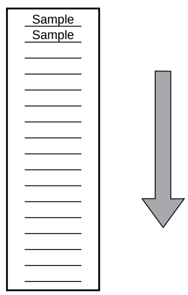
For example, data could be acquired from the force, strain, and displacement sensors each time force (selected as the master channel) changes 500 newtons.

Buffer Types

A buffer's size and type determine how data is recorded and how it affects other processes. You can set the data buffer to record from 1 to 16,000 data elements. A data element consists of the data from the master and slave channels along with a time stamp. The default buffer size is 1024 data elements.

Single Buffer

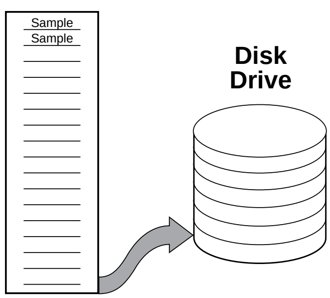
Data is recorded to fill the buffer once, then stops the process and saves the data to disk. The size of the data buffer determines how much data to collect.



This selection acquires specific data in a test. It is useful for triggering other processes.

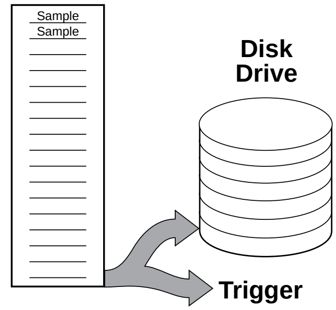
Continuous Buffer

In this mode, data is continuously taken and automatically stored to disk. Storing continues until the end trigger occurs or a process called step done is encountered. The only limit to the total number of samples is the drive's storage capacity.



Continuous Buffer with Trigger

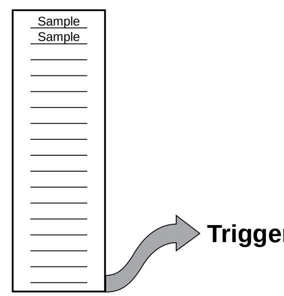
This buffer type functions the same as the continuous buffer except it issues a trigger each time the buffer if full as does the single buffer. Here you would specify the size of the buffer to determine when the trigger is issued. This process ends at the end of a step.



This selection is useful to trigger other processes at regular intervals while saving data.

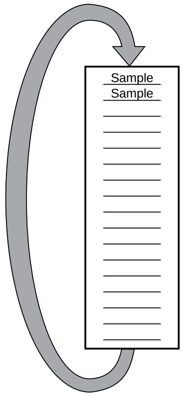
Trigger-Only Buffer

This buffer type functions the same as the continuous with trigger buffer except it does not save data. You specify the size of the buffer to determine when the trigger is issued. This process ends at the end of a step.



This selection is useful to trigger other processes at regular intervals without saving data.

Circular Buffer



A circular buffer continuously records data to the buffer. When the buffer is full, the data is loaded into the top again, overwriting the oldest data. This continues until there is an end trigger or the step ends. Circular buffers differ from the other types in that the data is held within the digital controller until the step calling for data acquisition stops. At that time, data is transferred to the computer, which saves the data to disk.

This type of buffering is useful when the data just before some event (such as specimen failure) is crucial, but data is not required for the whole test.

High Speed Data Acquisition

The optional 790.16 High Speed Data Acquisition process is similar to standard TestWare-SX data acquisition processes. Differences between the High Speed Data Acquisition and the standard process are:

- It acquires data from 100 Hz up to 70 kHz (for a single channel) versus 5 kHz for the standard process.
- It acquires data for up to eight input channels (sensors). Each channel of data can have different units assigned to it. However, increasing the number of data input channels reduces the maximum data acquisition rate.
- It acquires data according to a time increment using a single buffer. Other modes of acquiring data and other types of buffers are not supported by this process.

Phase Shift

Phase shift refers to the lag between a physical event in a test and the measured response of a sensor. This phenomenon occurs because sensors and their conditioners do not have perfectly flat frequency response. This is true regardless of who makes them or how they're being used.

In general, the phase shift of a given conditioner increases with frequency and the amount of filtering used on the signal. Also, different types of conditioners (ac and dc) have different phase shift characteristics.

The magnitude and relevance of the phase shift introduced depends on:

- Your test frequencies
- The type of sensor/conditioner pairs you use in the acquisition process, and
- The filters used in the conditioner.

The 790.31 Dynamic Characterization process automatically compensates for phase shift and other errors as it refines data. The other TestWare-SX data acquisition processes do not compensate for any phase shift that occurs between the physical event and the conditioner's response. These processes behave similarly to other data storage devices (such as oscilloscopes, pen plotters, strip chart recorders, etc.) in how they measure analog signals.

In some situations, effects such as amplitude roll-off and phase shift may adversely affect your data. Because of phase shift, measured phase angle relationships between input displacements and output loads may not be the same as actual relationships. In multi-axial systems, the requested phase between channels may be different from the actual interchannel phase. For systems used in determining dynamic properties using a dc load sensor and an ac displacement sensor with minimal filtering of the analog signal, the phase shift will be approximately 0.7 degree per 10 hertz.

The important thing is to be aware that it exists, and to anticipate its effect on your test results. As always, if you have questions regarding technical issues contact MTS through the HELPLine or your local MTS service representative.

Database

These are computer files stored on disk that hold collected data.

See also: *Files and Directories 67*

Data Display

This is a window that displays special test data. Its like a digital meter except it displays useful types of test data that a digital meter cannot.

See also: *Max/Min Data 105*
Peak/Valley 112
Span/Mean Data
Timed Data 146

Data Limit Detector

The data limit process is useful to trigger other processes. A limit can be a number segments, an amount of time, or a sensor signal value. A limit can be specified as a relative value. (starting when the process begins) or an absolute value (from a zero reference).

See also: *Processes 116*

DC Conditioner

DC conditioners provide a 10 Vdc excitation voltage to resistive devices (such as an force sensor). The conditioner processes the sensor's feedback to produce a proportional signal that represents the sensor's physical state.

See also: *Conditioner 31*

Default

Values that are preset and appear automatically in the software. These values may be changed. When ever you start TestStar or TestWare-SX, default values are used to get the program going.

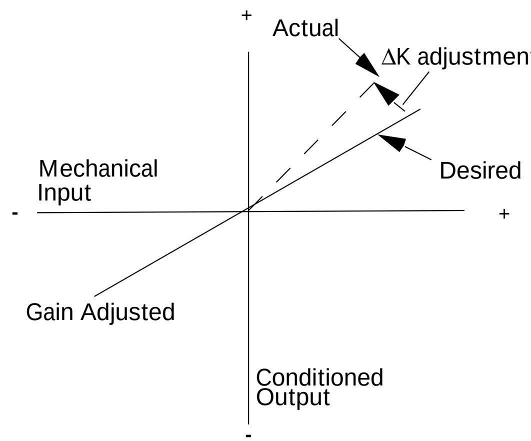
For example, Chapter 5 in the Installation manual describes how to establish an initial set of default values and parameter selections based on your test system. This creates a default configuration file which can be a base for future TestStar configurations.

Delta K

Delta K (ΔK) is a sensor calibration adjustment that compensates for differences in symmetry between the positive and negative outputs. The nonsymmetrical output of a sensor is due to differences in the sensor's sensitivity to positive and negative inputs.

For example, suppose you calibrated an LVDT extension with a gain adjustment. The retraction side of the sensor may require an additional adjustment to properly calibrate the sensor. Then you would calibrate an LVDT retraction with a delta K adjustment.

See also: *Calibration 24*



Delta K Adjustment

The gain is adjusted so that a full-scale command results in a conditioner output representing full-scale mechanical input to the sensor. ΔK is adjusted to compensate for differences in symmetry between the positive and negative outputs

Delta P

A delta P (ΔP) sensor measures the difference in pressure on each side of the actuator piston.

See also: *Actuator 15*
Differential Pressure Cell 48
Tuning 151

Derivative Gain

Derivative gain is also called rate. 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.

See also: *Tuning 151*

Detectors

Detectors monitor system signals. They can be used to notify you of changes in the test, they can shut down the test, or they can change the course of a test.

See also: *Detector Actions 47*
Error Detector 58
Fault Status Window 66
Sensor Limits 123
TestWare-SX 143
Underpeak Detector 158

TestStar Detectors

TestStar detectors let you know when something is going wrong with your test.

TestStar detectors notify you when predefined settings are exceeded. The level of notification depends on the selected *Detector Actions*. Each of these detectors can be enabled or disabled. They all activate the *Fault Status Window*.

Sensor Limits

Each sensor can have a high and a low limit. Each of which can be enabled separately. When a sensor exceeds its upper or lower limit, the selected detector action occurs.

Error Detector

The error detector monitors the servo loop error signal. This detector compares the difference between the program command signal (that goes to the specimen) with the sensor feedback from the specimen through the sensor of the current control mode. You can set two error detectors.

- One to detect a moderate error to simply warn you that something is about happen.
- One to detect a large error to shut down hydraulic pressure.

Underpeak Detector

The underpeak detector can be used during cyclic tests to ensure that minimum peaks and valleys are achieved each cycle.

TestWare-SX Detectors

TestWare-SX detectors are special processes that respond to test conditions or create conditions to trigger other processes. These detectors can change the flow of a test by triggering other processes.

Data Limit Detector

This detector monitors an input signal. It is used to trigger other process when an input signal reaches a specific level.

Digital Input Detector

This detector monitors up to 8 digital inputs (through connector J54) from external sources to end one process and start another.

Operator Event

This detector waits for an operator to press a specific button before triggering other processes.

Peak/Valley Change Detector

This detector monitors the peaks and valleys of an input signal. It triggers other processes if a peak or valley exceeds a tolerance level.

Detector Actions

A detector action is an event that occurs when conditions of a detector are true. This is also called a detector fault. The detector actions are available for all TestStar detectors.

Standard Actions

The following four predefined actions are available for every detector:

- **Disabled:** turns the detector off.
- **Indicate:** displays a message in the Fault Status window that a detector has been triggered.
- **Hydraulics Off:** turns off the hydraulic service manifold antisyphilis a message in the Fault Status window.
- **Interlock:** turns off the hydraulic pressure, generates a hydraulic interlock signal, clamps the servovalve, and displays a message in the Fault Status window

Customer Defined Actions

You can define actions. They need not indicate that an error has occurred; instead, these can be used in designing your test.

- **Hold:** Does not turn off hydraulic power if the detector trips. Instead, a control mode will maintain the existing state. **For example**, if a displacement control mode as been selected, the actuator will hold its current position.
- **Ramp:** Does not turn off hydraulic power if the detector trips. In this case, a control mode will ramp to a selected end level.

By using either of these, you could design a test procedure to proceed to a defined state (say, for example, to a certain strain sensed by an extensometer). If you are using the Hold function, the test could maintain a constant strain while you adjust the equipment, change parameters, and resume the test.

See also: *Error Detector 58*
Fault Status Window 66
Interlocks 96
Sensor Limits 123
Underpeak Detector 158

Differential Pressure Cell

Differential pressure (ΔP) is the relative pressure difference between the compressive and tensile ends of a hydraulic actuator. This differential pressure is what causes the actuator to move or to exert a force.

Differential pressure is detected by a special sensor consisting of two ports and bonded internal strain gages. The sensor is connected across the ends of an actuator's cylinder. The electrical output is proportional to the pressure differential (hence the name ΔP) in the actuator. Since the force applied by the piston is a function of the differential pressure, the ΔP cell's output is also proportional to the applied force. So, like the regular force sensor, the ΔP cell is a force sensor whose output can be connected to a dc conditioner and processed as an input.

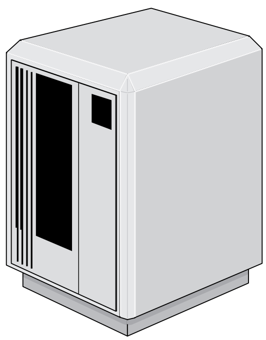
An advantage of ΔP cell is that in very large systems you can use the same sensor on a 10-kip actuator or on a 10,000-kip actuator. Its size and cost do not increase with force, as does the force sensor's.

Another use for a ΔP signal is for closed-loop stabilization for systems with large hydraulic fluid flow rates. It also compensates for compressed hydraulic fluid, which acts like a spring. This function is not needed with TestStar systems.

Digital Controller

The digital controller (also called a controller or test controller) provides the interface between the computer and the rest of the system. The interface includes machine control, sensor signal conditioning, and connections for external equipment.

The personal computer downloads the program code to the digital controller. This provides the digital controller with the code required to control the system.



TestStar Digital Controller

Machine Control Modules

The following electronic modules control the interface between the digital controller, and all other system components.

Processor

The processor provides the interface between the computer and the other modules. This module receives the operating code downloaded from the computer. It also coordinates the other modules.

Hydraulic I/O

This I/O provides control of the hydraulic power supply (HPS) and the hydraulic service manifold (HSM) for one test station. This includes all hydraulic and program interlock sensing.

Analog and Digital I/O

This I/O provides 16 analog-to-digital channels for analog inputs and up to 16 digital-to-analog channels for analog outputs.

Instrumentation Modules

The following modules are found in all systems. The quantity of each module type installed varies between systems.

Valve Driver

This module controls the servovalve.

DC Conditioner

This conditioner provides excitation and signal conditioning for resistive sensors. Typical sensors used with dc conditioners measure force, strain, and pressure.

AC Conditioner

This conditioner provides excitation and signal conditioning for reactive sensors. A typical sensor is the linear variable differential transformer (LVDT), which measures the displacement of the actuator's piston rod.

Instrumentation Bus Controller

The controller provides a digital interface between the plug-in modules of the instrumentation bus and the controller's processor module.

Interlock Module

This module monitors the plug-in modules for interlocks (error conditions).

See also: *Analog Signals 20*
Conditioner 31

Digital

Digital Input

A digital input detector process monitors up to 8 digital inputs from the rear panel connector J54. It can monitor switch contacts and/or a logic signal. The cable may have more than one destination. The process ends when the proper signal is detected by any of the eight input signals.

See also: *Processes 116*

Digital Meter

A meter can be connected to one of the Analog Readout connectors (J71 - J76) on the rear panel of the digital controller.

The TestStar software includes a digital display that works like a meter but displays certain test related signals that aren't available to a meter.

See also: *Meters 106*
Readout 120

Digital Output

The Digital Output process can signal up to eight external devices during a test. The process produces up to 8 output signals through the rear panel connector J55 (see Chapter 3 in the Installation manual).

All output channels that have an action assigned are issued when the process is executed.

See also: *Processes 116*

Digital Scope

A software generated oscilloscope.

See also: *Scope 120*

Displacement

The linear or angular change in position of a mechanical component, usually an actuator piston rod or vane. Displacement is usually measured with an LVDT.

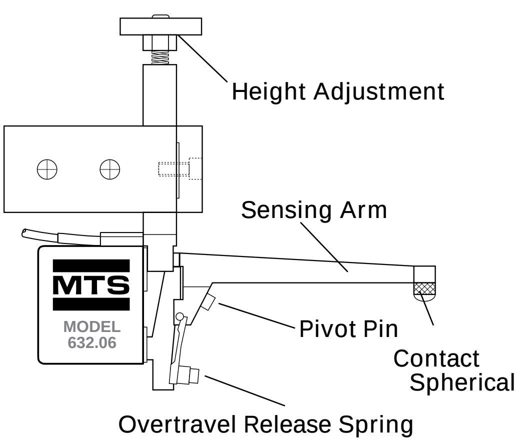
See also: *Control Channel 32*
LVDT 104
Temposonics Transducer 140

Displacement Control

A system control mode where the feedback from a displacement sensor (such as an LVDT) is the primary sensor in the control of the loop.

Displacement Gage

Displacement gages are designed for use in a applications where accurate displacement measurement and control are desired.



Displacement Gage

The gage consists of precision, resistance-type, foil strain gages bonded to a metallic element in a Wheatstone bridge.

A hardened spherical contact on a sensing arm contacts the specimen or force train part. Elongation or compression of the specimen or any movement of the force train causes movement of the sensing arm. This movement bends the metallic element, changing the resistance of the strain gages. The change in the balance of the Wheatstone bridge produces an electrical output that is proportional to the displacement of the sensing arm.

A single sensing arm extends from the gage's body to the measuring point. This sensing arm spring-loads the spherical contact against the specimen or force train component. The gage is protected against over-travel in all directions. If all force is removed from the spherical contact (such that there is no contact between the point of measurement and the spherical contact) the sensing arm is simply allowed to pivot. If, after the maximum travel range is reached, the force against the spherical contact continues to increase, the sensing arm disengages from the gage at the pivot pin when the force limit of the overtravel release spring is reached. Side loads against the spherical contact (such as when the specimen fails) that exceed the limits of the overtravel release spring also cause the sensing arm to disengage. If the sensing arm disengages, it can be reassembled without changing the position of the displacement gage body.

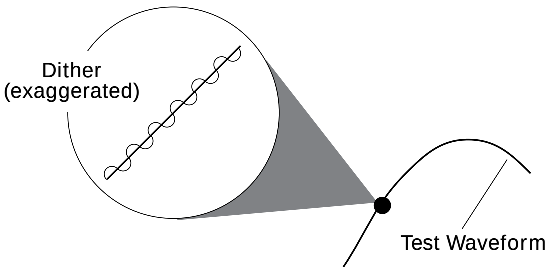
The gage is positioned with respect to the specimen or the force train part by turning the height adjustment handle.

See also: *Extensometers 61*
Gage Length 78

Dither

Dither is a small high-frequency sinewave applied to a servovalve spool to keep it in motion so that it doesn't stick. This provides improved small-signal resolution.

See also: *Hydraulic Fluid 82*
Servovalve 125
Tuning 151



How it Works

Hydraulic oil contains small particles of solid material. The larger particles can actually damage moving surfaces. A more hidden problem is caused by the small particles—those that are smaller than five microns. They can form a fluid dam that prevents uniform flow (such as between the spool and the cylinder in a servovalve). Although the particles do not damage the valve, they redistribute the hydraulic pressure around the spool. This creates a side load on the valve, causing it to stick or move erratically. The stick-slip effect is commonly called stiction.

The dam caused by the silt particles can withstand a moderately high differential pressure, but will break apart if the spool is moved even a modest amount.

This is the principle behind dither—by keeping the spool constantly in motion, a damming of the silt particles is unlikely.

When to Adjust

If you are running a test on a properly tuned system, you probably need to adjust dither if you observe either of the following:

- A sinusoidal test waveform is distorted at its maximum and minimum points (when the actuator is moving the slowest). This is more observable during a test that has a low-frequency or a low-amplitude test waveform. Dither amplitude needs to be increased.
- You hear a sound that is as irritating as a fingernail scraping on a blackboard. In this case, dither amplitude is excessive.

How to Adjust

A quick adjustment can be made simply by increasing dither until you can barely hear it. That amplitude, however, is often unnecessarily large. If an LVDT feedback is available, it is preferable to monitor the valve's feedback. As long as there is a measurable valve motion, then dither is sufficient. Remember that the objective is simply to verify that the valve spool is constantly in motion, preventing silt dam formation.

When Not to Adjust

Dither can help reduce the effects of stiction. If an appreciable amount of dither is required for acceptable operation, there is a good chance that there are fluid problems that you should look into immediately.

Drive

Drive is the general term applied to the interface of the digital controller with the actuator. TestStar sets up Drive to use either a servovalve or servomotor. Other peripheral devices, such as furnaces and pressure intensifiers, may also be controlled by Drive.

See also: *Control Channel 32*
Servovalve 125

Dynamic Characterization

The 790.31 Dynamic Characterization application is a specialized TestWare-SX process. It characterizes the dynamic properties of elastomeric materials and components. It allows you to sweep temperature, frequency, dynamic amplitude, mean level, and the phase relationship of multiple control channels. You can nest sweeps and sweeps can be stepped in a variety of ways. This software package also includes a set of macros that help you work with the acquired data in the Excel speadsheet application.

See also: *Software Options 132*

E

Elasticity

The ability of a material to return to its original shape when the force that caused the deformation is removed.

Elastic Limit

The greatest stress that can be applied to a material without causing permanent deformation (plastic behavior).

See also: *Modulus of Elasticity 106*

Elastomer

A polymeric material with resiliency (for example, rubber or plastic). There are several specialized processes designed for elastomer testing.

See also: *Dynamic Characterization 53*
790.33 Static Deflection 134
Elastomer Tearing Energy 54

Elastomer Tearing Energy

The 790.38 Elastomer Tearing Energy application is a specialized TestWare-SX process. It allows you to characterize the crack growth behavior of elastomeric materials. You can define a loading schedule to acquire stress/strain data at each strain level of interest. This process can also determine the pretest strain energy levels of a specimen.

Elongation/Strain

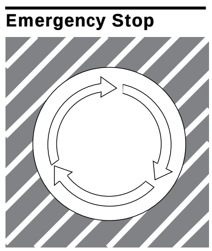
The increase in gage length of a body subjected to a tensile force, often expressed as a percentage of the original gage length.

This force places tension on the specimen, causing it to pull apart.

See also: *Extensometers 61*
Gage Length 78

Emergency Stop

Emergency stop (E-stop) switches are located at strategic places in a test system. This is a large red button on a yellow striped background. Pressing the E-stop switch automatically removes hydraulic pressure and shuts down any test in progress.



The emergency stop switch stays activated until you twist the knob as indicated by the arrows.

See also: *Interlocks 96*
Load Unit Control Panel 101

Energy

Energy is normally considered the capacity to do work. For the coverage in this manual, we shall consider the definition in ASTM Standard E6, where Mechanical Hysteresis is, “the energy absorbed in a complete cycle of loading and unloading.”

Consider the hysteresis curve shown to the right, which charts force vs. displacement for one cycle of an elastomeric material. As we apply force to a specimen (“load” it), the specimen absorbs energy. Some energy is returned when the specimen is unloaded. The shape of the hysteresis curve depends upon the material. A perfect spring gives back all of its energy—its curve would be a straight line.On the other hand, a fat curve indicates that the specimen has absorbed much more energy.

- We normally associate fat curves with squashy materials and thin curves with hard materials, but the shape is also affected by changes in temperature and test frequency

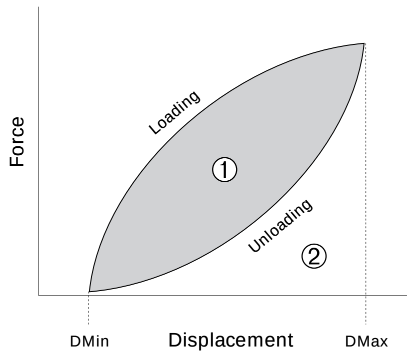
Although you will have no difficulty finding people who want to argue about it, in general think of a material with a lot of bounce as one that gives back energy—it has low hysteresis. A “dead” material has high hysteresis.

Strain Energy

Strain energy represents the energy under the loading side of the loading curve (combined areas ① and ②) at a specified amplitude. A program derives strain energy by integrating the area under the loading side of the loading curves at each amplitude.

Stored Energy

This is the energy under the unloading side of the loading curve at a specified amplitude. A program determines stored energy by integrating the area under the unloading side (area ② only) of the loading curve.



Stored Energy in a Loading Curve

Hysteresis Energy

Hysteresis energy represents the energy inside the loading curve (area ① only). A program determines hysteresis energy by subtracting stored energy from strain energy.

Tech Stuff

For those of you who think integral calculus is cool, the equation for total energy (areas ① and ②) is:

Expression:

$$\int_{D\,Min}^{D\,Max} \mathbf{F} \times \mathbf{D}$$

Where: D_{Min} = Minimum displacement where force is greater than 0.

D_{Max} = Maximum displacement

F = Force

D = Displacement

Units: Joules

Engineering Stress

This is a load (force) applied to a specimen in a tension or compression test divided by the original cross-sectional area of the specimen. In computing engineering stress, the change in cross-sectional area that occurs with increases and decreases in applied load is disregarded. It is also called conventional stress.

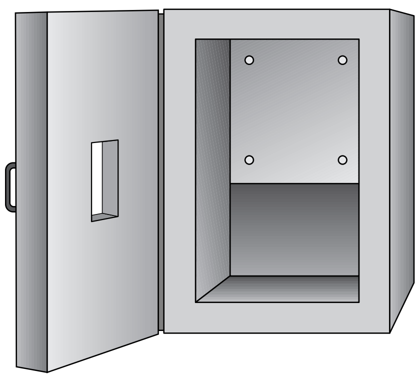
See also: *Stress 138*

Environmental Chamber

Environmental chambers enable you to test a specimen at low or high temperatures. These chambers permit you to run a test at low or high temperatures. They require additional hardware to control their operations

Various models offer temperatures as low as -200°F (-129°C) to +1000°F (540°C)

The chamber consists of an outer liner, insulation, and a stainless steel inner liner. An interior light and a viewing window permit you to watch the test in progress.



Heating capabilities are provided by two electrical heating elements; a fan with a baffle diffuses the convection heat for uniform temperatures. Cooling can be either by liquid nitrogen or liquid carbon dioxide.

It requires a Model 409.80 Temperature Controller with the RS-232 interface option.

A temperature sensor (normally a thermocouple) can be located anywhere within the test area. The temperature control process sets up a set point level (the desired temperature) and the dwell period (how long the temperature is to be maintained), and transmits the command to the temperature controller. The temperature controller returns the current temperature so that the process can control the temperature tolerance.

See also: *Furnace 77*

Error Detector

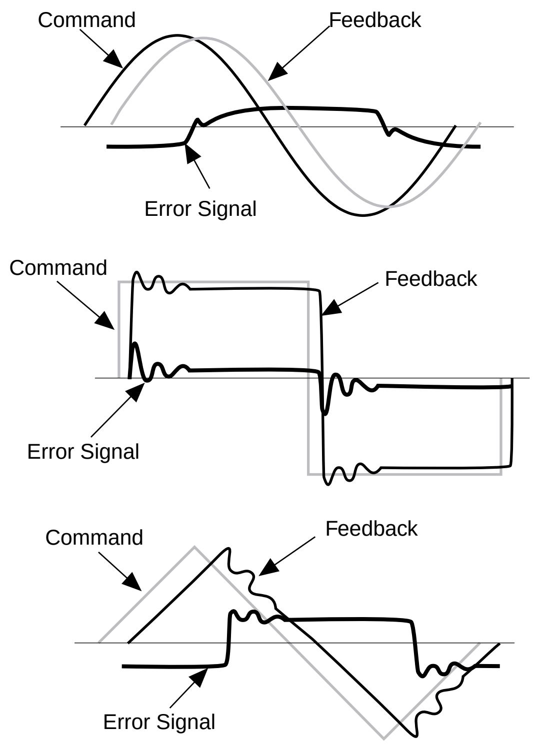
Error detection detects changes in specimen characteristics during a test. If the error exceeds a predefined setting, the function will perform detector action.

See also: *Detector Actions 47*
Fault Status Window 66
Tuning 151

Error Signal

The error signal is the absolute difference between the command signal and the feedback correction signal for the servo loop. The following illustration shows simplified waveforms of this function.

In a “perfect” servo loop, the program command and feedback signals would be exactly the same, and the error would always be zero. The system would correct it so quickly that an interlock is likely from a saturated circuit. In the real world, the feedback lags slightly, so there is a residual error signal. There is nothing wrong with that; in fact, you need one to have the loop work. It’s your judgment what effect an ever-increasing error signal should have on the system.



Error Signals in Sine, Square, and Triangle Waveforms

Error Detector Settings

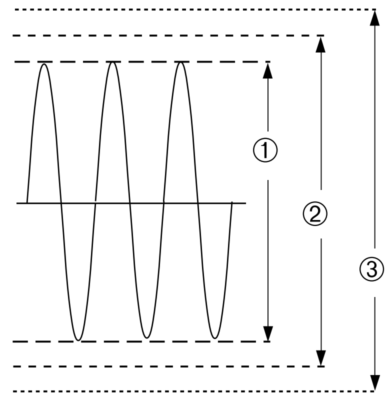
There are no formulas you can use to determine what value is best for any given test. To set the error detector, start the test, observe the error level, and then set up your limits.

Keep in Mind:

- The error detect circuit reads the absolute value of the error signal.
- Make sure to set limits too. They provide some advantages over error detectors because you can more easily establish precise limit levels.

In general, error detection is most useful for a fatigue test on a stiff specimen. By setting the error detection at a level that you expect to be less than a full failure, the detector can warn you (or shut down the test) before the failure.

For example, suppose that you are running a fatigue test under control of the force channel. As the specimen fails with time, the error peak-to-peak value grows. In this case, it might be appropriate to set the Minimum error to Indicate. (The Fault Status window pops up to indicate the situation.) You could set the Maximum error to shut down the hydraulics.



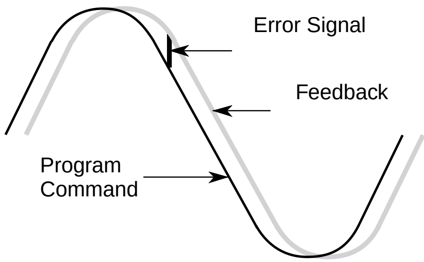
(Not to scale)

① Observed error at start of test
② Minimum (Indicate)
③ Maximum (Hydraulics Off)

Error Detection Ranges for Indication and Interlock

Error at Lower Frequencies

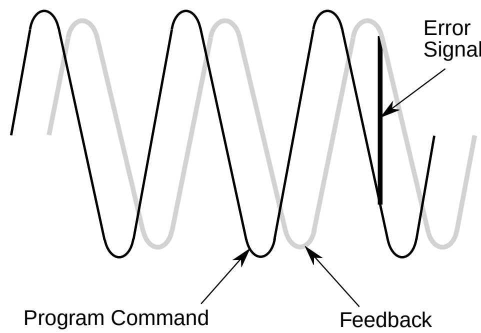
Lower frequencies and static tests usually have small errors because the feedback tracks the command closely. Here you normally set the error detector to a low level.



Error at Higher Frequencies

At higher frequencies the error level tends to be large because of the phase lag of the feedback. The error detector is typically used to detect loss of closed-loop control (due to specimen failure, for example).

The actuator may not have time to meet the peaks commanded by the program command. Because of this, you typically set the error detector to higher levels at higher frequencies.



Excitation

Excitation is a voltage or 10kHz signal applied to a sensor. The sensor modifies this voltage or signal to provide an output proportional to the physical property it measures.

Excitation is produced by ac or dc conditioners:

- DC excitation is a voltage.
- AC excitation is a 10 kHz signal.

See also: *Conditioner 31*

Extensometers

An extensometer is a sensor attached to a specimen that measures a dimensional change (gage length or strain) that occurs in the specimen while being tested.

Extensometers use precision resistance-type strain gages bonded to a metallic element to form a Wheatstone bridge circuit.

Because extensometers are dc devices, they receive their excitation from a dc controller. The shunt calibration capability is available for extensometers.

When the selected feedback source is the extensometer, the system is in “strain” control.

The following table shows typical extensometer types and uses

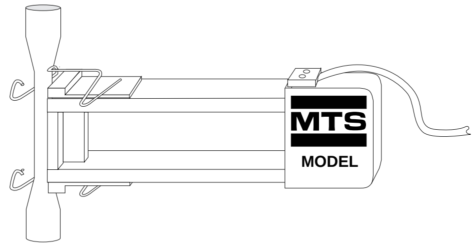
Extensometer Types

Type	Typical uses
Axial	Static and dynamic applications including testing of: tension/compression, low- and high-cycle fatigue, creep/stress relaxation, and strain rate.
Averaging axial	Simultaneously measures axial deflection of opposite sides of the specimen, usually on solid, tubular composite, or metal specimens.
Axial/torsional	Simultaneously measures the axial deflection and torsional strain on solid or tubular composite or metal specimens.
Biaxial	Provides axial and transverse outputs when performing Poisson ratio, composite, or metal formability tests.
Circumferential	Measures circumferential strain on round specimens.
Diametral	Diametral strain in tensile, compressive, and fatigue testing.

Special Designs for Extreme Environments

Many of these extensometers are available in designs for difficult testing environments. Some models can function with temperatures as low as -450 F (-265 C); others can operate at up to 2640 F (1240 C).

Axial Extensometer



This type is used to measure changes along the length of the specimen. Typical methods of mounting them to the specimen are:

- Quick-attachment springs
- Metal extension springs
- Elastic bands

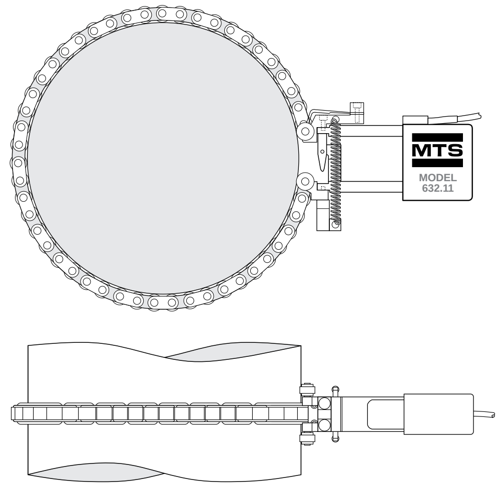
Extensometers can be versatile. For example, both this unit and the Circumferential unit could be Model 632.11—the only difference is their fixtures.

This version has two knife edges, mounted on the extensometer arms, to contact the specimen. Elongation or compression of the specimen causes movement of the arms. This movement is transmitted to the metallic element, causing it to bend, straining the bonded gages and changing their resistance. This change in resistance unbalances the Wheatstone bridge circuit, causing a change in electrical output that is proportional to the strain experienced by the specimen.

Circumferential Extensometer

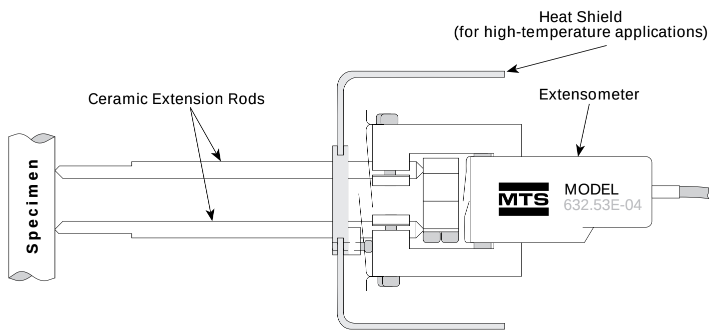
These are used to measure circumferential strains, and are usually used with an axial strain measuring system to determine Poisson's ratio. The roller chain design of these extensometers provides low hysteresis and high repeatability.

Circumferential extensometers can be mounted simultaneously with the axial extensometers in most MTS pressure vessels.



Special Axial Extensometer

The model shown here is an example of an extensometer designed for a special application, in this case for high temperatures. Other types can function in very low temperatures or corrosive atmospheres

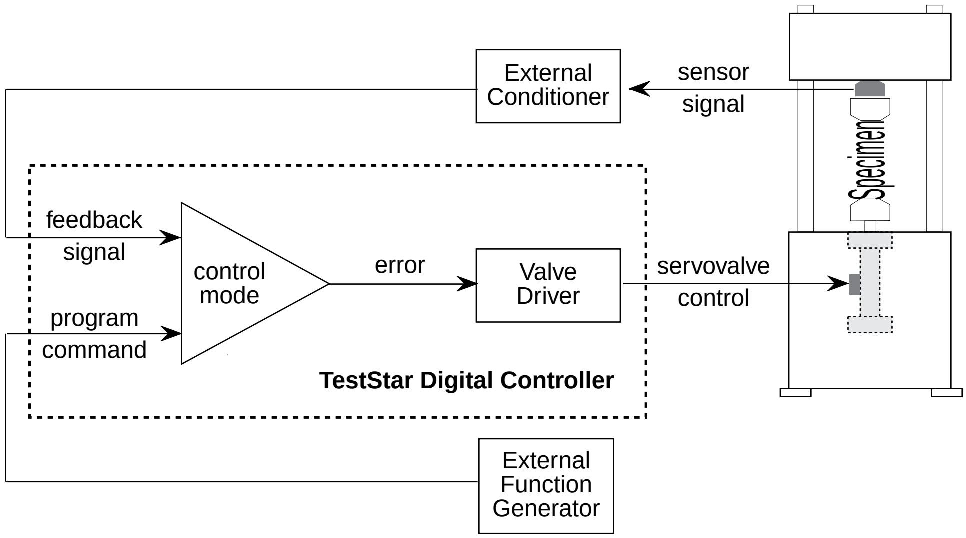


External Signals

External signals are signals that are generated outside the digital controller. Two types of external signals are used be TestStar:

- External commands
- External sensor signals

See also: *Command 29*
Conditioner 31
Sensor 121



External Command and Feedback (Sensor) Signals

External Command Source

An external command source is a test program command signal generated by an external device such as a function generator or profiler. An external command can be the command source for a control mode without using the TestStar Function Generator or TestWare-SX applications.

External Sensor Signal

An external sensor signal is a transducer signal that is processed (conditioned) by an external device such as an ac, dc, or specialized conditioner. An external sensor input provides feedback for a control mode or for data acquisition.

F

Fatigue Test

This is a method of determining the maximum life or maximum load for a material subjected to repeated loading.

See also: Software Options 132

High Cycle Fatigue Tests

These are tests where a material's fatigue properties are determined by applying a high number of relatively low-amplitude cyclic forces to the specimen. Typical HCF testing is characterized by:

- High frequencies (5-70 Hz)
- Small loads
- Load control mode, with no extensometer
- Long fatigue life
- Focus on peak and valley values and the number of cycles to failure
- Multiple peak and valley channels and strain gages for data collection

Low Cycle Fatigue Tests

Here the specimen receives a low number of relatively high-amplitude cyclic forces. Typical LCF testing is characterized by:

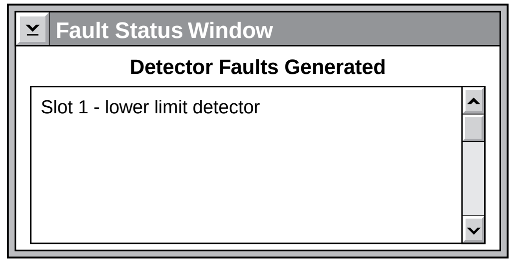
- Low frequencies (0.001 to 3 Hz)
- Large strains
- Strain control mode
- Short fatigue life
- Focus on loop data, inelastic strain, and modulus values

Fault Status Window

The Fault Status window automatically opens whenever a detector action occurs or a system fault is detected. You must use the Reset switch on the load unit control panel to clear the action.

The source of the detector action is displayed when the window opens. Sources can be:

- Input signal name for upper or lower limit detectors
- Control channel name for the error detector or underpeak detector
- Any interlock



See also: *Detector Actions 47*
Error Detector 58
Interlocks 96
Underpeak Detector 158

Feedback

Feedback is the output of a sensor whose output is proportional to its mechanical input. **For example**, the feedback from a force sensor indicates the amount of force that it is sensing.

See also: *Conditioner 31*
Input Signals 94
Sensor 121

Feed Forward Gain

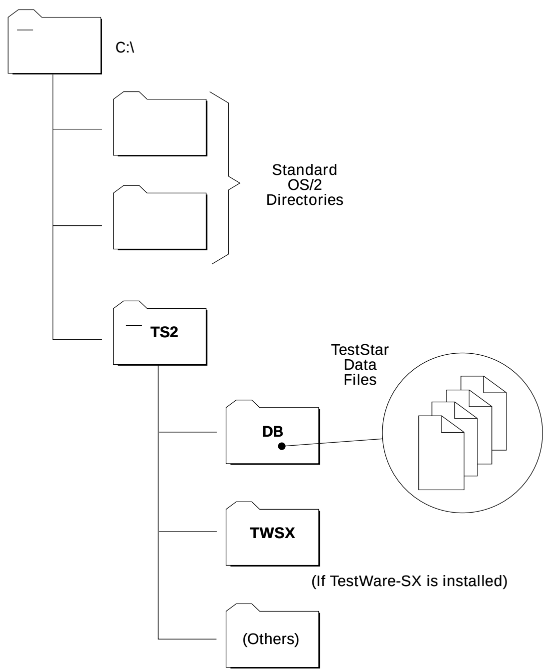
Feed forward introduces a derivative of the command signal. It anticipates how much of a valve opening is needed for a required response.

See also: *:Tuning 151*

Files and Directories

If you display the OS/2 Directory Tree window, you will get a display similar to the one below. (This chart ignores any other applications loaded on your system.)

The TestStar files are normally loaded into the directory C:\TS2. Information such as data base and configuration files are stored in the directory C:\TS2\DB. Although DB is the default, you can save information anywhere you select.



TestStar Directory Structure

File Extensions

Data files typically found in the DB directory have the following extensions:

***.CFG**	=	Configuration File (Version 1.X)
***.DB**	=	Sensor Data Base
***.TCC**	=	TestStar Controller Configuration (Version 2.X)
***.UAS**	=	Unit Assignment Set
***.000**	=	TestWare-SX template

Directory Paths

The directory locations for the various files you can create for TestStar and TestWare-SX may be located anywhere you wish. The following show the default locations:

- Configuration files (*.TCC) are located in the configuration directory (C:\TS2\Config).
- Sensor data files (*.DB) and unit assignment sets (*.UAS) are located in the data base directory (C:\TS2\DB).
- TestWare-SX template (*.000) and procedure (*.###) files are located in the TWSX directory (C:TS2\TWSX).

File Playback

File playback uses a file (an ASCII file that you create) that defines a series of monotonic commands. You can create the file using a spreadsheet program.

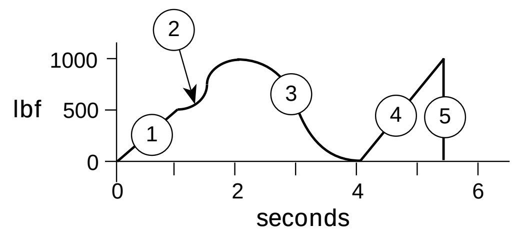
A playback file must specify the following for each command segment:

- A waveshape (example: haversine, ramp
- A rate type (example: frequency)
- An end level (that is, where the waveshape is to end).

The file can include up to four groups of data. These groups could be used for a four-channel test or four separate tests in a single-channel system.

When a playback file is selected, the program scans it to determine what kind of units will be used for the test. Units can be actual data (such as kilonewtons) or normalized units (a percentage of full-scale or a multiplier). The file is read in sequence to produce a waveform.

Waveform compensation can be disabled, manually scaled, or automatically optimized using a amplitude control algorithm.



The diagram and table shows the type of command program you can generate using this function. Time is in seconds. The Level_Data1 units depend on what control mode is active at this time.

Index	Shape	Time	Level_Data
1	Ramp	1	500
2	Haversine	1	1000
3	Haversine	2	0
4	Ramp	1.5	1000
5	Step	1	0

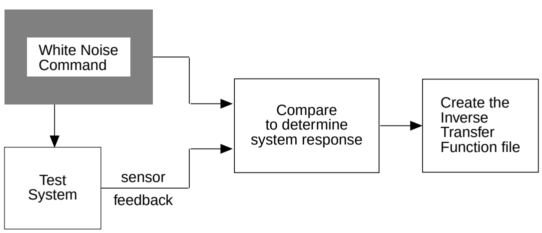
See also: *Amplitude Control 19*
Processes 116
Spectrum Amplitude Control 136
TestWare-SX 143

Frequency Iterative Technique

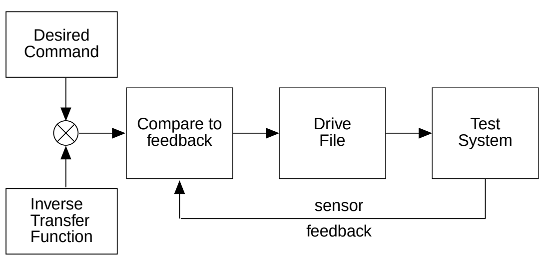
FIT is a frequency based iterative technique that dynamically optimizes the performance of your system. The mixed mode pulse cyclic command and the UDA cyclic command processes use FIT compensation.

Two compensation files work together to dynamically control system response, an ITF (Inverse Transfer Function) file and a Drive file.

- The ITF file contains information about the response of the system.
- The Drive file contains information to produce the desired waveshape.



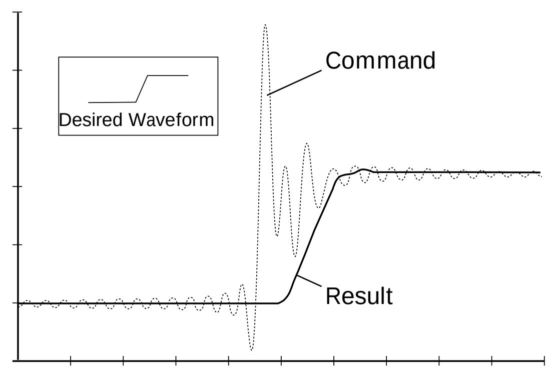
ITF File



Drive File

The frequency based iterative technique works basically like this:

1. The program sends a command signal to the system.
2. The sensor response to this command indicates how the system as a whole (the electronics, the hydraulics, and the specimen itself) reacts to the command.
3. The program analyzes the difference between the response and the command signal. The program attempts to close the difference by modifying the command signal.
4. This process continues, with each iteration, modifying the command again. The iterations compensate the response so that it approaches the desired pulse or arbitrary shape.



Iteration Process

See also: *Amplitude Control 19*
Compensators 29

Flexural Strength

This is the maximum fiber stress that develops in a specimen just before it cracks or breaks in a flexure test. For materials that do not crack in the flexure test, flexural yield strength is reported instead of flexural strength. An alternate term is modulus of rupture.

Flexure Test

Method for measuring behavior of materials subjected to simple beam loading. It may also be called a transverse beam test with some materials.

The specimen is supported on two knife edges as a simple beam and load is applied at its midpoint. Maximum strain and maximum fiber stress are calculated for increments of load.

Results are plotted in a stress-strain diagram. Maximum fiber stress at failure is flexural strength. Flexural yield strength is reported for materials that do not crack. Standard test procedures are given in ASTM D-790 (plastics), ASTM C-328 and ASTM C-369 (fired whiteware), ASTM D-797 (elastomers), ASTM A-438 (cast iron), and ASTM D-158 (glass).

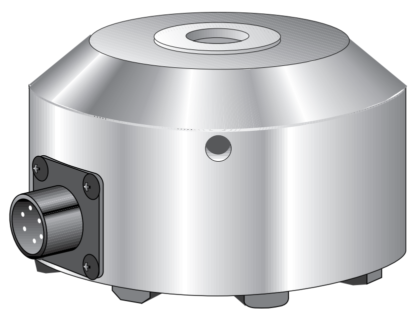
Force Sensor

This is a sensor (sometimes called a force transducer or the load cell) that provides an electrical signal proportional to the amount of force being applied to the specimen being tested. Typical force sensors are load cells and load washers.

Internally, a force sensor consists chiefly of a high-strength metal column (or columns) with strain gages bonded to it. The gages are electrically connected to form a balanced Wheatstone bridge. An applied force changes the column’s dimensions: this unbalances the bridge and produces an output voltage. By convention, the voltage is positive when the applied force is tensile and negative when the force is compressive.

Force sensors are dc devices that receive their excitation from a dc conditioner circuit.

The conditioned output is a voltage within ±10 volts representing the range from full tension to full compression. Not all sensors use this standard.



Force Sensor (Load Cell)

When the feedback source is the force sensor, the system is in “force” control.

Load

Force is a load, typically measured in pounds or newtons, that is brought to bear on a material specimen in order to learn about the material properties of the specimen. Force is usually measured with a force sensor such as a load cell (force sensor) or load washer. Force is commonly called Load.

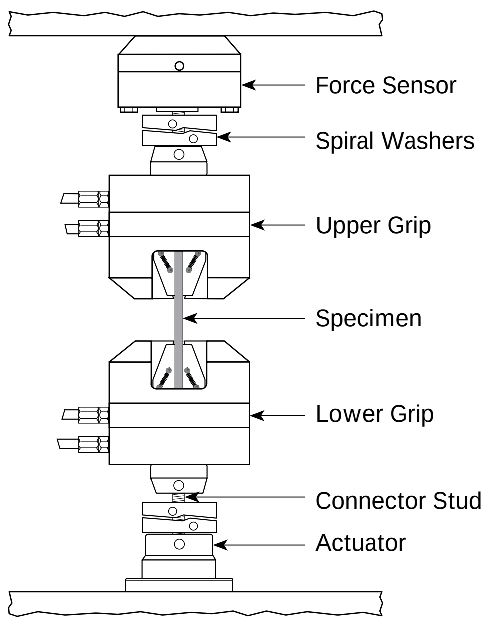
Force Control

A system control mode where the feedback from a force sensor (such as a load cell) is the primary sensor in the control of the loop.

See also: *Calibration 24*
Feedback 66
Input Signals 94
Load Unit 99
Sensor 121

Force Train

Part of a system's design is to select the proper mechanism to hold the specimen being tested. This can be anything from a miniature load unit to large structural test systems. This discussion concentrates on the "standard" load unit system, that is, a simple one consisting of one actuator and one specimen mounted between two reaction masses.



Typical Force Train Components

Factors that Can Degrade Accuracy

The Force Train

It is all too easy to run a test, gather data, and assume that the results reflect the characteristics of only the specimen. Unfortunately, more than the specimen is being tested. The data gathered also contains the characteristics of the load frame, the actuator, the force sensor, and anything else in the force's path—this is the force train. In other words, not only does the specimen have compliance, but the force train does too.

Machine Compliance

The combination can be determined as machine compliance, which is the amount of deflection that the machine (load unit and actuator), force sensor (load cell), and fixturing undergo when loaded.

The Effect on Data Accuracy

This deflection affects the extension measurement accuracy (and therefore, the strain accuracy) if the test's primary strain data source is an LVDT or an equivalent device mounted in the force train. While the force train's deflection may not be noticeable in the results if the material has a relatively low modulus, this response affects the results if the material is very stiff (very high modulus material), especially where the stiffness of the sample approaches the stiffness of the force train.

Extensometers are Unaffected

Machine compliance does not affect the accuracy of the strain data if an extensometer or strain gage is used, because these devices are attached to the specimen and not deflected during testing. We recommend using an extensometer when performing tensile and flex tests on materials with a high modulus.

The Load Unit

The load unit acts as a mass on top of a spring. The mass is the sum of the crosshead plus any fixtures mounted to the crosshead.

The Undesirable Spring

Like all springs, the load unit can store and release energy. If the load unit stores energy during part of the test, it releases the energy when the specimen breaks. Therefore, the test results are not an accurate indicator of the specimen's performance.

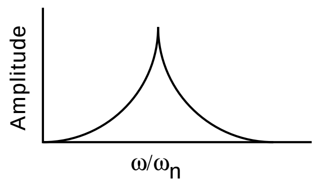
Solving the Problem

The best way to solve this problem is to make the force train infinitely stiff. Using the Load Path Stiffness Set Editor, you can create different load path stiffness sets.

In the real world, obviously, there must be trade-offs. These decisions are based on considerations such as cost and the nature of the material being tested.

The Natural Resonant Frequency

Every load unit has natural frequencies where it resonates (that is, it acts like a very big tuning fork) even though there are only small inputs. Or, in the simplified view below, where ω is the frequency of the test and ω_n is the natural frequency of the whole system.



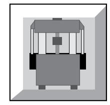
At that one spot (the peak, where $\omega \cong \omega_n$) a small change to the test's input results in a large change to the test's output. If serious enough, the load unit could actually oscillate or experience large deflections.

Minimizing the Resonant Frequency Effects

System design ideas to minimize these effects are:

- Have the first natural frequency of the system (ω_n) be much greater than the desired test frequency (ω). If at all possible, make it 10 times the test frequency.
- Increase the natural frequency by increasing the stiffness or decreasing the mass.
- If dynamic tests require a portion of the test to be run above the resonant frequency, go through it as quickly as possible.
- To reduce the sharpness of the peak (that is, reduce its amplitude), add damping.

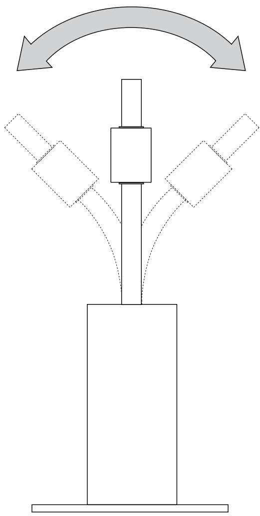
Load Path Stiffness Editor



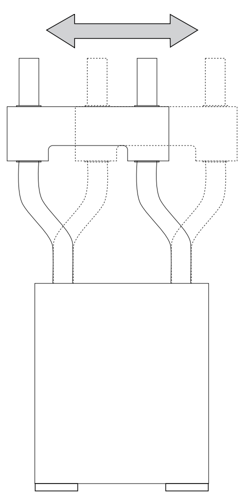
The Load Path Stiffness Editor creates sets of values that compensates for the amount of deflection in the load path. Load path stiffness sets are used by the 790.31 Dynamic Characterization application.

Load Unit Resonance

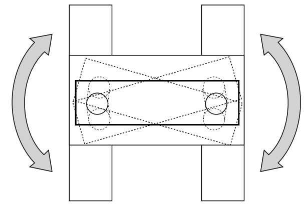
These diagrams illustrate the four primary modes of load frame resonance. Don't worry if you do not understand this (unless you are a principal system designer



Mode A—side view

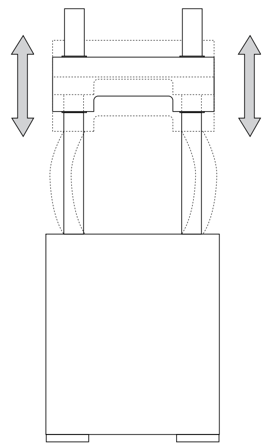


Mode B—front view



Mode C—top view

Mode C is the most important mode in torsional tests. Axial-torsional tests are a combination of modes C and D



Mode D—front view

Mode D is of greatest importance in standard uniaxial tests.

Tech Stuff

You can compute an approximation of its natural frequency by these formulas:

$$\omega_n = \sqrt{\frac{k}{mass}}$$

Where: ω_n = Natural Resonant Frequency (radian per second)

mass= Mass of crosshead plus crosshead mounted fixtures

$$(K) \approx \frac{A \times E}{L}$$

Where A = Area of Column

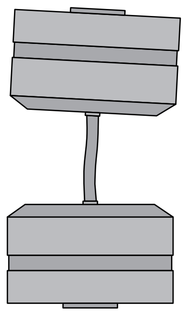
E = Young's Modulus

L = Length falcon

The Grips and Other Fixtures

MTS manufactures a wide variety of grips to hold specimens with many different sizes, shapes, and testing environments. It is, therefore, necessary for you to refer to the grip documentation that applies to your system. Some basic guidelines are:

- It is important for the grips to be aligned within the force train. **For example**, note the angular misalignment in the gripping example shown here. This will cause undesirable stresses on the specimen.



- (Refer to MTS' "Gripping Techniques and Concerns for Mechanical Testing of Ultra-High Temperature Materials" for additional information.)
- Inelastic materials such as composites and ceramics can be very sensitive. Obviously, they are the least tolerant of misaligned grips. Grips for composites should have wedge faces that are rough, but not biting; also these grips should not have stress risers (these are sharp points or indentations).
- When using cryogenic (super cold) grips, install and remove the specimen while the grips are at room temperature.
- At higher temperatures (without special cooling), the heat's effect on the hydraulic fluid limits the maximum grip temperature, not the grip itself.

MTS' grip design evenly distributes the force train forces through the grip. This holds the specimen firmly and reduces the compliance or vibration of the system. The grips are also designed to grip the specimen without inducing any axial loads before the test begins.

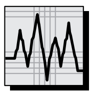
Full-Scale Capacity

This is the maximum allowable value that a measuring device can handle. It is always specified with the device. This would be full-scale load for load cells, maximum travel distance for an extensometer, etc.

For example, you may have an actuator with a full-scale capacity of 5 mm. The 100% range can be referred to as "±2.5 mm". You can have several calibrated ranges for the actuator.

See also: *Sensor 121*
Sensor Range 124

Function Generator



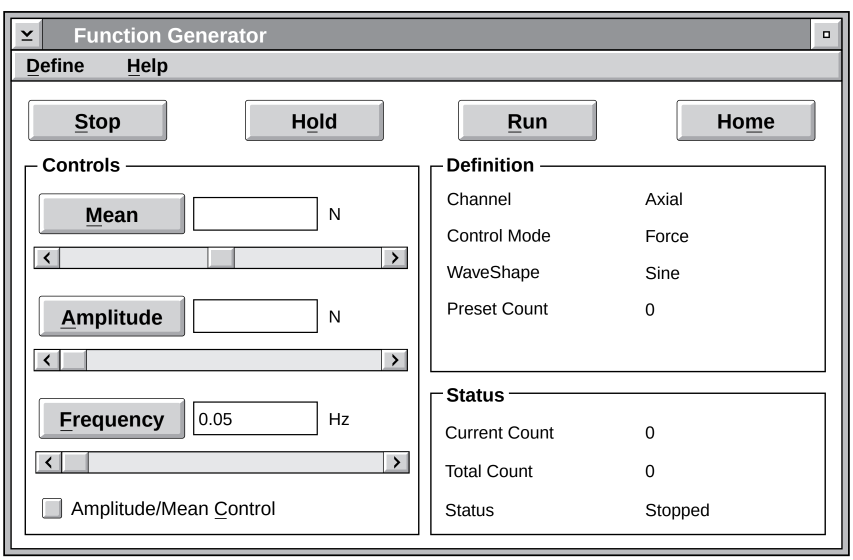
This program lets you to set up and to run simple tests. It is standard with all systems, and it provides the following capabilities:

- Selection of sine, squarewave, and triangles (ramps) waveforms.
- Control of the selected waveform's frequency, amplitude (peak-to-peak value or span) and mean level (set point). These can be changed while running the test.
- Another selection (Amplitude/Mean Control) automatically adjusts the gain of servovalve control signal to ensure that the testing waveform actually reaches its peaks. This is a compensation method that adjusts the command signal as necessary for the system to reach the amplitude end levels and the mean value you have selected
- Control of starting, stopping, and suspending the test. (Most of the control functions are also available on the load unit control panel.)

The function generator cannot control the system at the same time as another application (such as TestWare-SX). Also, you cannot save the settings before closing the window.

In TestStar, the function generator controls the Segment Generator (SG). The segment generator is a command source for control modes, it represents the function generator, TestWare-SX, and other TestStar applications.

See also: *Compensators 29*
Control Modes 34
Segment Generator 120
Software Options 132
TestWare-SX 143.



Function Generator

This is the main window you use to set up and to run simple tests.

Furnace

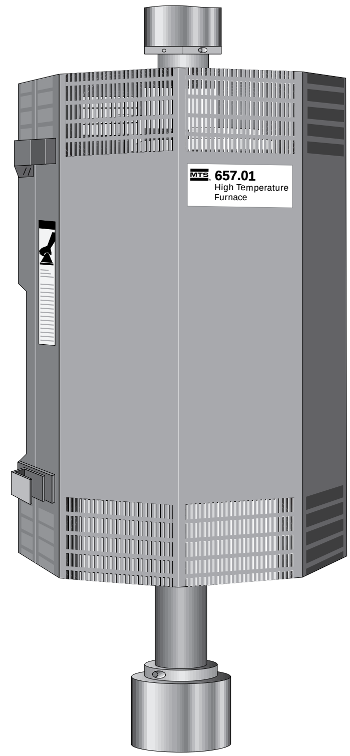
Furnaces provide a high-temperature environment for specimen testing with a load unit. A furnace can be used for tests required to characterize ceramic and composite materials in air.

Furnaces are available for use with bend fixtures and compression tests; other models are designed for tensile tests.

The furnace is divided into two halves hinged together for a split clamshell design. This allows simple specimen and fixture access. Dual-wall construction allows free convection between walls. This lowers the outer skin temperature and increases the element life by cooling the terminal ends. Ports are provided to accommodate thermocouples, extensometers, gas purging, and push rods to the grips.

A furnace requires a power controller and a temperature controller to create its own control loop. TestStar communicates with the temperature control loop through an RS-232 interface.

See also: *Environmental Chamber 57*
Temperature 139



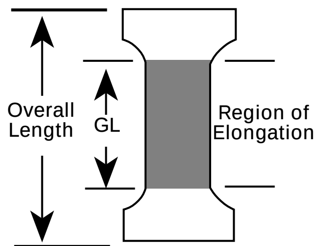
Furnace

The Model 657.01 High Temperature Furnace shown here is designed for use with bend fixtures and compression tests. It can heat specimens to 3100°F (1700°C)

G

Gage Length

Gage length has different meanings for different types of tests. Generally, it can be considered as the length on the test specimen to which the strain sensor is attached under no-load conditions. Note that this is a measurement of a change in length over a portion of the specimen, not the change in length over the entire specimen. Gage length must be accounted for since most specimens (especially some types of tensile specimens) do not elongate uniformly over their entire length.

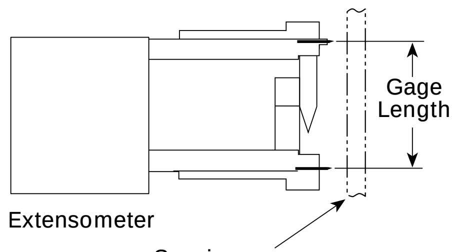


Gage length of a specimen

The total increase in gage length during testing is a measure of strain. This is usually expressed as change in gage length divided by the original length. Examples: in/in, mm/mm, etc.

In some cases, users collect strain data directly from a bonded strain gage. These devices do not have a gage length.

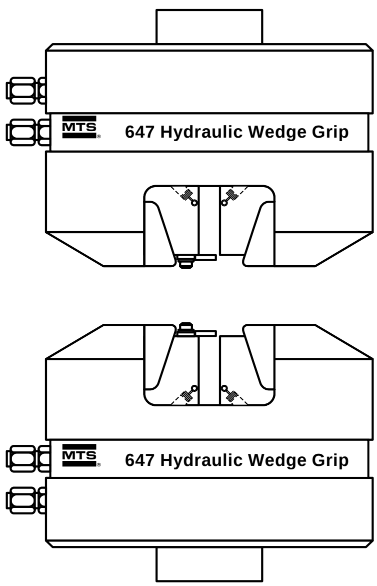
The following shows gage length when referring to an extensometer.



See also: *Extensometers 61*
Strain 137
Strain Gage 137

Grips

Grips grasp and hold a specimen in place while testing. MTS manufactures a wide variety of mechanical and hydraulic grips designed to hold different sizes and shapes of specimens.



Typical Hydraulic Wedge Grips

This style of grip is designed for static or fatigue testing of flat and round specimens.

These grips provide a constant, hydraulically actuated gripping force regardless of applied test loads.

Once a specimen is positioned between the grip wedges, hydraulic pressure closes the grip wedges securely against the specimen.

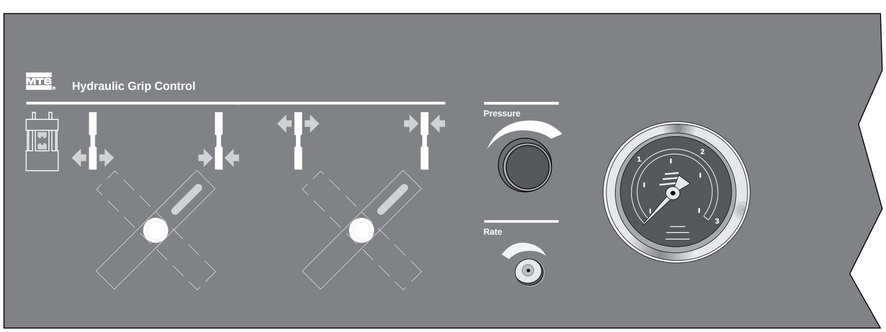
Other grips are designed to hold threaded specimens or button-end specimens.

Grip Control Module

Some load units come with an optional grip control module. The main parts are:

- A rate control to adjust the grips' clamping speed
- A force control to adjust the grips' clamping pressure
- A pressure gage to show grip pressure
- Grip controls to clamp and unclamp the grips

See also: *Force Train 71*
Hydraulic Grip Supply 81
Load Unit 99



Grip Control Module

This shows half the control module mounted on the load unit. The other half includes crosshead lift and lock controls (See also *Control Module 36*).

H

High Cycle Fatigue Test

The Model 790.20 Fatigue Test Application is a TestWare application that works with TestStar.

This is a specialized application that can produce high cycle fatigue tests.

See also: *Fatigue Test 65*

Histogram

A feature available in certain programs that provides a graphic representation of the frequency distribution of a test result.

Hold

See also: *Processes 116*
Load Unit Control Panel 101

Hold Command

The hold command process maintains a static level for a specified amount of time. When a load command begin, it reads the current value of the selected control mode and maintains that level.

Hold Program

You suspend any test command program with the Test Control switches on the load unit control panel. Also, the Function Generator and all TestWare applications include software controlled buttons that work the same as the Test Control switches on the load unit control panel.

Hooke's Law

Hooke's law states that stress is directly proportional to strain. Hooke's Law assumes perfectly elastic behavior and does not take into account plastic or dynamic loss properties.

HPS

An acronym for hydraulic power supply.

See also: *Hydraulic Power Supply 83*

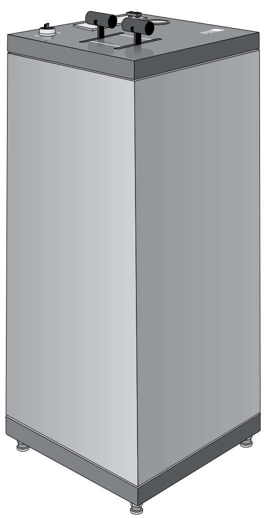
HSM

An acronym for hydraulic service manifold.

See also: *Hydraulic Service Manifold 87*

Hydraulic Grip Supply

Grips can have an optional grip control module to control the hydraulic pressure needed to clamp the specimen.



Some systems require independent hydraulic grip supplies. They are generally used for the following types of systems:

See also: *Control Module 36*

- Where the grip pressure needed to prevent specimen slippage exceeds the 3000 psi (21 MPa) pressure normally supplied by the hydraulic power supply.
- Where the grips are exposed to an extreme testing environment—down to -40°F/C or up to +350°F (+177°C).

Grip supplies are available that provide adjustable pressures of up to 10,000 psi (69 MPa) to accommodate the gripping requirements of different specimens. Each grip supply provides independent grip/release control of two grips; some supplies have a self-contained hydraulic fluid reservoir.

Grip supplies may be driven pneumatically or by an electric motor.

Hydraulic Fluid

The care and changing of your system's hydraulic fluid is covered in the product manuals; this discussion explains why some of the constraints are necessary.

Care of the Hydraulic Fluid

Hydraulic fluid is not interchangeable. Using the wrong fluid can cause problems such as piston rod galling, seal wear and leakage, pump wear, and servovalve wear. We recommend using Mobil DTE 25; if it's not available, then use Shell Tellus 46 (commonly available in Europe). Other brands may be entirely acceptable; however, it is more likely that they will not meet the long-term quality needs you expect. Unfortunately, manufacturer's specifications are usually limited to viscosity, density, etc. They do not normally provide significant information on lubricity, additives, or chemicals in the fluid.

Keep it Cool

Keep fluid reservoir temperatures below 60°C (140°F) to resist fluid breakdown. In turn, this helps prevent varnish deposits. The hydraulic power supply has a heat exchanger and over-temperature interlocks to assist in maintaining the correct fluid temperature.

Keep it Clean

Our experience is that clean hydraulic fluid is critical for satisfactory operation of servohydraulic systems. Obtaining close control (resolution) of servovalves requires that the friction level of the valve must remain low and have little stiction. The uniform method of specifying hydraulic fluid cleanliness is the ISO (International Organization for Standardization) Solid Contaminant Code. The code is assigned on the basis of the number of particles greater than 5 µm and 15 µm per unit volume. The smaller size assesses the silting condition of the fluid, while the larger size indicates the amount of wear elements. The code is expressed as the 5 µm number, a "/", and the 15 µm number. Try to keep fluid cleanliness meeting ISO 13/9 standards.

Keep it Dry

Water can contribute to corrosion. Also, see *Hydraulic Fluid Care Guide*, MTS part number 11568100.

See also: *Dither 52*
Hydraulic Power Supply 83

Hydraulic Interlock

An interlock caused by a problem in the hydraulic power supply:

- Low hydraulic fluid level
- High hydraulic fluid temperature
- Dirty hydraulic power supply filter

A hydraulic interlock can also be caused by TestStar and TestWare detectors.

See also: Detectors 46
Detector Actions 47
Hydraulic Power Supply 83
Interlocks 96

Hydraulic Load Limiter

An adjustable hydraulic device that can be preset to prevent hydraulic pressure applied to the tension and compression ends of a hydraulic cylinder from rising beyond preset values.

Hydraulic Power Supply

The hydraulic power supply (HPS) is the mechanical source of high-pressure hydraulic fluid necessary for test system operation. The HPS is available in various flow capacities (measured in gallons or liters per minute).

See also: Hydraulic Fluid 82
Hydraulic Interlock 83
Hydraulic Service Manifold 87
Load Unit Control Panel 101

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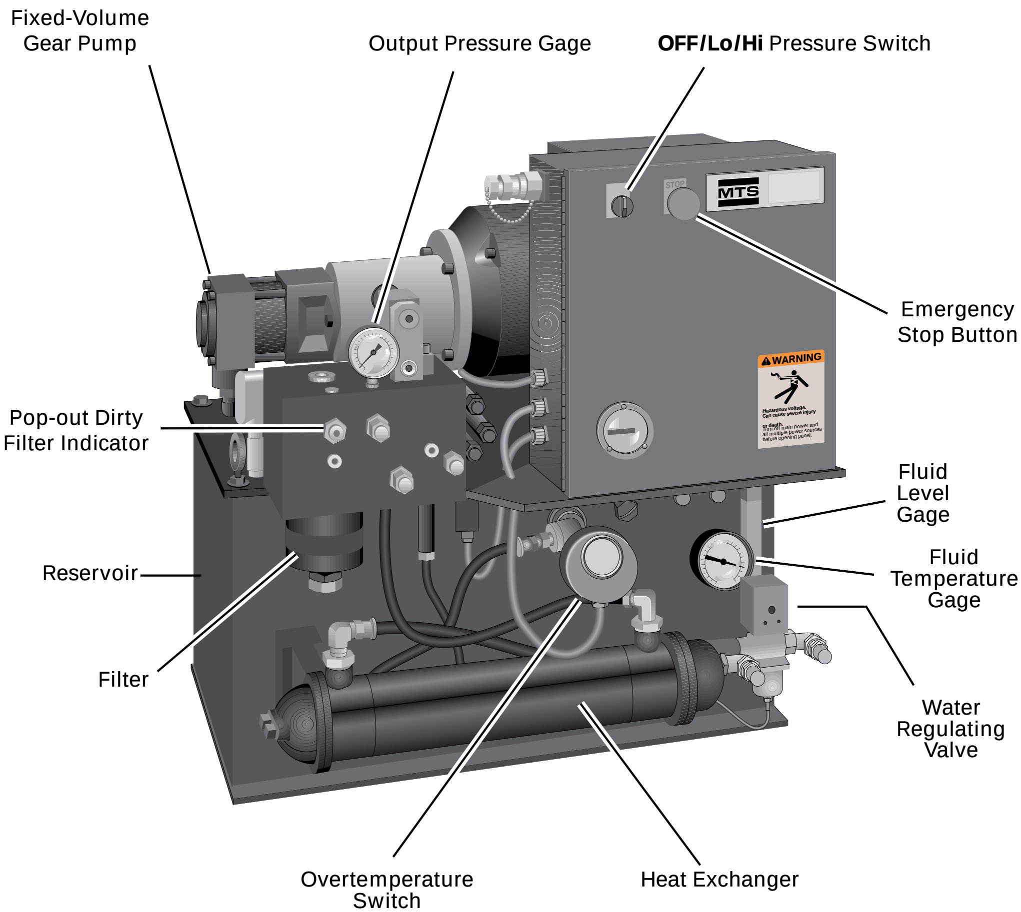


Hydraulic Power Supply

This is a typical HPS. Not all units have all the parts shown in this illustration.

HPS Capacities

The HPS uses either a fixed- or variable-volume, positive-displacement pump:

- Positive-displacement pump means that there is little or no internal fluid flow from the pump outlet back to the inlet.
- Fixed-volume units supply fluid at a constant rate, regardless of system demands. Any flow not needed by the system is diverted to the reservoir.
- Variable-volume units supply fluid as the system demands require.

The HPS outputs fluid at low pressure (150 psi or 1 MPa) or high pressure (3000 psi or 21 MPa):

- Low pressure is adjustable, and is normally used while installing the specimen.
- High pressure (normally 2000 psi or 3000 psi) is active during the actual test.

The Basic Controls

The HPS is controlled locally with its own switches or remotely from the load unit control panel.

Pressure

While in low-pressure operation, when the output pressure rises above the setting of a low-pressure needle valve, fluid is ported through this valve back to the reservoir to maintain the low pressure. When in operating in high pressure, this valve is blocked, applying full pressure to this system.

Filtering

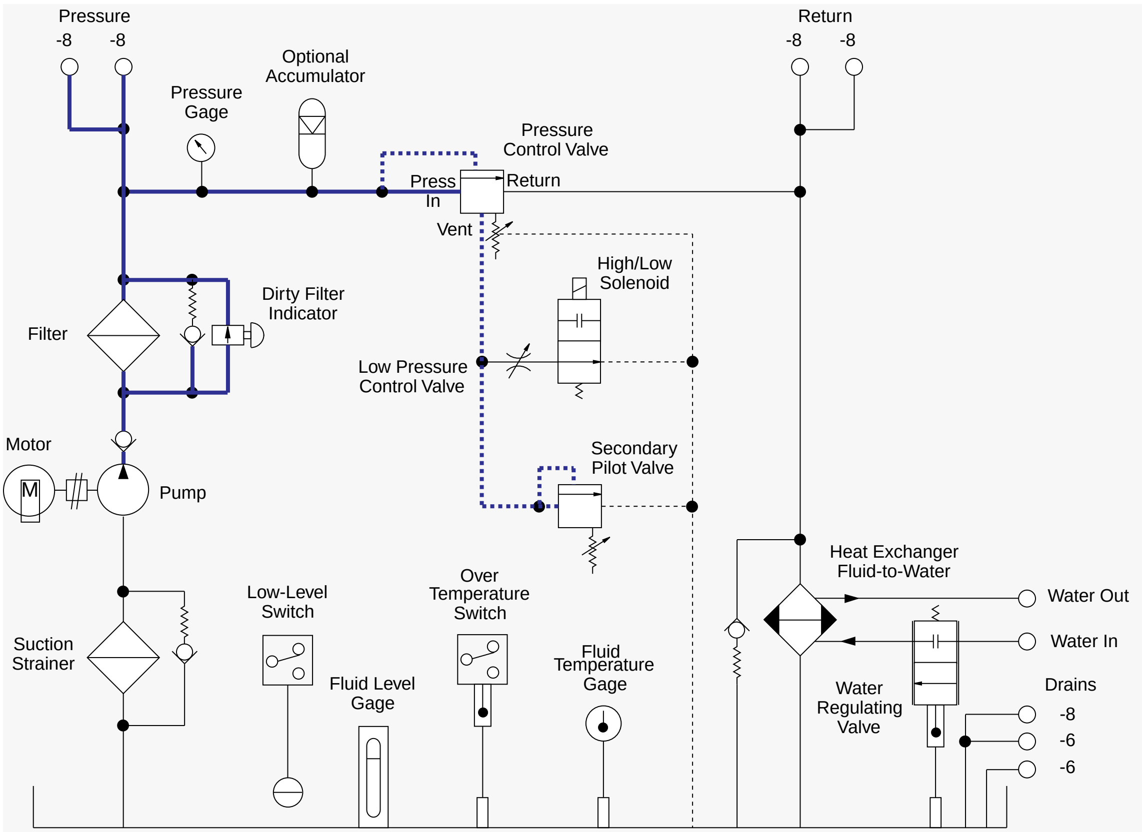
The filtration system protects against silting by cleaning the hydraulic fluid to an ISO particle count of 13/9. The filter change indicator pops out when the high-pressure filter needs replacement.

Temperature Control

Hydraulic fluid is maintained at the proper operating temperature by a fluid-to-water heat exchanger that cools the fluid as it passes over water-filled tubes. (Units with air-cooling are also available.) A water-regulating valve, which monitors the temperature of the hydraulic fluid, regulates the amount of water flow through the tubes. The temperature of the fluid is monitored by an over-temperature switch. If the fluid temperature exceeds 125°F (52°C), the switch opens and shuts down the HPS. The system cannot be re-started until the fluid cools.

Hydraulic Schematic

Tech Stuff



Model 506.01/.02 Hydraulic Power Supply Schematic

Hydraulic Service Manifold

The hydraulic service manifold (HSM), also called the actuator manifold, is a hydraulic component that provides control of high, low, or off hydraulic pressure to one work station. (For our purposes, consider a work station as one load unit having one actuator.) The HSM controls are independent of the hydraulic power supply's controls.

See also: *Accumulator 14*
Actuator 15
Hydraulic Power Supply 83
Load Unit 99
Load Unit Control Panel 101
Servovalve 125

How it Works

The basic function of the HSM is to provide line pressure regulation. This is partially accomplished by using accumulators to absorb excess fluid during pressure peaks and to return the fluid during low-pressure periods.

For example, a system configuration where the hydraulic power supply (HPS) is located some distance from the servovalve and actuator. As the servovalve opens, line pressure drops immediately at the connection to the servovalve. This pressure drop travels through the line to the HPS, which increases flow to compensate for the new demand. However, the mechanical limitations of the HPS pump, flow restrictions in the lines, and fluid inertia may prevent the additional fluid from reaching the servovalve fast enough to satisfy its needs. At certain operating frequencies, this may cause the servovalve to be “starved” for adequate fluid flow or pressure.

Inserting accumulators into the hydraulic lines permits some fluid to be stored under pressure a short distance from the servovalve and actuator. This has the effect of keeping fluid in the lines in motion and reducing the inertia and line restriction considerations.

Expanded Control Functions

Most HSM units are equipped with control functions beyond those of the basic unit. These control functions include electro-hydraulic circuits to permit selection of pressure off, low-pressure and high-pressure operating modes, slow pressure turn-on and turn-off, fast pressure unloading, and pilot pressure.

Control Manifolds

Certain HSM units are equipped with a control manifold. This manifold permits the application and removal of hydraulic pressure to the servovalve, and controls the pressure at the HSM pressure output ports. Some units control the output pressure to be on, low, or high. Other units have high/low only; in this case, the HPS pressure (high or low) is applied directly to the servovalve. HSM units equipped with a control manifold have the capacity to abort load by dumping the high or low hydraulic pressure.

Some units can slowly turn the HSM pressure on and off. These units can also set the high and low pressure values.

See also: *Proportional Valve 118*

Pilot Pressure

These models contain a pilot pressure circuit to supply pressure to the pilot stage of high-performance servovalves. If the external flow demands temporarily drop hydraulic pressure below 1000 psi, a pilot circuit maintains better operation of the servovalve's pilot stage.

These models may or may not be equipped with a control manifold. Fluid flows through a 3-micron absolute pilot filter, whose check valve protects the filter from backflow. A dirty filter indicator senses the pressure differential across the filter and provides a visual indication when the differential pressure increases to a level that implies a dirty filter. The accumulator connected to the pilot output line serves the dual function of stabilizing line pressure fluctuations caused by servovalve pilot stage demands, and by stabilizing the pilot output against pressure fluctuations in the HPS pressure line.

See also: *Servovalve 125*

Actuator Manifold

Actuator manifolds are usually mounted right on the actuator. They also serve as a mounting point for one or two servovalves. They are usually found on load units. An actuator manifold is illustrated on one of the next pages.

Servovalve

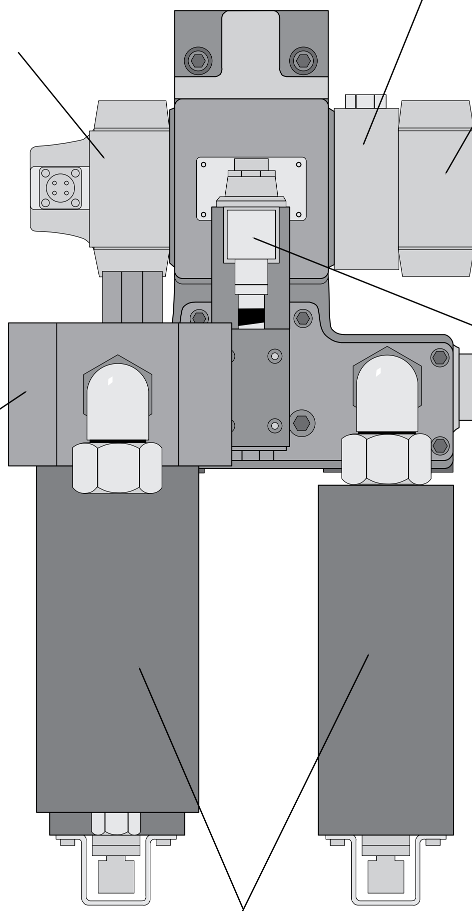
- Custom-made for MTS to provide high frequency response
- Flow ratings from 3.8 to 56 l/min (1 to 15 gpm)
- Designed for improved flows, low spool inertia, high full-flow roll-off frequencies, and high dynamic response.

Shut-off Valve (optional)

Provides single-valve or dual-valve operation.

Second Servovalve (optional)

- Can increase the maximum flow through the manifold to 112 l/min (30 gpm)
- Can have a flow rating equal to or different from the first servovalve.



Manifold Control

You have a choice:

- A manifold without manifold control, or
- A manifold with on/off control only, or
- A manifold with off/low/high pressure control, as well as adjustable low pressure, adjustable low-to-high pressure ramp rate and rapid pressure shutoff.

Filtration (optional)

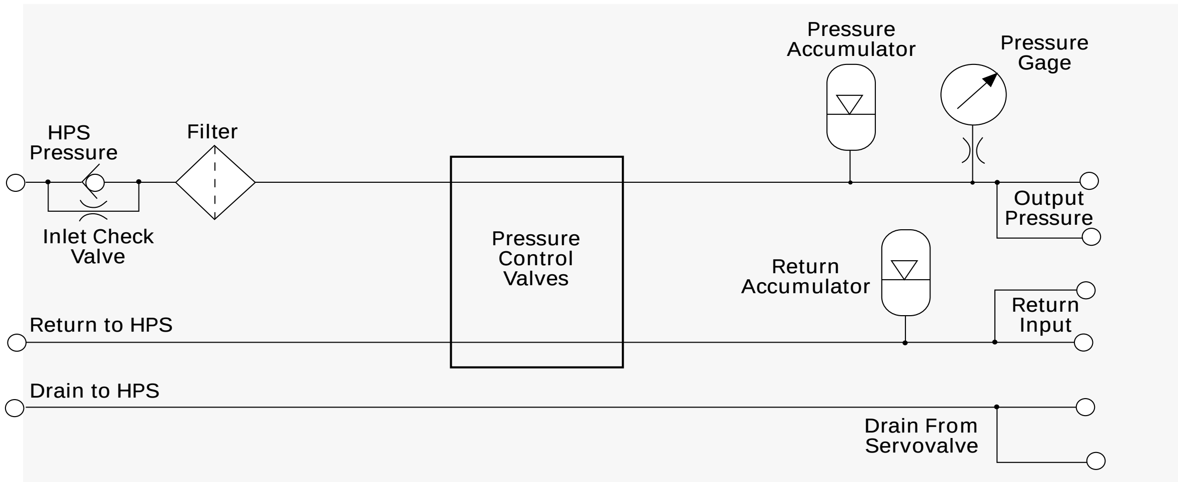
If required, a close-coupled 3 or 10 micron filter in addition to the HPS filter.

Accumulators (optional)

- Close-coupled pressure and return accumulators allow high-frequency response of servovalves
- Available in a variety of sizes.

Hydraulic Schematic

Tech Stuff



Basic HSM Hydraulic Schematic

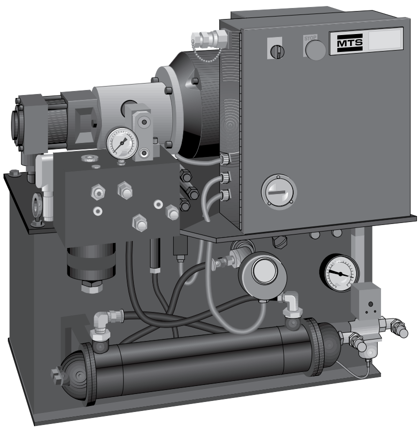
This schematic shows the components and fluid flow in a basic HSM.

- Fluid enters the unit at the HPS pressure port.
- The fluid passes through an inlet check valve, which provides protection for the filter element when supply pressure drops when the HPS is turned off.
- Fluid then passes through the filter.
- The pressure control values can be configured to turn hydraulic pressure on and off, or with off/low/high capabilities. A pressure gage and pressure accumulator are connected to the pressure output line.
- The output pressure is routed to the servovalve.
- Fluid returns from the servovalve through the return port. It passes through the HSM and exits to the HPS. A return accumulator is connected to the return line.
- The drain line is used to provide a path for collecting fluid allowed to flow past the high pressure seals in the actuator. It is connected back to the HPS.

Hydraulic System Overview

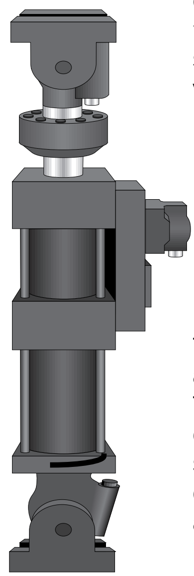
The hydraulic system is the muscle of the test system. High pressure hydraulic fluid is what actually moves an actuator. The electronic system controls the hydraulic system through the servovalve, which is an electronically controlled hydraulic device.

The hydraulic components work together to move the actuator to achieve the required forces or displacement.



Hydraulic Power Supply

The hydraulic power supply (HPS) provides the source of high-pressure hydraulic fluid necessary for the test system.

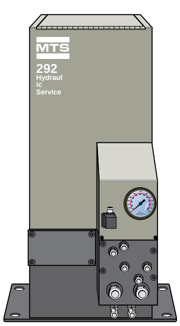


Actuator

The servovalve is usually mounted directly to the actuator. The actuator is a hydraulically powered piston that can extend or retract. The actuator is the business end of the hydraulic system. It connects to the specimen via grips, couplings, etc.

Servovalve

The servovalve is where the electronic and hydraulic systems come together. The electronic system produces a command signal to control the servovalve. The servovalve in-turn controls the hydraulic system with the actuator. The servovalve determines if hydraulic fluid extends the actuator or retracts the actuator.



Hydraulic Service Manifold

The hydraulic service manifold controls the hydraulic pressure from the HPS to the servovalve. Several HSMs can be used in a hydraulic system.

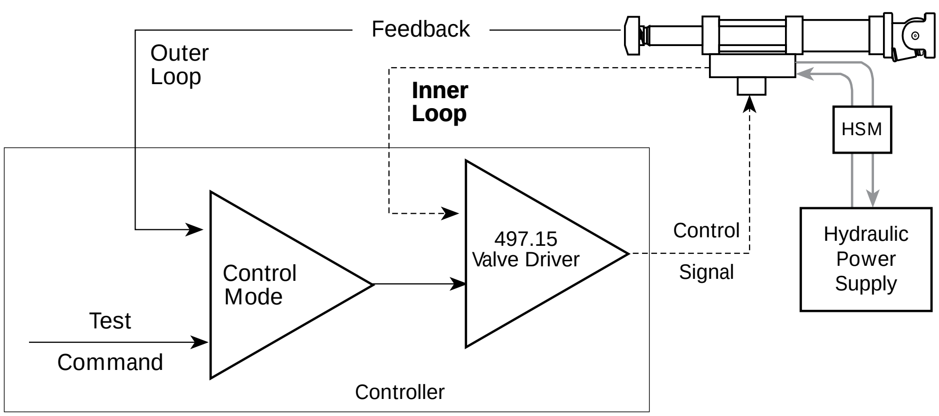
I-K

ID

Abbreviation for Identification. Also referred to as Operator ID. Log on name and password used to enter the TestStar program.

Inner Loop

All of the servo loop explanations in this manual discuss systems with one closed loop. Some systems have an additional loop called an "inner loop." This type of system is found in high-performance servovalves. Inner loop functions are found mostly in systems that need to move a lot of hydraulic fluid fast. Typical examples are vibration systems and many structural test systems.



Series 256 Inner Loop Diagram

This diagram shows the inner loop of a Series 256 Servovalve.

How it works

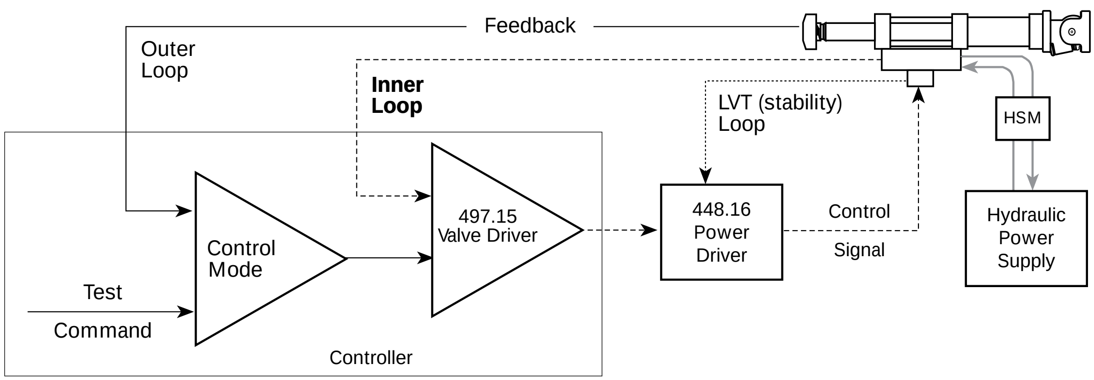
The Outer Loop

In the outer loop there is one servovalve control signal and one active feedback source. If there is no inner loop, a system has a two-stage servovalve—a torque motor and a single spool (the pilot, or second-stage spool).

The Inner Loop

These servovalves have another (and larger) spool added, called the third-stage or main spool. It is driven by the second-stage spool. In turn, the main spool controls the actuator. A second LVDT on the servovalve is connected to the main spool. This output represents the position of the servovalve's main spool. Therefore this signal (the inner loop feedback) is a position signal that is predicting where the main actuator is going. (It's "predicting" because the main spool is telling the actuator where to go before the actuator can actually get there.)

The valve controller now has two feedback signals: the Outer Loop (the primary control mode) and the Inner Loop (which is always displacement). By subtracting the inner loop feedback from the outer loop feedback, the result represents the difference between the desired opening of the servovalve and the actual opening.



Series 257 Inner Loop Diagram

This diagram shows the inner loop of a Series 257 Servovalve. In this example an LVT loop provides stability to the Power Driver. Only the Series 257 Servovalve

See also: *Closed-Loop Control 10*
LVDT 104
Servovalve 125

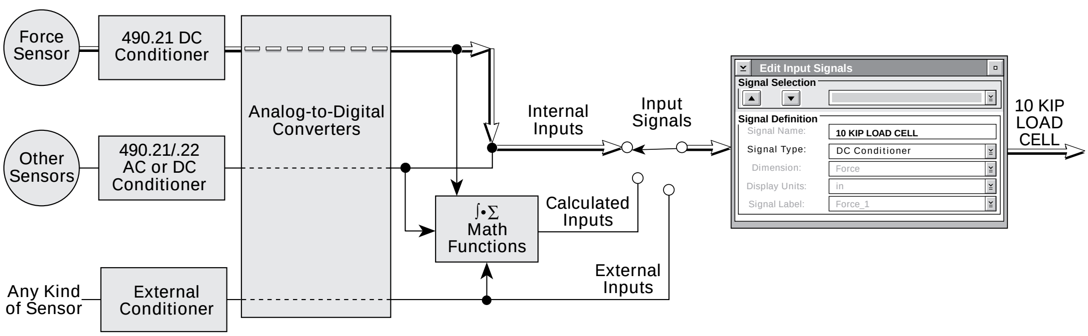
Comparison to Cascade Control

At first glance, this appears to be similar to the inner loop of the cascade control mode. Differences are:

- The cascade "inner loop" can be any feedback (force, displacement, strain, etc.). The regular inner loop is always displacement.
- Cascade can work with any servovalve. The regular inner loop is found only with Series 256 and 257 servovalves.

Input Signals

Input signals are the source supplying the feedback signals from the sensors to the control channel. You can define input signals with whatever names you choose. Input signals can be used to acquire data, to control the servo loop, or both.



Input Signals and the Edit Input Signals Window

When you use the Edit Menu to set up your system, you can define and name the inputs to meet your needs. This illustrates the relationship of the signals to the window.

Internal Input

Normally the sensors connect to conditioners that are plug-in modules of the TestStar digital controller. The feedback signal is fed directly into the digital controller's Instrumentation Bus.

External Input

For special cases, the sensor can connect to any compatible conditioner whose output, in turn, connects to the TestStar digital controller. These can be sensor signals from another control system or a custom conditioner for a special sensor.

Calculated Input

This uses a defined sensor (internal or external) whose output is modified by a mathematical function. Calculated inputs are real-time, that is, a calculation is performed with each servo loop update.

This function has many uses—your creativity can be valuable here. Existing uses include computing values such as true strain, area strain, average strain, stress, and true stress.

See also: *Conditioner 31*
External Signals 64
Feedback 66
Sensor 121

Integral Gain

Integral gain is used with static tests. Integral gain introduces an integral of the error signal that gradually over time, boosts the low frequency response of the command.

See also: *Tuning 151*

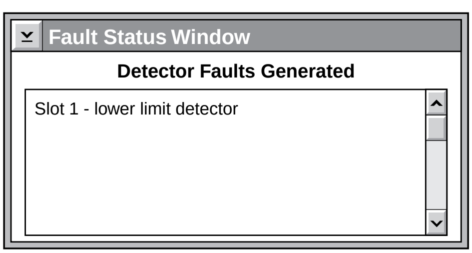
Interlocks

An interlock monitors specific conditions to prevent hydraulic pressure from being applied or starting a test before those conditions are satisfied. Once a test begins, an interlock can stop the test and remove hydraulic pressure if the condition occurs.

See also: *Detector Actions 47*
Fault Status Window 66
Load Unit Control Panel 101
Stopping a Test 137

If an Interlock Occurs

If an interlock occurs, check the load unit control panel Interlocks indicators. One or more of these indicators may be lit. Also, the Fault Status window pops open to display the cause of the interlock. There may be more than one interlock. If so, they are shown.



If an interlock occurs, the Fault Status window will pop up. Also, one of the indicators on the load unit control panel will turn on.

Once you have corrected the interlock, press the Reset switch on the load unit control panel to clear it. Sometimes an interlock causes other interlocks to occur.

Any interlock that has not been corrected will occur again, lighting the appropriate indicator and displaying the interlock in the Fault Status window.

Causes of Interlocks

- You see a problem and press an Emergency Stop switch.
- A component fails and causes an interlock.
- Some tests are designed to cause the specimen to fail. An interlock is used to stop the test and protect the equipment. This is intentionally set up by the operator, so it is not a malfunction (see Detector Actions).
- One of your initial detector settings may be inadequate for the test—you have set up a limit. The interlock may stop the test. You can readjust it and continue the test.

The more common causes of interlocks are shown in the following table

Interlock Descriptions.

Interlock	Explanation
AD Overrun	The analog-to-digital converters are overwhelmed by a high level of conversion activity. Review your test strategy.
Auxiliary Interlock	An auxiliary interlock does not remove hydraulic pressure; instead, it prevents a test from starting. This is usually caused when the crosshead is unlocked or by an external device connected to the digital controller's rear panel connector J43. Locking the crosshead automatically resets the interlock after a short delay. The indicator will light if you use the *Detector Action* with the Hydraulics Off option.
Controller Interlock	This is caused by a plug-in module. Check the **Fault** and **Error** indicators on the plug-in modules of the digital controller.
DRP Overrun	The data reduction process is overwhelmed when collecting too much data too quickly. Review the characteristics of any data acquisition process.
Emergency Stop	Any one of the Emergency Stop switches has been pressed.
Feedback Conditioner	This is caused by a loss of excitation to or from a sensor. Check the conditioner modules for a lit **Fault** indicator or for a disconnected sensor cable.
Hydraulic Interlock	This interlock is caused by the hydraulic power supply or servomotor. Check for one of the following: ◆ Low hydraulic fluid ◆ Dirty Hydraulic filter ◆ High hydraulic fluid temperature ◆ Motor thermal overload
Mechanical Interlock	This is caused by an external device connected to the digital controller's rear panel connector J23A or J23B.
Next Control Mode	This is caused by a conditioner reaching its maximum (saturated) or minimum output. Check the conditioner modules for a lit **Fault** indicator. This usually happens before hydraulic pressure is applied. This can be caused by the actuator being fully retracted or the actuator is retracted beyond the full-scale capacity of the sensor.

Kip

One thousand pounds. Usually used in reference to forces (loads).

L

Load

Another word for force.

See also: *Force Sensor 70*

Load Absolute

Type of procedure to find a break point. Often used for fiber and fabric testing. The break point is defined as the point where the material returns to a specified load after passing its peak load value.

Load Cell

A force sensor (also called a force transducer) used to measure forces that are essentially static (do not change much with time).

Load Frame

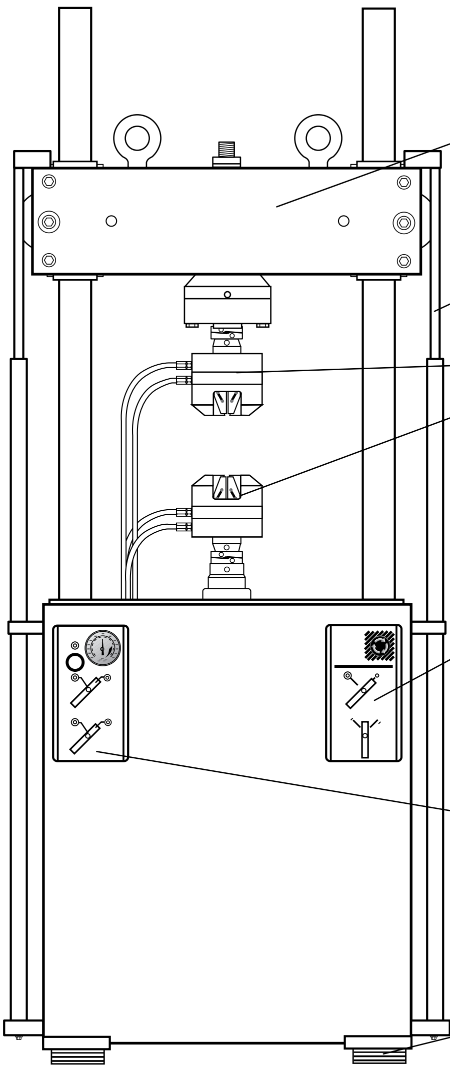
The reaction structure portion of a load unit.

Load Unit

The load unit is the primary structure for most materials testing. It is a stand-alone testing unit. The load unit consists of the load frame plus additional parts, such as hydraulic crosshead lifts and control modules.

Load units come in different sizes and shapes. This is a typical load unit with common accessories.

See also: *Force Train 71*
Test Frames 141



Crosshead

Moves up and down the columns to accommodate specimens of different lengths.

Hydraulic Crosshead Lifts

Raise and lower the crosshead. (Optional)

Grips

Grasp and hold the specimen in place during testing. Hydraulic grips are shown, but there are many different kinds of devices available to hold specimens.

Control Module

Controls raising and lowering the crosshead on units with hydraulic crosshead lifts. Also has locking/unlocking control for units with hydraulic locks.

An Emergency Stop switch allows you to immediately remove hydraulic power.

Grip Control Module

Has a hydraulic pressure gage and controls to clamp and unclamp hydraulic grips.

Isolation Pads

Dampen the natural frequency to about 20 Hz.

Load Unit (front view)

Hydraulic Crosshead Locks

Clamps the crosshead to the columns.

Force Sensor (Load Cell)

Measures the compressive and tensile forces applied to the specimen.

Actuator

Applies forces to the specimen. A linear actuator is shown, it applies compressive and tensile forces. Other types of actuators are available (such as rotary actuators).

Servovalve

Controls the rate and direction of hydraulic fund entering the actuator.

Hydraulic Service Manifold

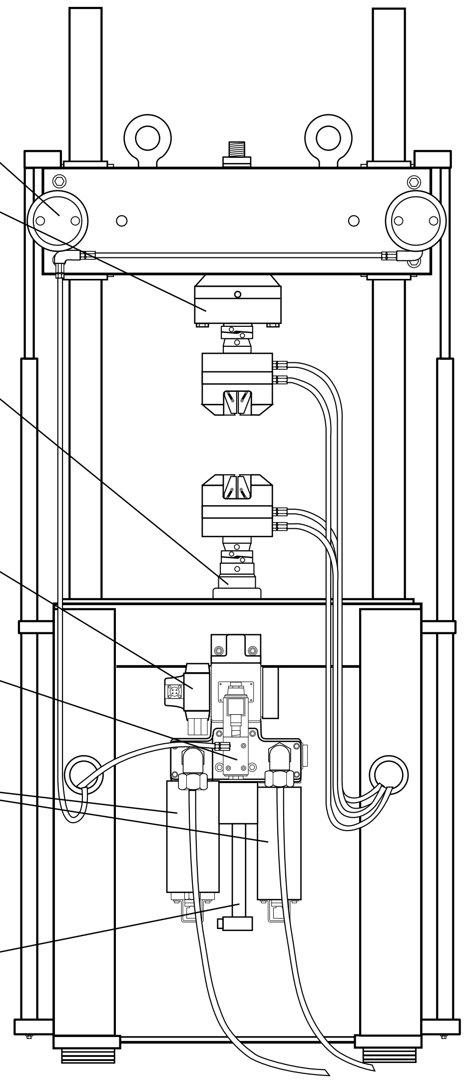
Controls the application and removal of hydraulic pressure to this load unit.

Accumulators

Improves the actuators response and reduces hydraulic line fluctuations. One accumulator connects to the pressure line, the other to the return line.

Displacement Sensor (LVDT)

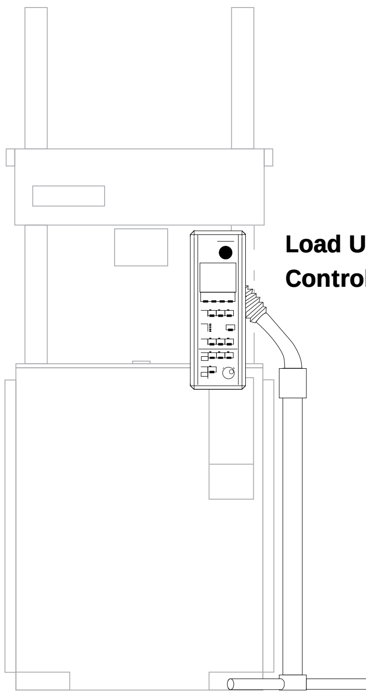
Measures the position of the actuator. The sensor is mounted inside the actuator.



Load Unit (rear view)

Load Unit Control Panel

The load unit control panel (LUCP or "Pod") is a stand-alone module that provides an operator interface to the load unit when installing a specimen or running a test. It is located near, or mounted onto, the load unit.



Panel Modules

The panel consists of a main module and up to 4 control channel modules.

- The main module contains the controls and indicators that are common to all control channels.
- One control channel module is added to the main module for each actuator in the test system.

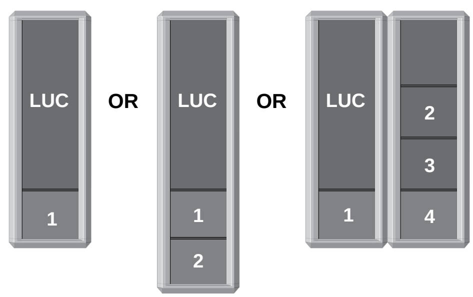
Control Channel Configurations

The control channel modules are available in three different configurations based on the capabilities of the hydraulic service manifold.

- An HSM that has Off, Low, and High pressure capabilities includes switches and indicators for these functions.
- An HSM with Off/On pressure control does not include a Low pressure switch.
- If an HSM is not used, no hydraulic switches are included.

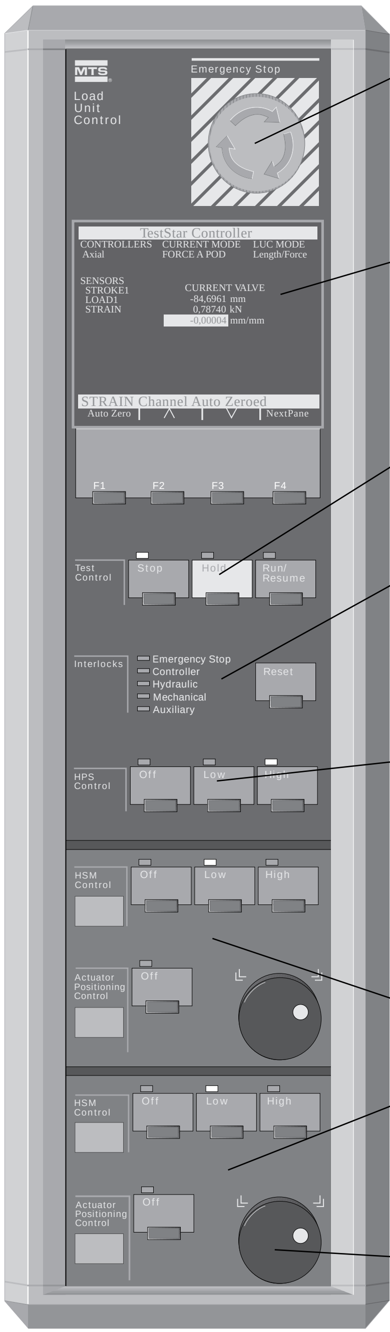
LUC Chassis Configurations

Control channel modules added to the main module require different LUC chassis configurations.



Here are chassis configurations for 1, 2, 3, and 4 channels.

Control Descriptions



Emergency Stop Switch

Pressing this switch removes hydraulic pressure and stops the test program. The **Interlocks Emergency Stop** indicator then turns on. To restore normal operation, reset the switch by twisting the knob as indicated by the arrows.

Display Screen

Shows key information that assists with installing and removing the specimen. See the *Display Screen* topic on the next page for more details.

Test Control

Controls the operation of the Function Generator program or any TestWare application.

Interlocks

An interlock indicator lights when a problem is detected. The indicator helps determine the cause of the interlock so it can be corrected. When the cause of an interlock is corrected, press the Reset switch to turn the interlock indicator off.

HPS Control

Controls the hydraulic pressure of the hydraulic power supply.

- **Off**—turns off the HPS.
- **Low**—turns on low hydraulic pressure, typically 300 psi (2 MPa).
- **High**—applies high hydraulic pressure, typically 3000 psi (21 MPa).

HSM Control

Controls the hydraulic pressure of the hydraulic service manifold. These switches affect pressure only at the test station being served by one manifold. The HPS must be on first. The switches work the same as the HPS switches.

Actuator Positioning Control

Enabling this control causes the actuator to extend or retract (rotate left or rotate right).

Display Screen

The display screen shown here has a typical complement of display items. You can configure the display contents by using the Edit LUCP Display window. Use the function keys to zero sensors and change control modes.

F1

When a sensor is selected, the F1 switch zeros the sensor output providing the auto zero feature is unlocked and the sensor is not being used as the active control mode.

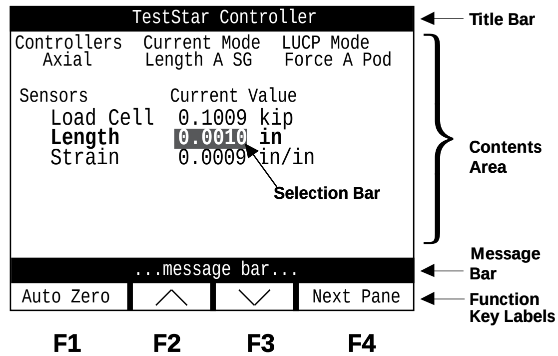
When a control mode is selected, the F1 switch changes the current control mode to the selected next control mode.

F2 and F3

Use these switches to move the selection bar around the display screen.

F4

You can define two display screens. Use this switch to move between the two displays.



Load Washer

A high frequency force sensor. Load washers are used to measure forces applied to a specimen at frequencies above approximately 50 Hz.

LCD

Acronym for Liquid Crystal Display. A digital display that forms visible characters from control voltages, even though no light is generated.

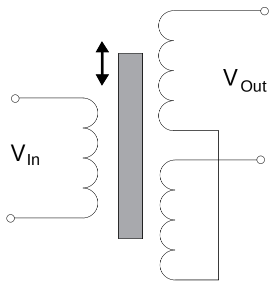
See also: *Force Sensor 70*
Sensor 121

LUCP

See also: *Load Unit Control Panel 101*

LVDT

Linear Variable Differential Transformers are commonly called LVDTs. They provide an output voltage that is proportional to the displacement of a movable core.

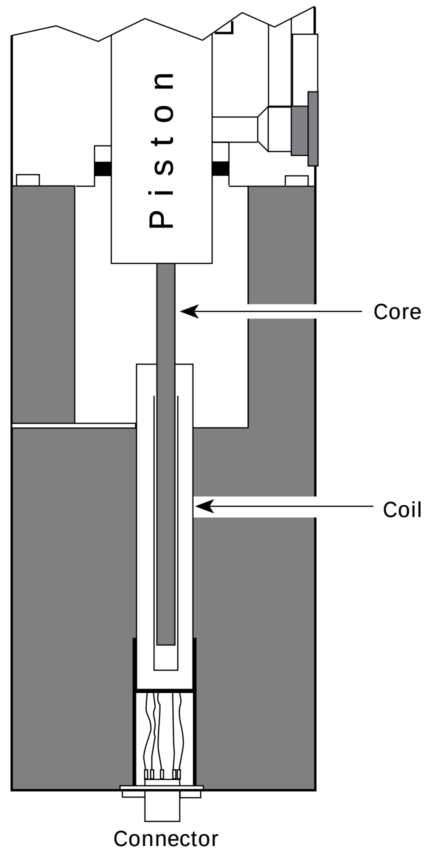


An LVDT consists of a transformer with one primary and two secondary coils wound on a common cylindrical form. This assembly, along with a core, is usually mounted inside the hydraulic actuator so that the core moves with the piston rod. (There are also external versions.)

LVDTs are calibrated with the middle of the actuator's normal operating range as the "zero point." The electrical output is then at zero (null). Displacing the core increases the mutual conductance between the primary and one secondary—the other secondary's output decreases—and a net output voltage results. The phase of the net output signal indicates the direction of displacement.

The net output voltage increases linearly over a prescribed distance, called the linear range. Because the core can be displaced in both directions from electrical null, the total range is twice the linear range. For example, an LVDT with a total linear range of 4 inches has its useful operating range expressed as ±2 inches.

When the selected feedback source is the LVDT, the system is in "Length," "Displacement," or "Stroke" control.



LVDT in an Actuator

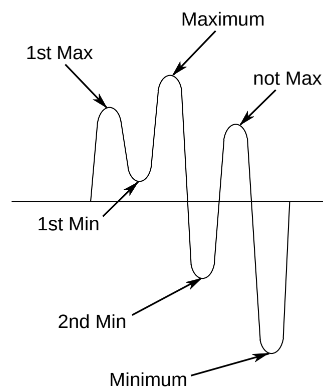
Because LVDTs are reactive devices, they receive their excitation from an ac controller. The Shunt Calibration capability is not available for LVDTs.

See also: *AC Conditioner 13*
Calibration 24
Sensor 121

M

Max/Min Data

Max/Min data saves the highest and lowest values recorded since the test began for a given sensor. Max/min data can be monitored with the TestStar digital meters.



If you compare this with Peak/Valley, note that a test can have only one max/min, but can have many peaks and valleys.

See also: *Meters 106*

Mean Level

Mean level is the midpoint in a cycle when using the TestStar meters. It can also be another term for set point which is an offset from zero from which a test begins.

See also: *Offset*
Set Point
Span/Mean Data

Mechanical Interlock

An interlock caused by an external device connected to J23A or J23B on the digital controller rear panel. For example, the door of a test guard.

See also: *Interlocks 96*

Meters

TestStar includes up to four digital meters to monitor test signals. Real meters are also supported through the rear panel Readout connectors.

TestStar Meters

The TestStar meters (data display) can display specialized test signals using a digital style meter. The type of information that can be displayed include:

- Maximum/Minimum data
- Peak/Valley data
- Span/Mean data
- Timed data

Up to four meters can be defined. The TestStar digital meters can monitor any input signal or any valve signal.

See also: *Input Signals 94*
Max/Min Data 105
Peak/Valley 112
Span/Mean Data 135
Timed Data 146

Readout Connectors

Meters, oscilloscopes, x-y recorders, and other readout devices can be connected to the Readout connectors (J71 - J76) on the rear panel of the digital controller. The type of signals that can be monitored include:

- Any sensor input signal
- The valve command signal from any control channel
- The program command to the active control mode
- The error signal from the active control mode
- Any *Analog Signals*on the analog bus

Each readout connector must be defined with the Edit Output Signals window. Digital readout signals and analog signal can be output. Each output can be scaled and offset.

See also: *Output Signals 111*
Readout 120

Modulus of Elasticity

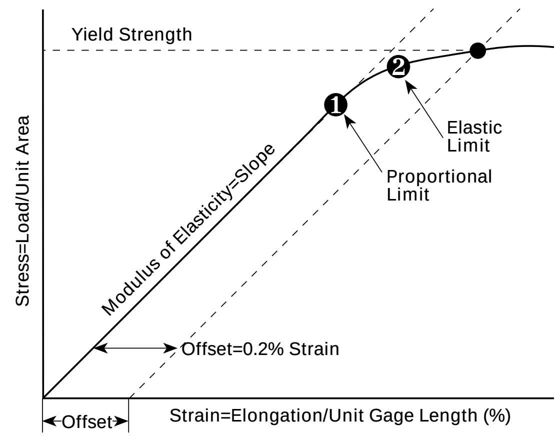
This is the ratio of stress to its corresponding strain expressed in terms of force per unit area (e.g. pounds/inch2).

The higher the modulus of elasticity, the stiffer the specimen. It is also known as Young's modulus when considering how stiff a specimen is under both tensile and compressive loading.

Basic terms

The following diagram shows some of the key materials testing terms.

- The stress (shown on the Y-axis) increases linearly with the specimen's elongation. It is called the elastic region because the specimen will return to zero elongation when you remove the stress. This reversible deformation is called elastic deformation.
- The slope of the linear section is called the modulus of elasticity, elastic modulus, or Young's modulus. The modulus of elasticity is about 10 x 10^6 pounds/inch^2 for aluminum and is about 30 x 10^6 pounds/inch^2 for mild steel.
- As the stress increases, the material reaches point ❶, or the proportional limit. Deformation is nonlinear (its elongation is greater than that anticipated by its modulus of elasticity); however, the material is still elastic.
- Finally, at point ❷, the specimen reaches the elastic limit. Plastic deformation has begun, and the specimen will be permanently deformed when the force is removed.
- It can be extremely difficult to accurately determine the proportional and elastic limits. This problem is countered by drawing a straight line parallel to the linear portion of the curve. The line is offset by 0.2% for metals. (It is normally offset by 2% for plastics.) We can now determine the yield point or yield strength, which is the point where this new line intersects the curve.
- In some cases (not shown here), the yield point is not a definite "knee" or other bend in the curve. Instead, the curve is a series of jagged peaks, valleys, or some other complex discontinuous shape that requires additional analysis. This complex part of the curve is called yield point elongation. The condition can be encountered in some low-carbon steels.



Monotonic Command

A monotonic command starts at the current level and ends at a different level. It is more or less a command to ramp from one setting to another. You assign one of three wave shapes, a time base and a control mode. The waveshapes include:

- Haversine
- Ramp
- Step

You can specify the time base as:

- Frequency
- Time
- Rate

See also: *Processes 116*
TestWare-SX 143

N/O

Offset

Generally speaking, offset is the displacement of a signal from zero. It can be intentional or unintentional.

See also: *Function Generator 76*
Mean Level 105
Zero 160

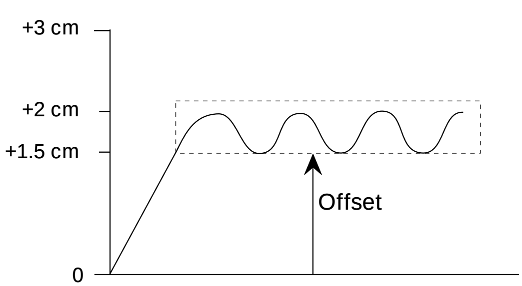
Intentional Offset

Offset can be used in a number of ways. The following are common uses.

Offset a Command signal

The test program shown here can be created with the Function Generator. The offset for the cyclic command is set with the Mean control.

For example, suppose you have a test program that ramps to 1.5 centimeters and then cycles between 1.5 and 2 centimeters.



Offset for Readout Signals

If you want to monitor a specific part of a signal, you can use offset (and gain) when defining an output signal that can be monitored by an external readout device.

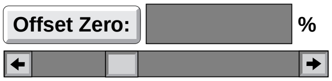
For example, suppose you are monitoring the signal shown above and you want to zoom into the cyclic command. In this case, you would use offset and gain to monitor the cyclic waveform inside the dotted area of the waveform shown in this topic.

Offset for External Sensors

A calibrated sensor output from an external conditioner may change due to cable length/ resistance or environmental factors. TestStar permits you to determine this offset and to compensate for it.

Offset Zero

This is an electrical offset that is applied to the sensor input signal (in percent of full-scale).



Offset=0:

Suppose an LVDT is calibrated with zero at midstroke. The sensor electrical output is zero when the actuator piston is at mid-stroke.

Offset≠0:

Suppose the LVDT is not at midstroke after a specimen is installed. Using auto zero or manually adjust the offset control to zero the LVDT output. The sensor electrical output is zero when the actuator piston is displaced (offset) from true mid-stroke.

Unintentional Offset

An unintentional offset can be observed while a test in progress.

Suppose you want to monitor a waveform cycling between 1.5 and 2 cm to determine if the endlevels are actually being achieved. You could setup a meter to monitor the Span/Mean of the LVDT. If the mean level is not 1.75 cm, an unintentional offset is observed. This can be cased by an out of balance servo valve or poor tuning.

Operator

Generally speaking, the operator is the person who sets up the software and runs the test. Throughout the TestStar manuals we figure the person reading the information is the operator so we like to call the operator YOU.

See also: *Processes 116*
TestWare-SX 143

The following are just a few things you could do with this process:

- Prompt the operator to before the test begins
- Trigger a data acquisition process
- Manually trigger the end of any process or step
- Manually set a digital output channel

Operator Event

The operator event process produces a window that appears when the test begins. The window can show up to three buttons that represents up to three separate operator events. These buttons also appear in the load unit control panel display. The operator event process lets you customize the flow of the test. The buttons can be single shot or issue a trigger each time it is pressed.

Operator Information

The operator information process is a special process that prompts an operator for a variety of test related information. The process lets you decide what information to provide to the operator and what information the operator may type into entry fields.

Operator Input

TestWare-SX offers you a chance to type information about a test and save it with the test data file. The Data menu includes a Description selection that allows you to type a test description that is saved in the beginning of the test data file. The Data menu also has a Note selection that allows you to add information to the data file while the test is running.

Outer Loop

The main servo control loop.

See also: Closed-Loop Control 10
Inner Loop 92

Output Signals

Output signals are signals that can be output through the digital controller rear panel readout connectors. They are used by monitoring equipment such as a meter, oscilloscope, or X/Y recorder.

See also: Analog Signals 20
Meters 106

Readout signal

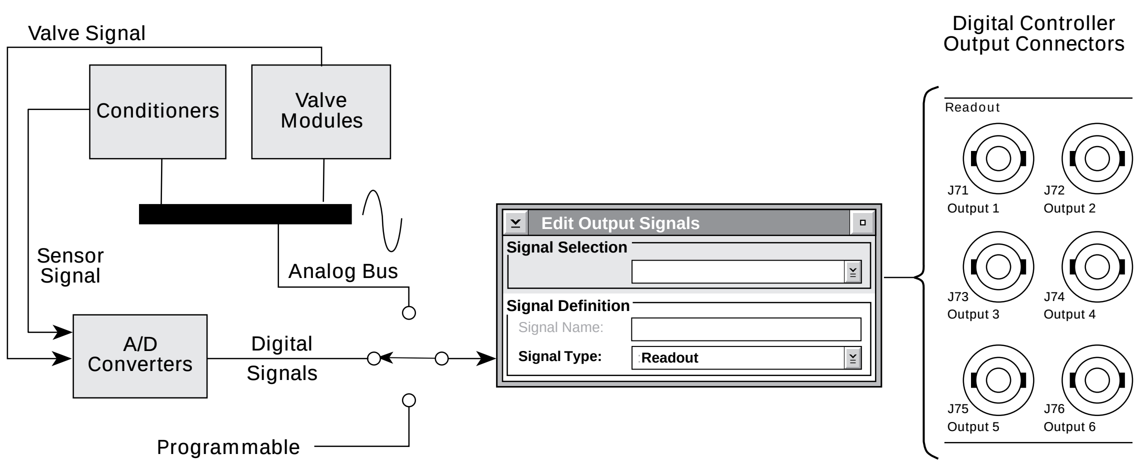
These are digital signals including sensor feedback, valve drive signals, test command, error signals, etc.

Analog bus

The analog bus includes true analog signals, before they have been digitized. Its signals are related primarily to the plug-in modules. These are valve signals (such as Valve Current and Error) and sensor signals (such as the raw feedback signal).

Programmable signals

These are specialized functions reserved for use by optional applications.

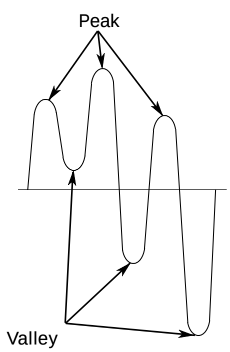


P/Q

Peak/Valley

Peak/Valley data records the highest (peak) and lowest (valley) value for each cycle of the test.

- Peak/Valley data can be monitored with the TestStar digital meters.
- Peak/Valley data can be acquired with the data acquisition process in TestWare-SX.



See also: *Compensators 29*
Data Acquisition 39
Meters 106

Peak/Valley Change Detector

The peak/valley change detector process monitors any input signal for changes in the peak and valley values. When the process starts it detects the peak and valley values and uses them to establish a tolerance band. If the process detects a peak or valley outside the tolerance band, the process triggers.

Peak/Valley Compensator

The peak/valley compensator is also called amplitude control. This compensator detects any amplitude roll-off and any difference in the mean level. Amplitude roll-off is the difference between the amplitude of the command and the amplitude measured by the sensors.

Enabling peak/valley compensation helps achieve the programmed amplitudes.

- Peak/Valley compensation is available only for cyclic commands.
- Peak/Valley compensation is available on all control channels and uses very little of the systems resources.

Peel Strength

Measure of the strength of an adhesive bond. It is the average load per unit width of bond line required to part bonded materials where the angle of separation is 180 degrees and separation rate is 6 in/min (ASTM D-903).

Phase and Amplitude Control

The phase and amplitude compensator (PAC) detects any amplitude roll-off and any phase lag. Amplitude roll-off is the difference between the amplitude of the command and the amplitude measured by the sensors. Phase lag refers to the time lag between the command producing a physical event and the measured response from a sensor.

See also: *Amplitude Control 19*
Compensators 29

- PAC is available only for sinusoidal command waveforms. If expects feedback to be balanced about a mean level.
- PAC compensation is available only on control channels that have PAC enabled in the Edit Control Channels window. Its computational requirements may limit the sampling rate on multi-channel systems.

PIDF

Abbreviation for Proportional Gain, Integral Gain, Derivative Gain, and Feed Forward Gain.

See also: *Tuning 151*

Pilot Pressure

Auxiliary pressure used to actuate or control hydraulic components, typically the pilot stage on certain servovalves.

See also: *Hydraulic Service Manifold 87*
Servovalve 125

Plastic Deformation

Deformation that remains after the load is removed. It is the permanent part of the deformation beyond the elastic limit of a material. It is also called plastic flow and plastic strain.

See also: *Modulus of Elasticity 106*

Poisson's Ratio

The absolute value of the ratio of the transverse strain to the corresponding axial strain for a material subjected to axial loading.

Pressure Intensifiers

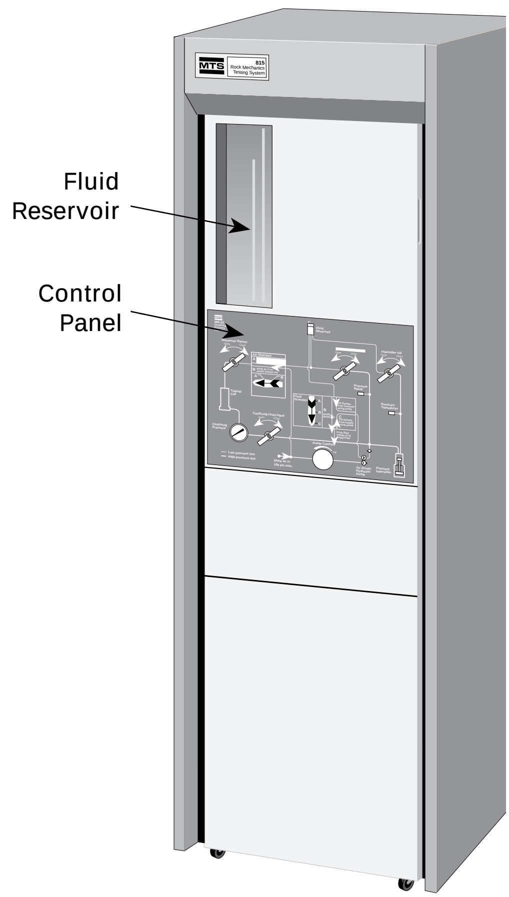
Pressure intensifiers are used primarily during triaxial testing to boost the hydraulic pressure from the HPS (normally about 3,000 psi) to as much as 20,000 psi. The intensifiers are mounted in a console with a control panel on the front. A schematic diagram on the control panel indicates the function of each valve, providing a clear "map" of the operation of the intensifier.

TestStar controls the intensifier's servovalve, that is, the pressure intensifier has a control channel just like any other part of the system with an actuator. The feedback for pressure control is usually a differential pressure cell or a displacement transducer. These sensors allow the intensifier to be operated in either displacement control (which is proportional to volume) or pressure control.

See also: *Triaxial Cell Assemblies 148*
Triaxial Test 150

Confining Pressure Intensifiers

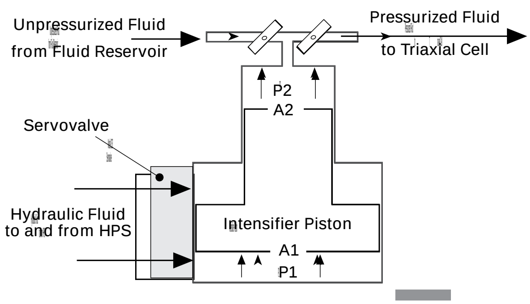
Confining pressure intensifiers are used to fill and pressurize a triaxial cell, as well as to provide servo-control of the confining fluid in the triaxial cell. They also control the flow of air to and from the triaxial cell while it is being filled and drained. The normal confining fluid is refined mineral oil.



Model 286.20 Confining Pressure Intensifier

How it Works

Each intensifier assembly consists of a single-ended servovalve-controlled actuator with unequal piston areas. The intensifier cabinet's control panel controls the flow of fluid from the fluid reservoir to the chamber in the actuator (P2 in the diagram), and from this chamber to the appropriate port on the triaxial cell.



With the actuator fully retracted, adjust the appropriate valves on the control panel to allow the low-pressure fluid from the fluid reservoir to fill the P2 chamber and, if desired, the triaxial cell. When P2 is filled, the controls are readjusted to isolate the fluid reservoir.

Tech Stuff

The force (F) applied to area A1 is the product of the pressure from the HPS (P1) and the large piston area (A1):

$$F = A1 \times P1$$

The resulting pressure in the P2 chamber applied to the triaxial cell is derived by dividing the force (F) by the smaller piston area (A2):

$$P2 = F / A2$$

Applying hydraulic pressure from the hydraulic power supply (HPS) to the P1 chamber increases the pressure in the P2 chamber in proportion to the ratio of the unequal areas A1 and A2.

Pore Pressure Intensifiers

Pore pressure intensifiers are used to saturate jacketed specimens, and to pressurize and servo-control the pore fluid in the specimen. A pressure sensor and integral displacement sensor provide feedback to control the intensifier servovalve.

The intensifier assembly, which essentially works the same as the confining pressure intensifier, contains a single-ended, servo-controlled actuator with unequal piston areas. The pore pressure intensifier has a smaller fluid reservoir, as the fluid volume of the specimen is small compared to the volume of the triaxial cell. The fluid is normally pure water, a noncorrosive water solution, or refined mineral oil.

The fluid pressurized by the intensifier is applied to one end or both ends of the specimen. Drained and undrained tests can be performed. The displacement sensor in the intensifier allows the pore fluid flow rate to be calculated.

Pressure Test

A method of determining the behavior of a material in hollow cylindrical form subjected to internal or external hydraulic pressure, usually under closed loop servo control.

See also: *Triaxial Test 150*

Procedure

This is a term in TestWare-SX that represents a test procedure, a sequence of command and data acquisition processes.

See also: *TestWare-SX 143*

Processes

The processes in TestWare-SX are organized by function. The following are the standard processes available in TestWare-SX.

See also: *Software Options 132*
TestWare-SX 143

Command Processes

These control the servovalve. They use the segment generator to produce command waveforms.

- *Monotonic Command*
- *Cyclic Command*
- *External Command Source*
- *Hold Command*
- *File Playback* command

Data Collection Processes

These processes can acquire data from any sensor input signal.

- *Data Acquisition*
- *Temperature Data Acquisition*

Event Processes

These processes either respond to detectors (test conditions) or the create conditions that trigger other processes.

- *Data Limit Detector*
- *Digital Input*
- *Operator Event*
- *Peak/Valley Change Detector*

External Control Processes

These processes issue control signals to devices external to the digital controller.

- *Analog Output*
- *Digital Output*
- *Temperature Control*

Special Processes

These processes provide capabilities beyond the other category definitions. They can combine functions of the other categories along with specialized capabilities into a single process.

Program Control

Operator Information

Program Control

The program control process works like a custom interlock. Use this process to stop the test before it is complete. It is commonly used in conjunction with other event detector processes.

See also: *Processes*
TestWare-SX

Proportional Gain

Proportional gain increases system response by boosting the effect of the error signal on the servovalve.

See also: *Tuning 151*

Proportional Valve

A proportional valve (also called electrical pressure reducing valve) has the following features:

- Low hydraulic pressure adjustment setting
- Adjustable ramp rate from off to low hydraulic pressure
- Adjustable ramp rate from low to high hydraulic pressure
- Adjustable ramp rate from high to off (rapid shutoff)

All of the settings are set when the TestStar software is installed. The settings can be changed by running the SETUP program in the Reconfigure Hardware mode.

Low Pressure Setting

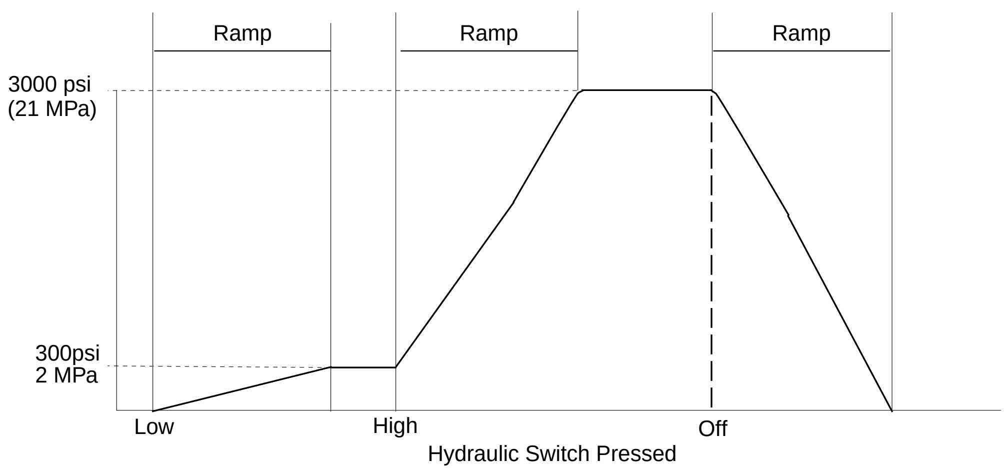
The low hydraulic pressure setting can be adjusted between 0 and 95% of high pressure (3000 psi/21 MPa). The nominal setting for low pressure is 300 psi (2 MPa).

Note: *However, the minimum low pressure setting to open a proportional valve is 120 psi (0.8 MPa).*

Ramp Rates

Each of the three ramp rates can be set between 0 and 480 seconds.

An adjustable ramp rate controls how fast the proportional valve output changes from low to high hydraulic pressure (and vice versa).



R/S

Range

Each sensor input signal can be calibrated for different ranges within its full-scale capacity.

See also: *Calibration 24*
Sensor Range 124

Range Cartridge

Range cartridges are used with only the 490.21 DC Conditioner. It contains shunt cal resistors and bridge completion resistors.

See also: *Sensor Cartridge 122*

Rate Gain

Rate is another name for derivative gain. Rate is used with dynamic test programs. Rate introduces a derivative of the feedback signal. 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

See also: *Derivative Gain 155*
Tuning 151

Readout

The Readout connectors (J71 - J76) are located on the rear panel of the digital controller. Each connector defined with the Edit Output Signal window. When an output is defined as a Readout type of an output, it allows you to monitor digital signals including sensor feedback, valve drive signals, test command, error signals.

See also: *Analog Signals 20*
Meters 106
Output Signals 111

Reset Gain

Reset is another name for integral gain. Reset introduces an integral of the error signal that gradually over time, boosts the low frequency response of the command. Reset is used with static tests.

See also: *Integral Gain 156*
Tuning 151

Scope

This TestStar window functions in a manner similar to an oscilloscope. It provides a visual representation of digital signals being processed by the system.

See also: *Output Signals 111*

Segment Generator

The segment generator (SG) is a software module that generates the test command signal. The most basic segment is a simple ramp.

For example, to create a haversine, a lot of short ramps are assembled to create a waveform that looks like a haversine.

See also: *Function Generator 76*
TestWare-SX 143

Sensitivity

This is the amount a signal must change for the system to detect a change in the signal's value.

For example, peak/valley data must change more than the sensitivity value, or else the change is not recognized.

If set too low
Signal noise will incorrectly be recognized as a valid change.

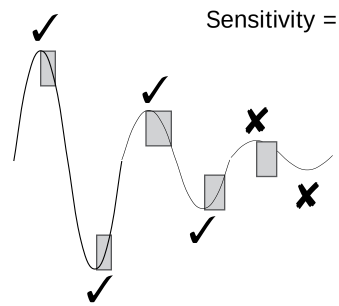
If set too high
A small but valid change will not be recognized.

Understanding Sensitivity

Two of the displays, Peak/Valley and Span/Mean, have Sensitivity settings. Sensitivity is the minimum change (ΔV output from a sensor) that must be attained for the ΔV to be recognized as a change.

Setting sensitivity permits you to determine how much change is required to detect a peak or valley.

This diagram shows how sensitivity works, using peak/valley as an example.



The shaded area shows the sensitivity setting. The peaks and valleys shown by the ✓ symbol have changed more than the sensitivity setting, so each of these can be recognized. The signal changes that are less than the sensitivity setting (shown by the ✘) are not recognized.

Sensor

A sensor is a component that converts measured mechanical values (such as force, displacement, pressure, etc.) into a corresponding electrical signal usable for readout or as feedback to the servo system. Sensors are also called transducers.

See also: *Sensor Cartridge 122*
Sensor Limits 123
Sensor Range 124

Typical sensors

Many different kinds of sensors can be used with TestStar. The following table describes some of these sensors.

- The Sensors column lists their names. Some sensors are identified with alternate names (such as force sensor/load cell).
- The Type column lists the type of conditioner used with the sensor.

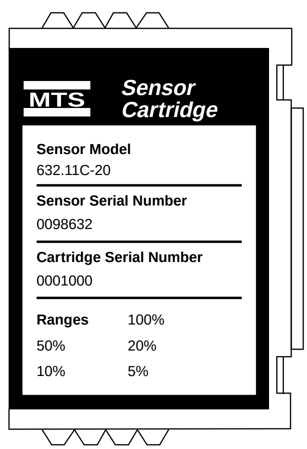
Sensor	Measures	Location	Type
Force Sensor Load Cell	the force applied to a specimen	on the load unit crosshead or actuator piston rod	dc
LVDT Displacement Length	the placement of the actuator piston rod	in or on the actuator	ac
Extensometers Clip-on Gage Displacement Gage Strain Gages	the deformation (strain) over a portion of a specimen	attached to, or contacting a specimen	dc
Thermocouple	temperature	in an environmental chamber or a furnace	dc
Pressure	atmospheric pressure	in a pressure chamber	dc
RVDT[2]	degrees of rotation	at the end of an actuator	ac
ADT[3]	degrees of rotation	at the end of an actuator	dc
Temposonics Transducer	the position of an object or medium	on an object or in a medium	ac

1 Linear Variable Differential Transformer
2 Rotational Variable Differential Transformer
3 *Angular Displacement Transducer*

Sensor Cartridge

The sensor cartridge is located in the front panel of each dc conditioner. It has room for five shunt calibration resistors and three bridge completion resistors.

See also: *Bridge Completion*
Calibration
Sensor
Range



Each sensor cartridge includes information about the sensor it is associated with.

Shunt Calibration

Each range of a resistive-bridge type transducer (dc sensor) uses a shunt calibration resistor to check the calibration accuracy of the sensor/conditioner combination. Whenever a dc sensor is connected to the digital controller, be sure that the sensor cartridge associated with the sensor is installed in the corresponding dc conditioner module.

Bridge Completion

Strain gages are sometimes bonded directly to a specimen to measure its deformation under stress. The gages are usually connected in a Wheatstone bridge configuration. One or more arms are bonded to the specimen with the remaining arms installed in a bridge completion circuit.

Sensor Limits

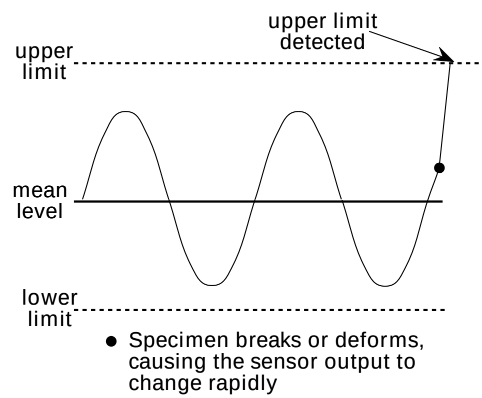
Setting limits is a critical operation in system setup and testing. You must set limits to reduce the chance either of injuring people who happen to be nearby or of damaging the equipment.

Upper and Lower Limits

The upper limit defines the most positive (or least negative) level the sensor output is allowed to achieve during a test.

The lower limit defines the least positive (or most negative) level the sensor output is allowed to achieve during a test.

If the sensor output exceeds either limit, the digital controller performs the action that you assign. Set the limits to establish the normal operating range of the sensor for a test.

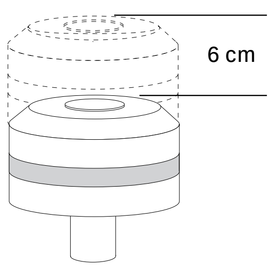


For example, suppose your test is to cycle ±1 centimeter about the mean level. Setting the limits slightly beyond the expected operating range detects unexpected changes.

Sensor Range

Each sensor has a full-scale capacity that defines its maximum operating range.

For example, a hydraulic actuator that can move its piston up to six centimeters from its fully retracted position to its fully extended position. This is sometimes referred to as an actuator with a “6-cm stroke.” A typical sensor would be an LVDT—its electrical output is proportional to the amount of piston displacement.



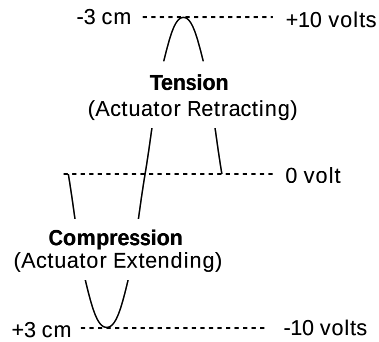
Sensor range is the control of the electronic amplitude of the sensor’s feedback signal to provide better signal resolution (which is a fancy way of saying “magnify”).

Calibrating a Sensor

Don’t confuse a sensor’s full-scale capacity with its range. Sensors are calibrated over their normal operating range. The 0-volt output is at the midpoint of this range. A 6-centimeter LVDT is calibrated with the actuator at the center of its stroke (displacement).

Since a typical sensor is calibrated about its midpoint, its range also refers to the same midpoint. Therefore, the 6-centimeter LVDT has a maximum range of ±3 centimeters, not ±6 centimeters.

The 0-volt output is obtained when the actuator is in the center of its stroke. For a ±3-centimeter LVDT, the 10-volt output is obtained when the actuator is at one of its limits.

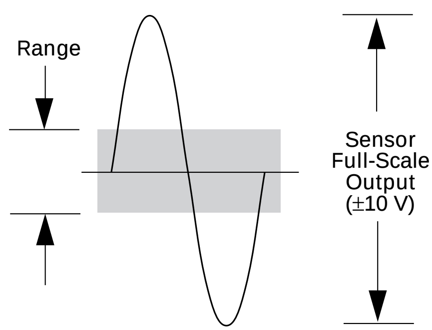


Sensors can be calibrated for different ranges.

For example, this ±3-centimeter LVDT could be calibrated to operate over a range of ±2 centimeters.

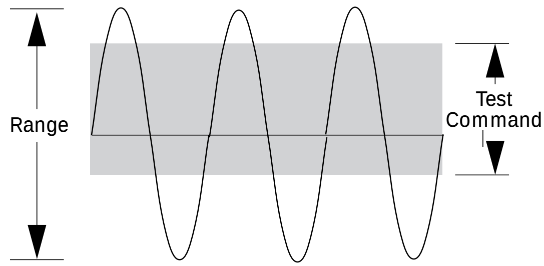
Selecting the Sensor’s Range

In many cases, it is unnecessary to use the full output of a sensor. **For example**, only two centimeters of a six-centimeter actuator may be used in a given test.



A Sensor's Range vs. the Test Command

This shows the comparison of the two. When you are setting up a test, try to keep the range just slightly larger than the largest value expected for the test. The smaller the range, the better the resolution of the sensor's signal. Note that the command limits do not have to be symmetrical about the mean level.



See also: *Calibration 24*
Sensor Cartridge 122

Servomotor

TestStar is able to control systems containing closed-loop devices other than just servohydraulic mechanisms. The servomotor is one example of a servomechanical component.

Instead of a servovalve, a high-torque, low-speed, brushless dc motor controls the actuator. This motor drives the nut of a ball screw, converting rotary motion into linear motion—like an actuator.

This type of system is also called a screw machine.

Minor changes include, for example, changing switch titles from Hydraulic Pressure to Electric Servo Motor.

See also: *Drive 53*

Servovalve

The heart of the servohydraulic system is the servovalve. It is the final control element in most MTS closed-loop systems. The servovalve responds to command signals generated by the software and routed through the digital controller and out of the valve driver module, which opens the pressure and return ports to the actuator. The servovalve regulates the direction and flow of the hydraulic fluid entering the actuator. The direction that the spools move determines the direction of fluid flow to the actuator. Unequal pressure is what causes the fluid to move.

MTS Systems Corporation offers three series of servovalves. Each series of servovalves is designed for different applications. And each series has several models offering a range of specifications. The series of MTS servovalves is as follows:

- *"Series 252 Servovalve" on page 128*
- *"Series 256 Servovalve" on page 129*
- *"Series 257 Servovalves" on page 130*

How a Servovalve Works

There are different types of servovalves, but they fundamentally work like this:

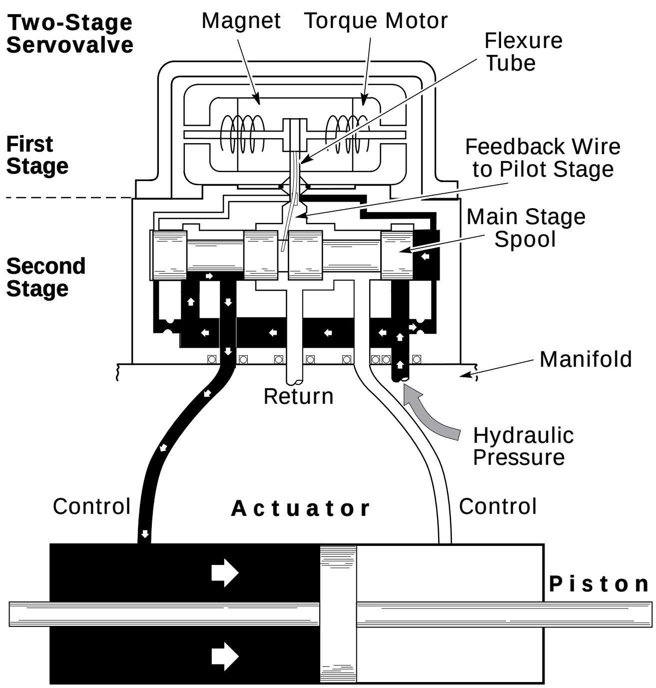
The Servovalve at Rest

The servovalve's controlling element is the torque motor, which receives an electrical input from the digital controller. A flapper is attached to the armature of the torque motor. The flapper moves from side to side as the armature moves in response to control signals from the digital controller. The flapper assembly is mechanically attached to the armature. There are two nozzles: one on each side of the flapper.

Because the nozzle-flapper valve is the first control point of hydraulic fluid, it is called the first stage.

As long as there is no command for actuator motion, the flexure tube is centered between the two nozzles. Because the flexure tube is so close to the two nozzles, there is a slight resistance (back pressure) against the fluid through the nozzles.

At the same time, pressurized hydraulic fluid entering the valve is applied equally to both sides of the spool. It does not move. This is the second stage.



MTS Series 252 Servovalve

Starting the Spool Moving

An unbalanced “valve drive” command pulls the flexure tube away from one nozzle and towards the other. The difference in back pressure from the nozzles causes the spool to displace from the null (no flow) position to the left or right. The spool’s moving opens the pressure and return lines from the hydraulic supply to the actuator.

As the Spool Moves

Its feedback wire—think of it as a fancy word for a spring—generates a torque that opposes the torque motor. The flapper moves back toward a centered position. The valve is in equilibrium when the torques are equal. Although the pressures are equal on both sides of the spool (so the spool is no longer moving), control flow from the servovalve keeps the actuator moving.

When Motion is to Stop

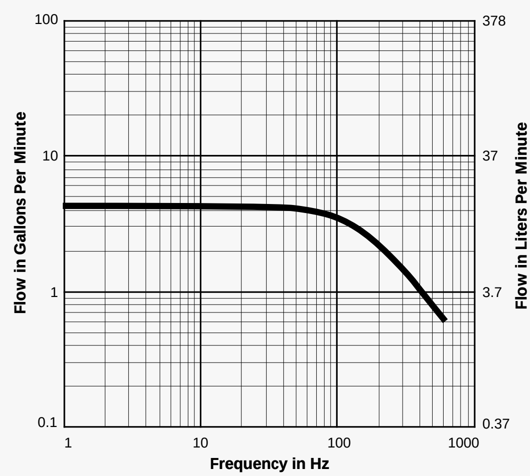
Finally, when the actuator has moved the desired amount, the valve drive command decreases to zero. The flapper creates a pressure imbalance at the opposite end of the spool. The spool moves back until the pressure is again equalized. Hydraulic fluid flow to the actuator stops, so the actuator stops.

Selecting the Servovalve

Selecting the servovalve for any given system is a series of trade-offs. A servovalve that is too small will give poor performance. On the other hand, keeping the servovalve as small as possible provides greater positioning accuracy and better performance for higher frequencies. Not to mention money.

Tech Stuff

The flow versus frequency performance curve shown here indicates the performance capability of a sample servovalve at various frequencies. The curve is derived by driving the servovalve at the indicated frequency with a sinewave control signal and ± full current to the coil.



Servovalves with an Inner Loop

The discussion so far has been limited to servovalves with two stages. They function within a part of the closed-loop system called the outer loop.

The LVDT on the servovalve is connected to the main spool. This output represents the position of the servovalve's main spool. This is different from the LVDT mounted in the actuator.

See also: Inner Loop 92

Larger Servovalves

A third stage can be added, much larger of course, where the second stage's fluid flow controls the third stage. Another option is to mount a small servovalve to a large servovalve, enabling the fluid flow from the smaller one to move the spool of the larger one. This configuration (typically used when flow rates exceed 50 gallons per minute) enables the control signal to effectively regulate a flow rate substantially greater than the full-flow rating of the smaller servovalve.

Servovalve Types

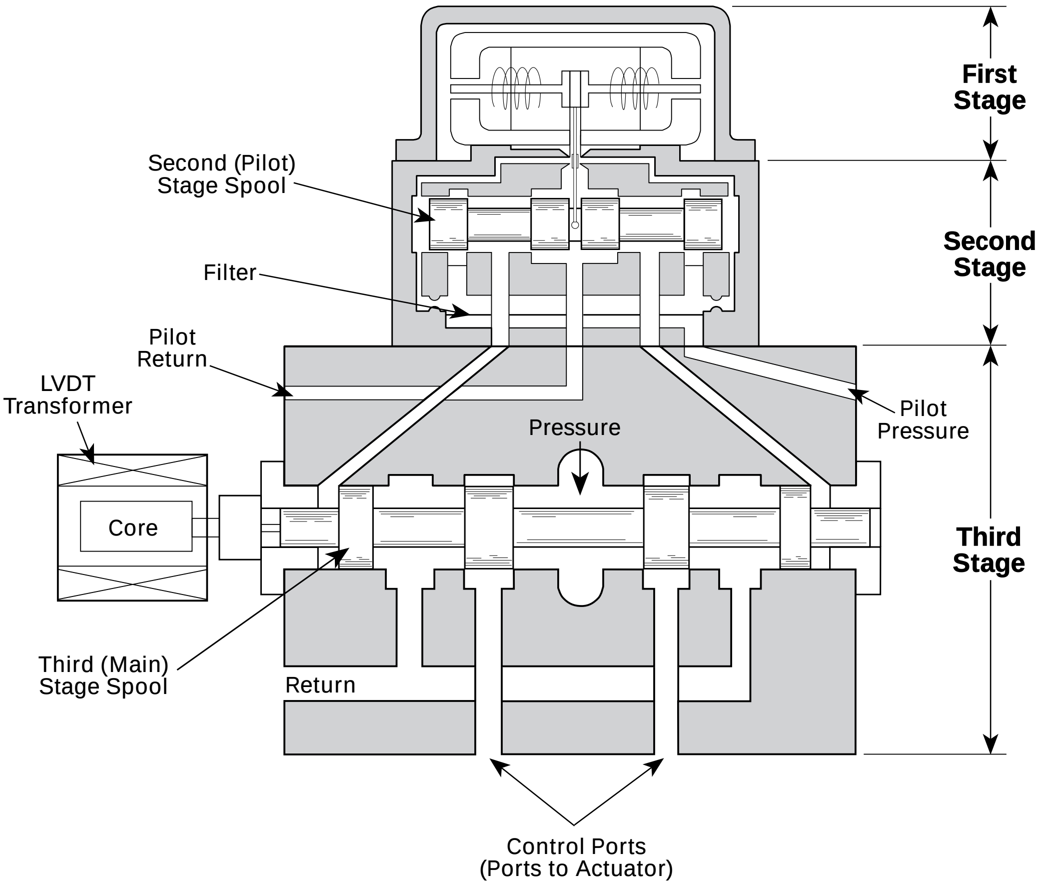
All MTS servovalves are the "four-way" type. They have: a pressure port, a return port, and two control ports. This allows positive control of the actuator in both directions, for through zero tension and compression testing.

Series 252 Servovalve

These servovalves are the most common valves used in load units. These valves offer a large range of flow ratings from 1 - 60 gpm. These valves can also be configured to operate two valves in parallel for higher flow rates. These valves are controlled via the 490.14 Valve Driver module. The cross-section drawing on the previous page is of a Series 252 servovalve.

Series 256 Servovalve

These servovalves have another (and larger) spool added, called the third-stage or main spool. They are designed for high flow applications. The Series 256 servovalve essentially have a Series 256 servovalve bolted to a third (main) stage. The main spool controls the actuator. These valves offer a range of flow ratings from 30 to 400 gpm (113 to 1500 l/min). These valves require the 490.17 3-Stage Valve Driver module to process the inner loop signals.



MTS Series 256 Servovalve

Series 257 Servovalves

The MTS Series 257 Servovalve has flow ratings from 30 to 400 gpm (113 to 1500 l/min). These servovalve applications need design expertise and qualified maintenance.

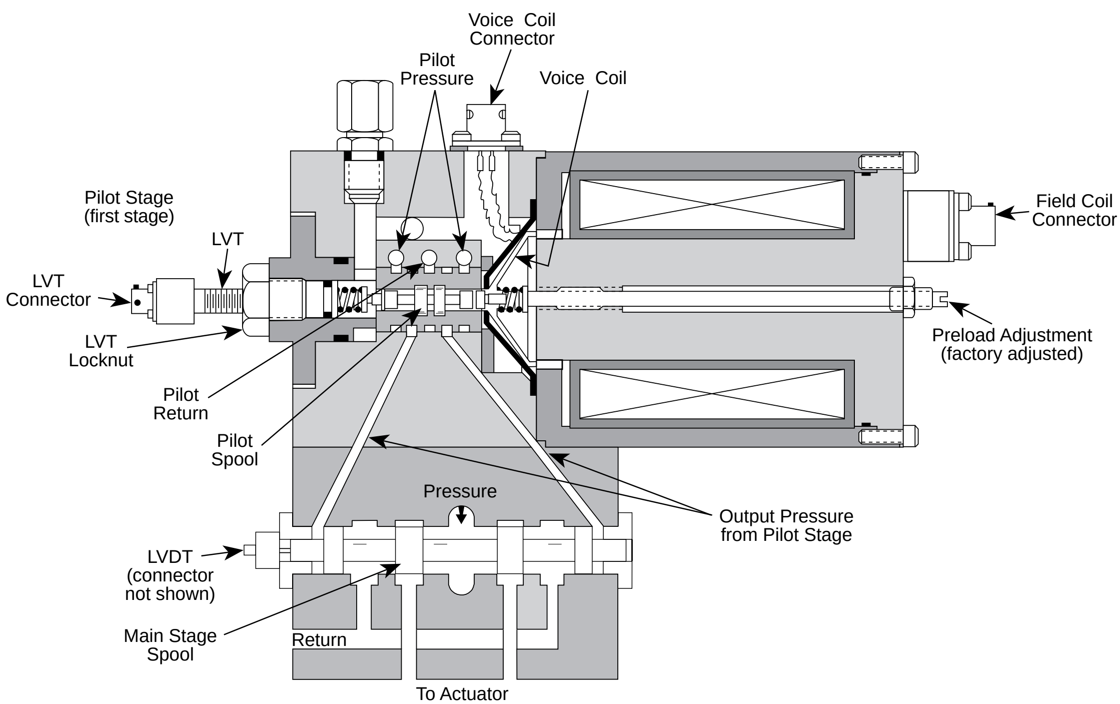
The servovalve consists of a high-response, voice coil-operated pilot stage that controls a high-flow, four-way main stage. Movement of the spool typically produces a maximum pilot flow of only a few gallons per minute.

These valves require the 490.17 3-Stage Valve Driver module to process the inner loop signals. It also requires a 448.15C Power Driver to increase the current to control the voice coil.

Voice coil control is like an audio speaker. It has the advantage of high performance at higher flow rates with low hysteresis. It also costs more.

The core of the main stage LVDT is driven relative to the main stage spool position to create the servovalve inner loop feedback signal used by the valve controller.

The pilot spool movement causes the magnetic core in the LVT (linear velocity transducer) to move; it creates the pilot velocity feedback signal that is summed with the valve command signal in the power driver to allow higher inner loop gain settings.



MTS Series 257 Servovalve

Set Point

Another term for mean level or offset.

See also: *Span/Mean Data 135*

Side Load

An undesirable condition existing when a force, or a component of a force, is not aligned with the major axis (primary loading axis) of the force train.

See also: *Force Train 71*
Grips 79

Shunt Calibration

Each dc conditioner has a sensor cartridge with at least one shunt calibration resistor. A shunt calibration resistor is required for each calibrated range.

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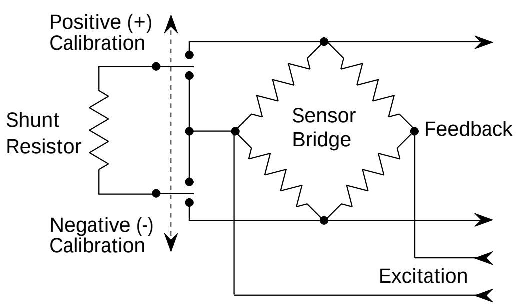


The "Shunt Cal" Test

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. This function is available by using a pushbutton in the Adjust Input Signals window. Although your own testing requirements define the required accuracy, the reference value and shunt cal values should be within 20mv. If they are not, then one of the following most likely happened.

- The excitation voltage has drifted or been misadjusted.
- The Offset Zero control in the Adjust Input Signals window is misadjusted.
- The sensor has been changed, damaged, misused, etc.
- The test checks the sensor and digital controller electronics. Run Shunt Cal if you change the conditioning module.

When to use Shunt Cal

You should perform this operation whenever you start a new test or swap a dc conditioner module. Another way of looking at it is to do this test as often as you back up your data files. If you back up your data once a week, it means that you're willing to lose a week's work of testing if your disk drive crashes. An erroneous Shunt Cal value provides incorrect data.

See also: *Calibration 24*

Slack Adapter

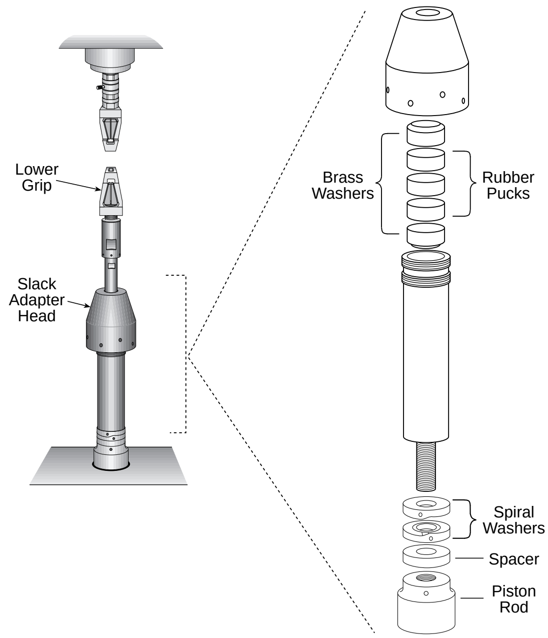
Slack adapters are used in certain tensile tests where it is necessary to ensure that the specimen is pulled (loaded) at a constant velocity throughout the test. Adapters do this by removing the slack in the force train before the specimen is actually loaded.

When the test starts, the actuator initially pulls the lower slack adapter assembly down while the upper portion of the slack adapter and the specimen remain stationary.

Shortly thereafter (when the slack is taken up), the lower portion of the slack adapter engages the upper portion, which is attached to the specimen.

The amount of slack can be changed by varying the number of pucks inside the adapter body.

See also: *Force Train 71*
Grips 79



Slack Adapter Assembly

Software Options

MTS provides a variety of software options for TestStar. The options contain prepackaged complex tests or TesrtWare-SX processes to meet specialized testing needs.

- Some of these options are processes that work within the TestWare-SX environment, that is, they can be integrated within larger tests that you create.
- Others are independent applications that work within the TestStar operating system in place of TestWare-SX. All testing parameters and procedures are already built in.

790.10 TestWare-SX

The TestWare-SX application is a flexible general-purpose program used to create and run a wide variety of tests.

790.13 Run-Time Plotting Process

This process lets you plot data while it is being acquired. You can define how and what data is collected.

790.14 Advanced Function Generation

This option includes three command processes. The UDA Cyclic process allows you to define a segment shape that can be repeated. Mixed Mode Sine and Mixed Mode Pulse processes use two control modes—one as a mean level offset, another for the segment shape (sine wave or pulse).

790.15 RPC Utilities for TestStar

This is a file play back process that is designed to run RPC (Remote Parameter Control) files on a TestStar system.

790.16 High Speed Data Acquisition

This data collection process acquires data at rates up to 50 kHz (vs. 5 kHz for the standard data acquisition process). The high-speed process acquires data according to a time increment using a single buffer. No other configurations are supported. This process also requires a second Model 490.40 Analog I/O module installed in the digital controller.

790.17 Data Monitor TestWare

Includes two processes designed to monitor long tests. Both processes can produce run-time plotting windows. The Trend Monitor process displays minimum, maximum, and mean levels of TestStar sensor signals. The Dynamic Property Monitor process can monitor up to seven dynamic properties.

790.19 Run-Time Ramp Control

This process lets you perform incremental ramps stepping toward an indeterminate end level. You can also define an intervening pause to collect data.

790.20 Fatigue Test

This application software is used for the definition, test, and analysis of constant-amplitude fatigue testing of metals, composites, advanced materials, and plastics. It provides execution of:

- A Low Cycle Fatigue test in a constant control mode (load, strain, or calculated inelastic strain). The LCF testing frequency range is 0.000001 to 5 hertz.
- The option of transitioning to a load-controlled high cycle fatigue to failure, or specified test termination.
- A High Cycle Fatigue test in a constant control mode (load, strain, or displacement). The HCF testing frequency range is 0.01 to 70 hertz.

790.31 Dynamic Characterization

This process allows you to characterize the dynamic properties of elastomeric materials and components. It allows you to sweep temperature, frequency, dynamic amplitude, mean level, and the phase relationship between control channels on up to four control channels simultaneously. It also allows you to nest sweeps inside one another.

790.33 Static Deflection

This process allows you to characterize the dynamic properties of elastomeric materials and components. The process loads the specimen between predefined load or displacement end levels and acquires subsequent timed data. This process then calculates the sample's stiffness as a chord or tangent modulus during the loading or unloading portion of the test, or as an average of the two. Finally, the process compares the calculated stiffness to predefined limits. It can also compare individual load and displacement data pairs to predefined envelopes for quality control applications.

790.35 Production QC

This is a hardware/software option that is available for the 790.31 Dynamic Characterization process and the 790.33 Static Deflection process. This option also includes special hardware to aid in performing quality control tests in a production environment. Test results are recorded and can be formatted for a variety of third party analysis applications.

790.37 Resonant Search

This process allows you to find the frequencies at which your specimen resonates. You can define frequency sweeps at a constant amplitude with a dwell between sweeps. Frequency sweeps can be linear or logarithmic.

790.38 Elastomer Tearing Energy

This process allows you to characterize the crack growth behavior of elastomeric materials. It allows you to define a loading schedule to acquire stress/strain data at each strain level of interest. When you start the test, the process allows you to enter crack growth data as it occurs, and allows you to modify the schedule to achieve the desired rate of crack growth. If desired, the process can also determine the pretest strain energy levels of the specimen.

790.40 Fatigue Crack Growth Test

This is designed using MTS' interpretation of ASTM standards. The Fatigue Crack Growth Template allows you to conduct tests per MTS' interpretation of ASTM E647-93 with the exception of section 8.3.4, where it is in compliance with the more restrictive 1991 standard for C(T) specimens. Other functions like inspection holds and crack length checks help you to investigate the status of a specimen.

Procedures contain the main test parameters for such things as control mode, test termination, etc. Procedures can be reused as many times as desired to perform additional tests. Batches can group together test specimens having the same fracture mechanics coefficients. Test results are reported for all specimens in a batch. The software provides:

- The ability to define one test, while executing a different test and analyzing yet a third test.
- Data is displayed to you during testing and analysis through the use of tabular and graphical displays.

790.50 Fracture Toughness Test

The JIc and KIc Fracture Templates allow you to conduct tests in accordance with MTS' interpretation of the appropriate ASTM specifications, and to determine the fracture toughness of metallic materials. Other functions (inspection holds, crack length and modulus checks) help you to investigate the status of a specimen. It also contains many of the features already listed for the 790.40 Fatigue Crack Growth Test.

790.61 Uniaxial Rock Mechanics

This application includes predefined templates for: Uniaxial Compression, Uniaxial Compressive Deformability, Uniaxial Direct Tension, Uniaxial Indirect Tension, Uniaxial Compress Deform Post Fail, and Uniaxial Creep.

790.62 Triaxial Rock Mechanics

This application includes predefined templates for: Triaxial Compressive Strength, Triaxial Creep, Triaxial Compression—Single, Triaxial Compression—Multiple, and Triaxial Compression—Continuous.

790.63 Fracture Toughness for Rock

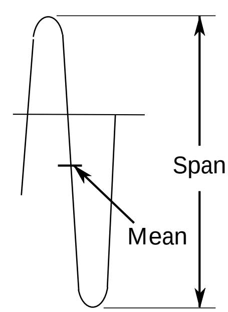
This application includes predefined templates for Fracture Toughness, Levels I and II tests.

790.90 TestWorks™ for TestStar

This is a complete monotonic test application that performs tensile, compression, flex, and other ASTM/industry standard tests. The program controls the test, acquires data, and graphs and analyzes the results. You can customize the test methods and calculations to meet specific requirements.

Span/Mean Data

Span is the difference between the peak and valley of each cycle when using the TestStar meters. It is also another term for amplitude when using the Function Generator.



Mean level is the midpoint in a cycle when using the TestStar meters. It can also be another term for set point which is an offset from zero from which a test begins.

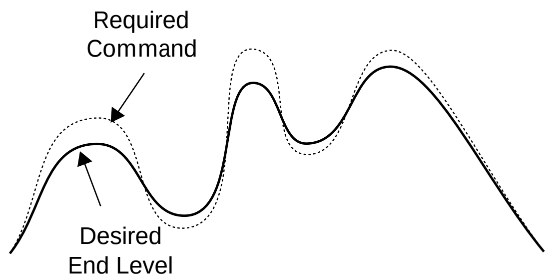
The TestStar meters can monitor Span/Mean data which shows the peak-to-valley (span) and midpoint value (mean) for each cycle.

See also: *Function Generator 76*
Meters 106

Spectrum Amplitude Control

Spectrum Amplitude Control (SAC) is an algorithm that uses a table while the test is running to keep track of end levels. As the test is running, the controller monitors the test progress and compares each command end level with its feedback end level. The difference between the command end level and its feedback is continuously monitored and the over programmed level table is adjusted continuously. You can setup a missed end levels counter to monitor accuracy.

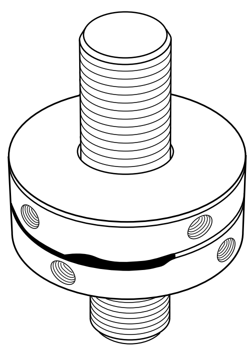
SAC is designed for use with the file playback process.



See also: *Compensators 29*
Processes 116

Spiral Washer

Spiral washers preload elements of the force train to provide backlash-free connections. They are typically used to attach swivels and force sensors to the actuator for cyclic testing. The washers are placed over the threaded studs at each connection and rotated in opposite directions (producing a camming effect) to a position that places a constant preload on the stud.



To install these washers, you clamp a dummy specimen with the grips. You apply a tensile force to this specimen. This creates small gaps between the fixtures such as grips, force sensor, and actuator. Turning the washers closes these gaps.

Removing the tensile force on the specimen lets the washers apply their own constant tensile preload to the connecting studs. This preload eliminates backlash as the grips cycle between tension and compression as well as protecting the studs from premature fatigue failure.

See also: *Force Train 71*
Test Frames 141

Step

Used with the TestWare-SX program. Steps are logical groups of processes.

See also: *TestWare-SX 143*

Stopping a Test

There are several ways to stop a test:

- If using the Function Generator, TestWare-SX, or one of the specialized TestStar applications, the test will stop when it accomplishes the task you have specified (such as applying a force to a certain level). Each of these controls also has software pushbuttons (or their equivalent) that enable you to suspend or to stop the test.
- You can use the outputs from the sensors to stop the test (or to simply indicate that a sensor-detected condition has occurred).
- If a hardware or software malfunction occurs.
- Press the Emergency Stop button.

See also: *Detectors 46*
Emergency Stop 55
Interlocks 96

Strain

Strain is the elongation or compression of a specimen in relation to its original undistorted length. It is a dimensionless value, but is usually expressed in inches per inch or percent. Strain is commonly described in terms of engineering strain, which is the change in length divided by the original length.

See also: *Extensometers 61*
Control Modes 34
Gage Length 78

Strain Control

A system control mode where the feedback from a strain sensor (such as an extensometer) is the primary sensor in the control of the loop.

Strain Gage

A sensor bonded to a structure or specimen that measures its elongation or compression during a test. Its output is calibrated in units of strain.

See also: *Bridge Completion 23*
Sensor Cartridge 122

Stress

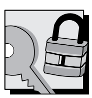
Stress is the force acting across a unit area in a solid material resisting the separating, compacting, or sliding that tends to be induced by external forces. As used with most mechanical tests, engineering stress uses the original cross-sectional area without taking into account changes in area resulting from the applied force.

Stroke

Another term for displacement and length.

See also: *Displacement 51*

System Administration



This is a TestStar program that allows the system supervisor to assign user names, passwords, and access to other TestStar and TestWare programs.

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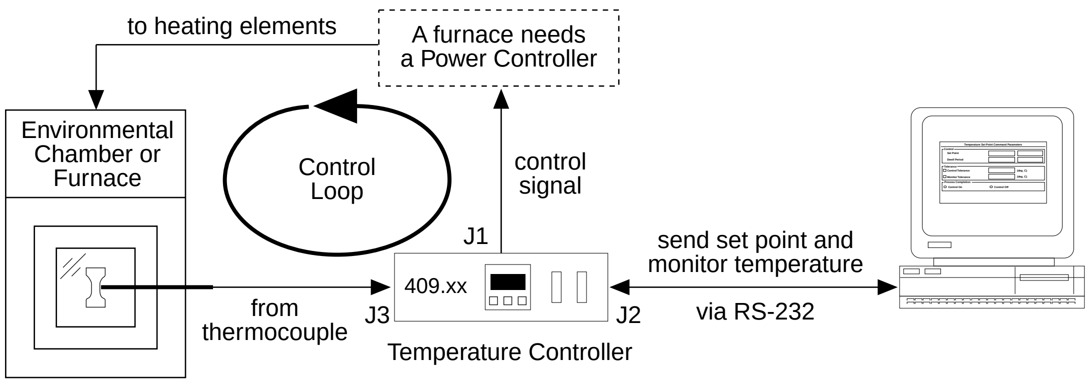
Temperature

Both temperature processes interface with the MTS Series 409 Temperature Controllers via an RS-232 interface.

See also: Environmental Chamber 57
Furnace 77



Closed-Loop Control of Temperature

Temperature Control

The temperature control process is an external control process. Use it to set the temperature in an environmental chamber or a high temperature furnace.

Temperature Data Acquisition

This is a data acquisition process. It acquires the temperature from an environmental chamber or a high temperature furnace.

Temposonics Transducer

MTS Temposonics™ linear displacement transducers measure the position of an external permanent magnet. In turn, the magnet can be attached to an actuator piston rod or any moving machine part.

How it Works

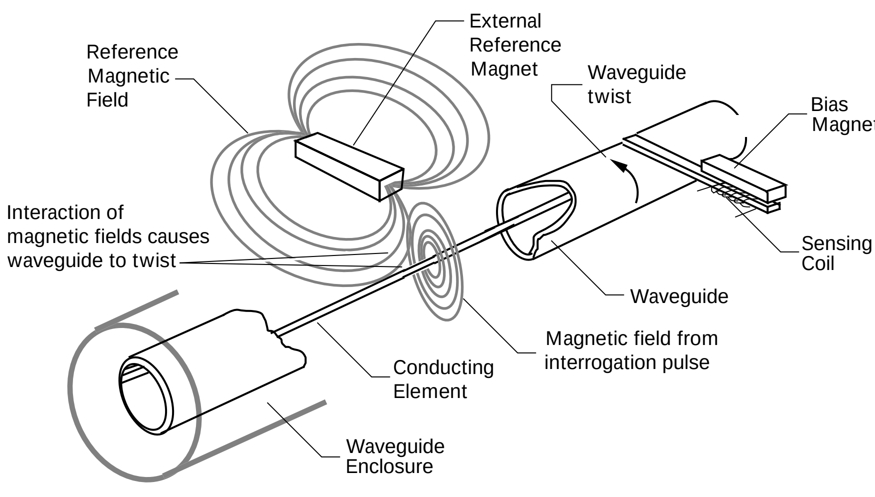
A short (20-microsecond) low-power interrogation pulse is applied to a conducting element threaded through the waveguide. As this pulse travels it creates a magnetic field that surrounds the waveguide.

The reference magnet creates a second magnetic field. The intersection of the two magnetic fields (from the waveguide and the magnet) create a rotational force.

The rotational force creates a torsional pulse or waveguide twist that travels at the speed of sound along the waveguide.

The head of the transducer houses the sensing circuit that detects the waveguide twist and converts it to an electrical pulse. The distance from a reference point to the magnet is determined by measuring the time interval between initiating the interrogation pulse and detecting the return pulse, and by knowing the speed of the return pulse through the waveguide medium.

See also: *Displacement 51*
Input Signals 94
Sensor 121



Temposonics Linear Transducer

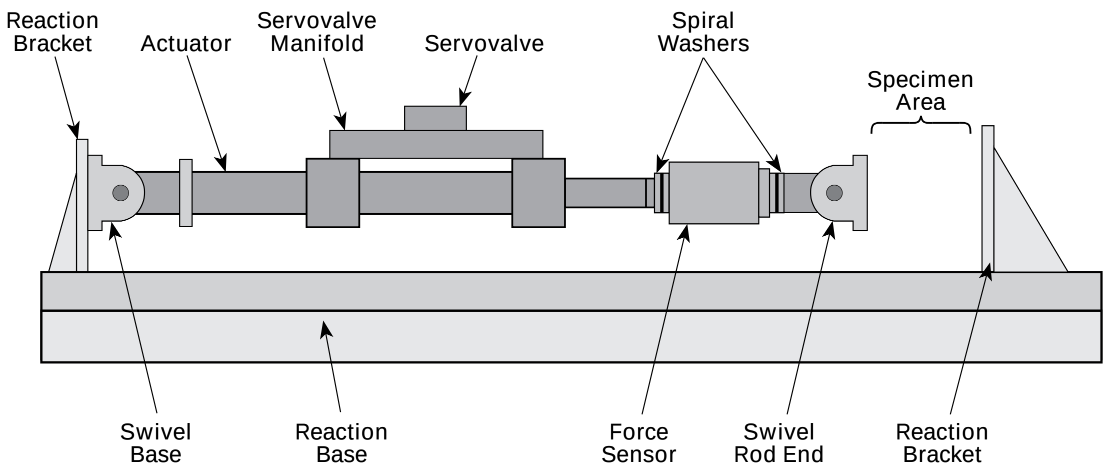
Tension

A force applied to the ends of a test specimen that tends to pull the specimen apart.

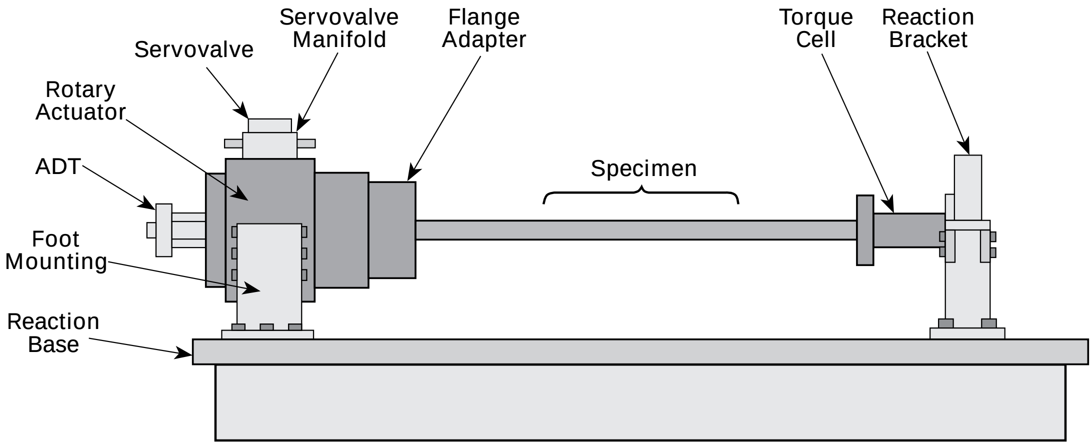
See also: Control Channel 32

Test Frames

Test frames are places to mount the various hardware needed to test a specimen. They serve the same purpose as a load unit. There are a wide variety of test frames from standard load units to custom-built buildings. Testing systems can use different types of actuators and actuator setups.



Test Frame Example: Linear Actuator



Test Frame Example: Rotary Actuator

Test Frame Components

Actuator Assembly

The choice of this force-generating device depends on displacement, force, and frequency requirements. An internally mounted LVDT is used as a feedback device to the digital controller for precise control of the piston rod's position.

ADT (Torque Cell)

Torque-measuring sensor that provides an electronic feedback to the digital controller so that the torque applied on the specimen can be precisely controlled or monitored.

Flange Adapter

Used to attach the specimen to the actuator shaft.

Foot Mounting

This is normally a standard attachment to the actuator. It uses a flexure-absorbing design to reduce damage from specimen windup deflection-induced loads.

Force Sensor (Load Cell)

This linear force-measuring sensor provides electronic feedback to the digital controller. It allows you to precisely monitor and control the force applied to the specimen.

Reaction Bracket/Reaction Base

A reaction bracket is attached to reaction base and allows test components to be mounted to the force train. In some cases, the reaction bracket can be as simple as the illustration shows. In other cases, it's necessary to fabricate a fixture for holding a specimen in a desired position for proper application of the applied force. A reaction bracket is necessary where both ends must be attached to provide proper force. For example, when testing shock absorbers. It is not necessary when testing a whole car, where the weight of the car provides the necessary reaction force.

Rotary Actuator

Applies carefully controlled torque forces to the article you want to test, by twisting the specimen.

Servovalve Manifold

Mounts the servovalve (single or dual valves) to the actuator and provides a connection point for hoses from the hydraulic system.

Servovalve

Controls the flow of hydraulic fluid to the actuator piston. This determines the magnitude of the force and displacement the actuator applies to the specimen.

Specimen

The item being tested. There's no limit to the kinds of specimens this type of hydraulic force train can test. In some cases it's necessary to fabricate a special fixture or mounting bracket to hold a specimen. This illustration shows single-axis loading of a specimen. Multiple-axis testing is easily accomplished by adding more control channels.

Spiral Washers and Studs

These studs are threaded connecting fixtures used to firmly join two inline members of the force train. Spiral washers prestress the stud to provide a backlash-free connection.

Swivel Base/Swivel Rod End

Mounts the actuator to the reaction bracket or directly to the test base. The swivel allows actuator movement and helps prevent side loading on the actuator bearings caused by specimen geometries or unnatural specimen deflection while during testing. The swivel rod end provides a fixture for attaching the specimen between the hydraulic force train and the other reaction bracket.

See also: *Load Unit 99*
Types of Test Systems 6

TestWare-SX

TestWare-SX is a general-purpose software application program available for TestStar systems. It is used to create and run material test programs. The TestStar and TestWare-SX programs run in parallel to control the test. The basic version of TestWare-SX lets you design tests in a step-by-step manner, defining the function generation and data acquisition requirements for each part of the test. The test can be anything from a simple standard test to a unique complex solution to your test requirements.

See the 790.10 TestWare-SX Application Manual before you attempt to design or run a test.

See also: *Processes 116*
Software Options 132

Templates

A template is the primary element of TestWare-SX. You cannot run or create a test without at least starting with a template. Although you must first have a template, you can create a new one from scratch or else open an existing one and change it to meet your needs.

A template sequences the order processes are run (it also names the processes). It describes a type of test, such as a high cycle fatigue test.

The process parameters (things like amplitude, frequency, and other specifics) have initial settings. By default, all values are initialized to 0 and all selections are set to the first item in a list.

A template is the default test procedure, in fact you could establish initial process parameters that can actually run a specific test. Templates have the file extension of .000.

Procedures

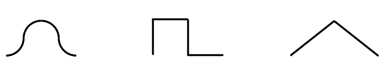
Each template can have up to 999 procedures defined. A procedure is the same as a template except some or all of the process parameter values and selections are different. A procedure is nothing more than a template with specific numbers assigned to each of the actions to be performed within the test.

For example, a high cyclic fatigue test template may have several procedures, each set to run the test at different frequencies and/or amplitudes.

Processes

A process is the basic building block of a test. Processes can be very simple commands or complex complete tests provided by MTS.

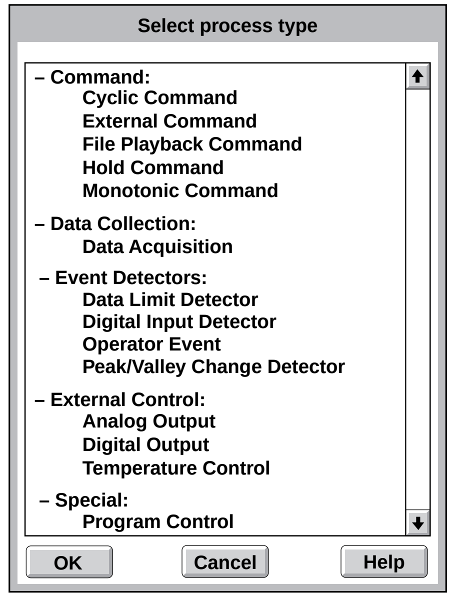
The process is the smallest element of this application. Processes can be really simple little things like the following commands:



Haversine Step Ramp

Processes can also be large packages with extensive command, data acquisition, and analysis functions. The window called “Select process type”, shows the standard processes supplied with TestWare-SX.

Other applications provide additional specialized processes.



Process List

When you are creating a test, TestWare-SX provides you with a roster of predefined processes. The actual list you will see on your system depends on which software options you may have purchased.

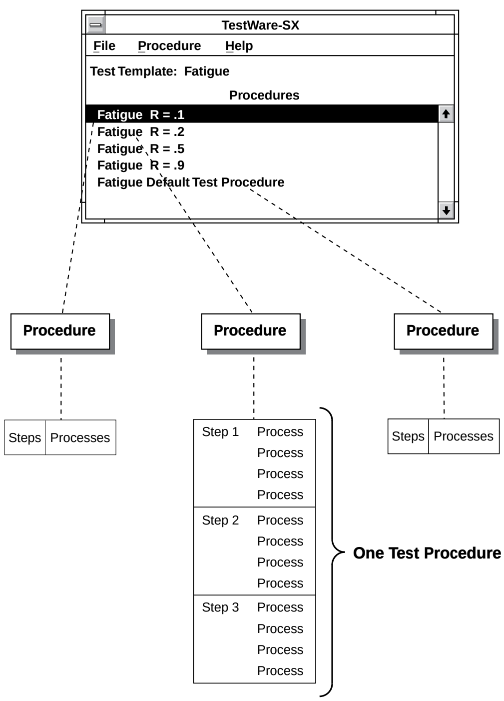
Steps

A step is a grouping of processes together into one convenient package. Although every test must have at least one Step, there is nothing magical about the number of Steps in a procedure—all they do is modularize a Procedure into logical units. You as the test designer decide what is logical.

Steps versus Processes

One common question in designing and modifying a test is, "What is the right way to arrange steps and processes?" The politically correct answer is, "It's your choice." It is your choice; however, here are some guidelines we have found useful in organizing a test:

- When you are new at designing a test, use a lot of steps with few processes in each step. Reason: As the test executes, the Execute Procedure window displays steps, but not processes. Debugging can be helped by having a display of the continual step-to-step operation.
- If you want to have loops in your test, combine all of the processes in that loop into logical steps; you can repeat steps, but not processes.



- If your test is acquiring data, remember that data acquisition turns off between steps. So any tests that need data to be acquired for a long time need all of their processes in the same step.
- If your test is acquiring data, always set up your template so that the data acquisition process occurs before the process that commands the actuator (even though they may share the same start trigger). Reason: There is approximately a 50-millisecond delay between processes. (The actual time depends on your computer's processor.) So if acquiring data at the start of the test is important, you will find the gap annoying.

Other Testware-SX capabilities

Explaining all of the features provided by this application is far beyond the scope of this manual. Not only does the basic application provide many features, but the specialized versions offer their own significant capabilities.

See also: *Software Options 132*

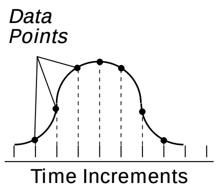
Using Spread Sheets

The TestWare-SX data files are in ASCII format, you can easily import the test results into many of the popular spreadsheet or wordprocessing programs. You can then process and manipulate the data as you wish, depending upon how much you've read their manuals.

Timed Data

Timed data can be obtained via a TestStar digital meter or from a data acquisition process in TestWare-SX.

- Timed data is acquired at equal time intervals.
- The TestStar meters display timed data every second.
- You can specify the time increments in the data acquisition process.

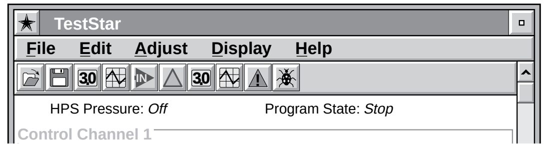


See also: *Data Acquisition 39*
Meters 106

Toolbar

The toolbar is a row of pushbuttons displayed below the menu bar. Each pushbutton icon represents a unique TestStar window. Clicking on the icon opens its associated TestStar window.

Pushbuttons with the same icon can have different colors. The changes in color represent a common label, such as Edit Meters and Display Meters.



TestStar Toolbar

The toolbar permits you to customize your menu with pushbuttons that represent the windows you open most often.

Torsional Test

A test using a hydraulic actuator constructed to apply rotational forces (torsion) to a test specimen.

See also: *Rotary Actuators 15*

Transducer

Device used to convert one form of energy to another. A transducer is also called a sensor.

See also: *Input Signals 94*
Sensor 121

Transputer

A high-performance microprocessor that contains on-chip RAM and bidirectional serial links for communications with other processors. One of its significant features is the ability to perform hardware multitasking.

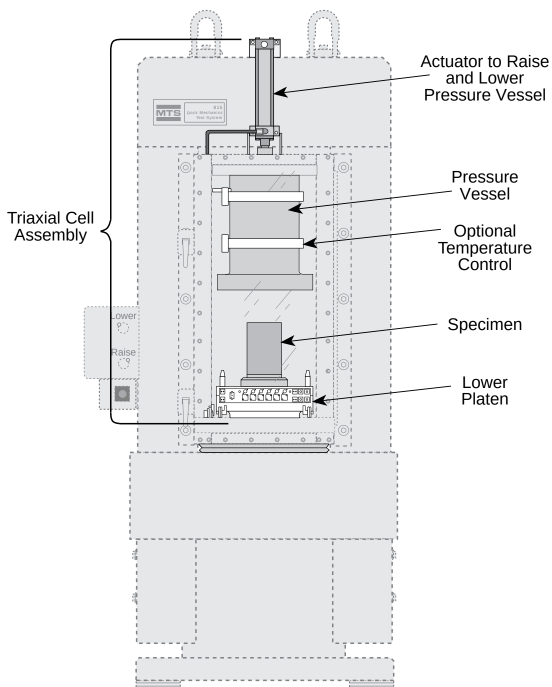
The TestStar digital controller uses several transputers to communicate with the various controller functions.

For example, the controller communicates with load unit control panel through a pair transputers (one at each end).

See also: *Digital Controller 49*

Triaxial Cell Assemblies

Triaxial cell assemblies are generally used to simulate natural conditions (such as stresses, temperature, and pore fluid pressure) on a material. The most common application is in rock and concrete mechanics testing systems. They are also used to investigate effects of changes to those conditions. MTS triaxial cell assemblies are compatible with various models of MTS load units.



Model 656 Triaxial Cell Assembly

Shown installed within a Model 315 Load Frame Assembly.

How it Works

The operation starts when the operator installs the specimen and measuring accessories such as extensometers (which measure the specimen's strain).

The pressure vessel, when lowered onto the baseplate, forms a sealed pressure chamber for the specimen and extensometer assembly. Screws hold the pressure vessel to the baseplate.

Confining Pressure

The chamber fills when confining fluid enters the lower confining fluid port, forcing air out the upper confining fluid port. Confining pressure is applied outside the specimen.

Pore Pressure

Pore fluid is applied to the specimens through the upper and lower pore fluid ports. A Teflon or rubber jacket is typically placed around the specimen to provide a barrier between the pore fluid and the confining fluid. Pore pressure is applied inside the specimen.

Note that this arrangement allows three independent forces to be applied to the specimen: axial (through the piston shown in the diagram), confining pressure, and pore pressure. These three forces are controlled in real-time by three TestStar control channels.

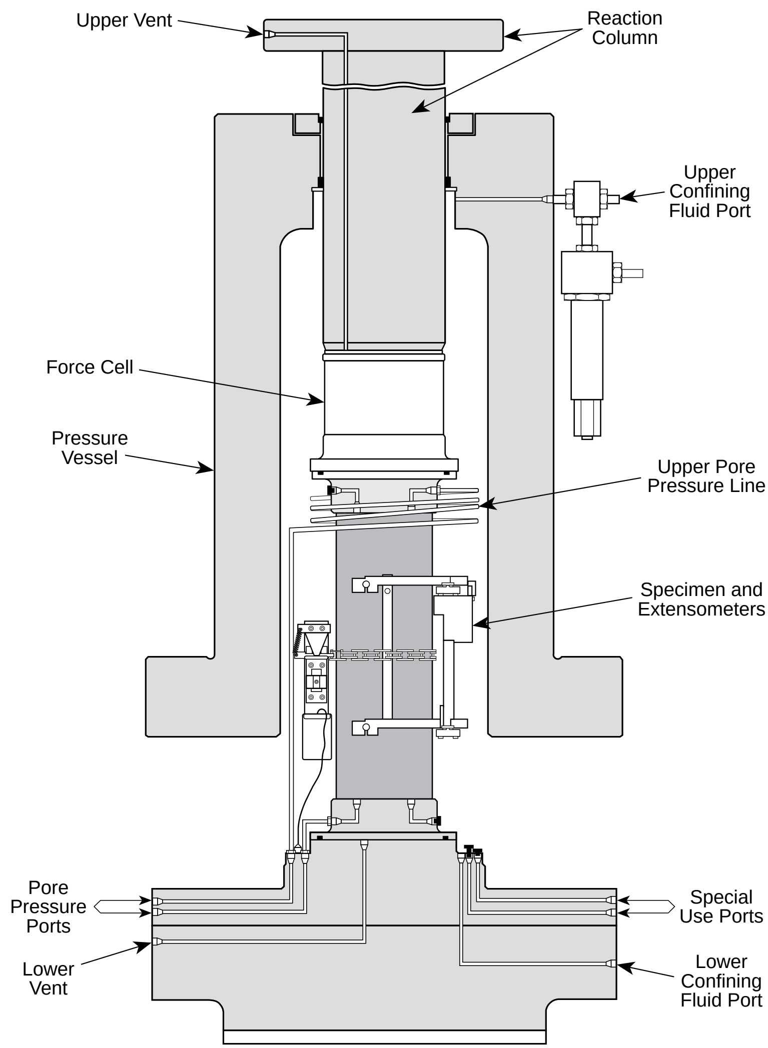
Deviatoric Stress

A form of stress called deviatoric stress results from the difference between the lateral and axial stresses applied to the specimen. Confining fluid pressure alone produces the lateral stress.

The axial deviatoric stress results from the force developed by the actuator and, unless set up for extension testing (optional), from the confining stress acting axially.

Triaxial Cell Components

Use this cut-away view as a reference when referring to the "How it Works" section.



Pore Test Fixture

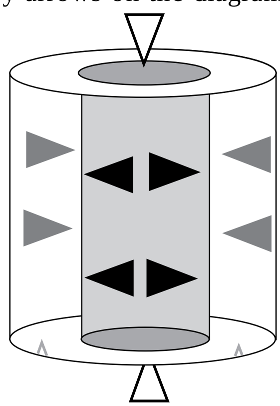
Options

- A spherically seated platen accommodates specimens whose ends are not parallel.
- An internal force sensor directly reads the true deviatoric load on the specimen. When using an external force sensor, it is necessary to compensate for the effects of seal friction and confining fluid pressures within the pressure vessel to find the true deviatoric load.
- Another option is a High-Temperature Control Package, which provides the equipment to raise the temperature inside the triaxial cell.

Triaxial Test

This is a test using three control channels that simultaneously apply force along three axes. One type could have the axes as axial, torsional, and internal pressure.

Another type could be as shown below (indicated by arrows on the diagram):



- As a load (white arrows).
- As confining pressure pushing in toward the specimen (gray arrows). Confining pressure is an equal pressure applied to all sides. This simulates, for example, the pressure applied to rocks in their natural environment.
- As pore pressure pushing out from the specimen (black arrows). This is actually stress. Using rocks as an example again, this would be the stress transmitted through the rocks by the fluid within them. Pore pressure is also called neutral pressure or neutral stress.

See also: *Pressure Intensifiers 114*
Triaxial Cell Assemblies 148

Tuning

Tuning is one of those magical words that technical gurus like to use to keep us impressed with their knowledge and how indispensable they are. After all, they say, tuning is a very complex subject, and it is more art than knowledge. It can be taught only by learning the secrets that cloud men's minds.

Not true! Actually, an informal definition of tuning could be: Tuning is adjusting the 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 the system just like setting the timing on an automobile improves its performance. Tuning is discussed at length in the TestStar Reference Manual.

Don't get too hung up on tuning. 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 system behave the way you want it to. If the system is meeting your expectations, then leave it alone.

See also: *Cascade Control 26*
Channel Limited Channel 27
Closed-Loop Control 28
Control Modes 34

A Review

Remember that when you remove all of the bells and whistles from a servo loop, you end up with a simple summing junction (guru term). A summing junction can be anything from a simple network of resistors to an elaborate electronic circuit, but all it does is add voltages together.

All servomechanisms (of which autopilots, inertial guidance systems, and materials test systems are only a small sample) basically have 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 guys are out of agreement by this much."

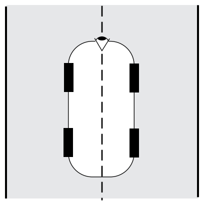
This means that Error = Command - Feedback

That's all there is to it. You want to get the summing junction to drive the error to zero, and to do it smoothly and efficiently.

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

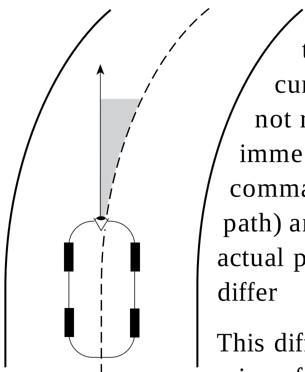
An Analogy

To understand how tuning works, let's take 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's off and in what direction



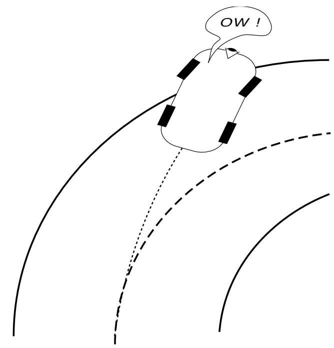
As the car moves, the road begins to curve. The driver does not respond immediately, so the command (the desired path) and the feedback (the actual path) are starting to differ

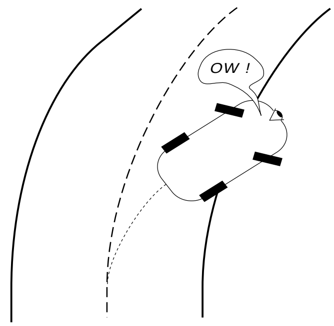
This difference (command minus feedback) is error. It's indicated by the shaded triangle

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's a problem.

Turn the steering wheel too little, and the car responds too slowly.



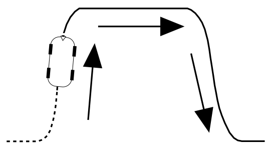


Turn the steering wheel too much, and the car overresponds.

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, and the insurance company saves money.

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.



Let's change the road into something more practical. This sample diagram is a squarewave. This is one type of test waveform used. We want our test (the car) to follow the desired test (the road) in all respects. That means the test system should exert exactly the 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 Aunt Minnie's weekly drive to the store, the tuning differs too. A system properly tuned for a soft specimen will go crazily unstable if you install a very hard specimen.

The Ultimate Goal

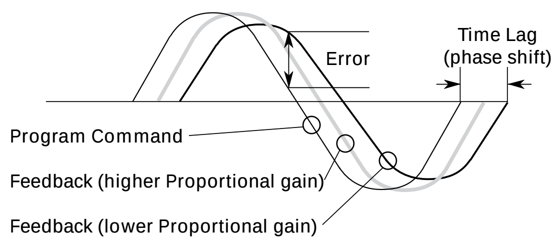
Simple. Get the error signal to be a small as possible at all times, because:

- 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.



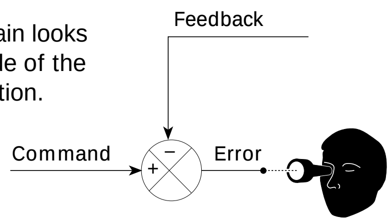
Proportional Gain

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 burning (amplitude) is proportional to how much we want to correct, and how fast. This is proportional gain. Our formula is now:

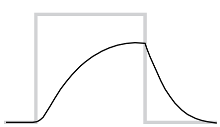
Error = Gain x (Command - Feedback)

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

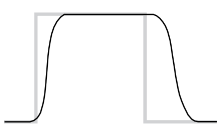


The shaded square wave represents the test command.

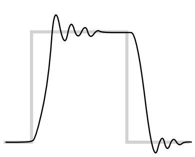
This waveform shows a sluggish (low gain) feedback signal.



The solid waveform shows an idealized feedback signal.

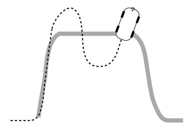


This waveform shows an unstable (high gain) feedback signal.



Note: *Note that proportional gain is not speed (how far your push down on the gas pedal), it's 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's nothing subtle about an unstable loop--you'll hear it. If the test fixture is large enough, you'll 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 survivable more moves the oil faster into the actuator.
- Moving oil faster makes the loop respond quicker, reducing the error faster. This is your "higher system response."

Derivative 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. Same car, same road, only now you're going really fast and the curves are electrifying. But it's 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're 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.

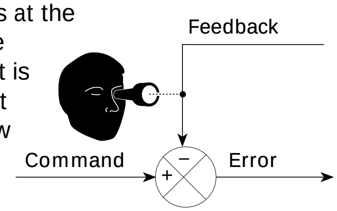
Derivative gain is the same concept. It stabilizes the system by reducing the error signal when its rate of change is the greatest. This reduces overshoot and ringing at high proportional gain settings.

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

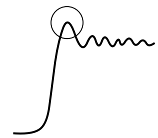
Derivative Gain =
gain x (Command - Feedback)'

(If you're not mathematically inclined, the little ' in the equation above means "first derivative." But then, if you're not mathematically inclined, the term "first derivative" is meaningless too. Fortunately, you don't have to worry about it.)

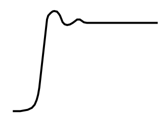
Derivative gain looks at the feedback side of the summing junction. It is the derivative of that signal, indicating how fast the feedback is changing.



Here is a signal with high with a high 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.



Do you need derivative gain? There's 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.

Integral Gain

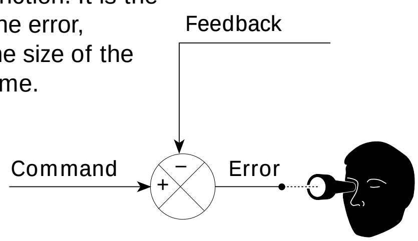
Integral gain generates increased gain over longer time spans (including steady state). Integral gain is sometimes called Reset gain.

To return to the car analogy: The race is over. You've won the TestStar Grand Prix and the trip home is an easy one. You're driving on a straight highway feeling so mellow that you aren't really paying attention.

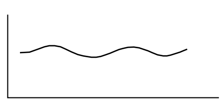
The car drifts off of its desired path. The problem is that this happens so slowly that you don't realize it. You need something to boost your attention.

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.

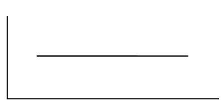
Intergral (Reset) gain looks at the error side of the summing junction. It is the integral of the error, indicating the size of the error over time.



An error signal made unstable by too much integral gain.



An error signal that is stabilized by correct gain.



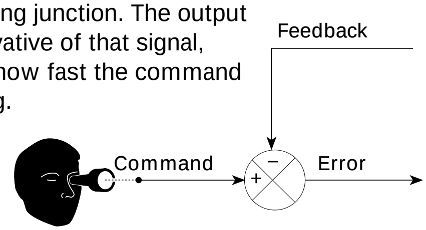
Feed forward Gain

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's 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's the gizmo that gives a quick slug of gas when you suddenly floor the gas pedal.

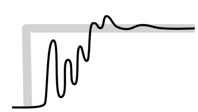
This mode is like Derivative mode, except that it anticipates changes rather than reacts to them.

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.

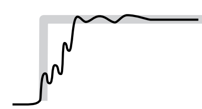
Feed forward gain looks at the command side of the summing junction. The output is the derivative of that signal, indicating how fast the command is changing.



Inadequate feed forward.



Correct feed forward.

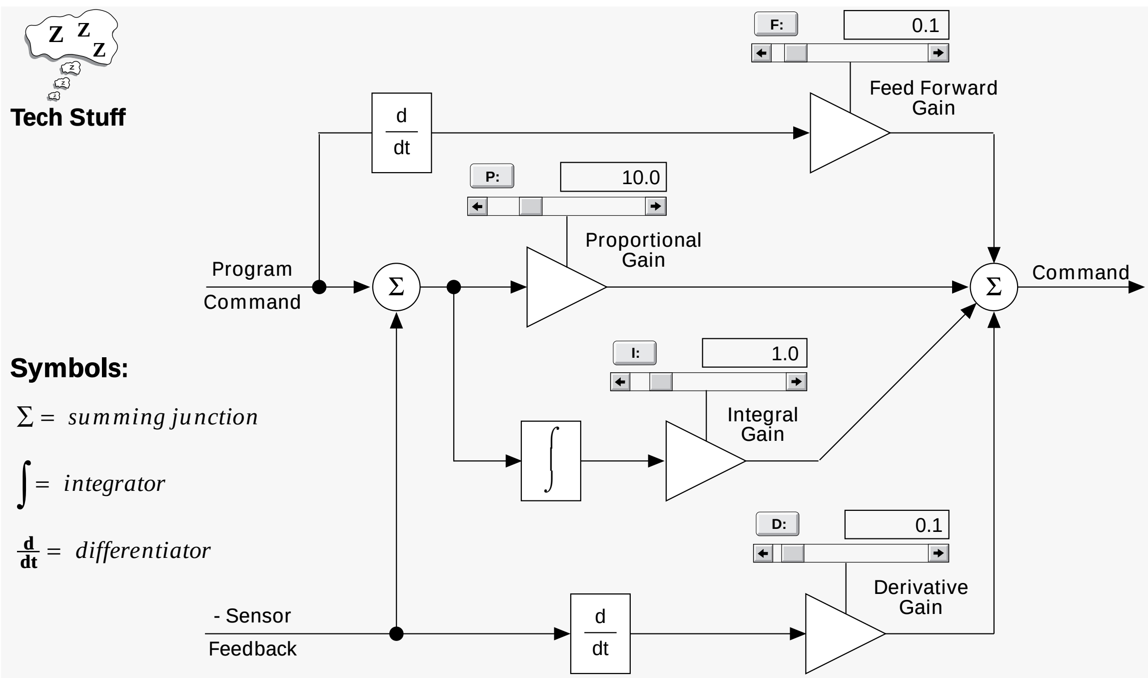


So look at feed forward as a form of a "predictor" of where the actuator should be going. The signal gives the servovalve a early wakeup call to tell it that it needs to open faster than would be expected from the existing error signal.

To Review

PIDF is the abbreviation for Proportional Gain, Integral Gain, Derivative Gain, and Feed Forward Gain. These gain controls have the following functions:

- Proportional gain (P) increases system response.
- Integral gain (I) increases system accuracy during static or low-frequency operation and maintains the mean level at high frequency operation.
- Derivative gain (D) improves the dynamic stability when high proportional gain is applied.
- Feed forward gain (F) increases system accuracy during high-frequency operation.



Auto Tuning

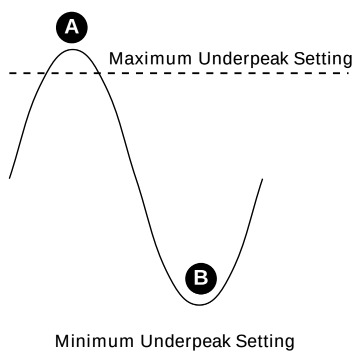
TestStar has an auto tuning feature. What!? You've just read pages of tuning stuff and now you find out that TestStar can tune itself.

The auto tuning feature tunes any PIDF control mode to a moderate level of tuning. It exercises the actuator while monitoring the feedback. Then it calculates the PIDF tuning parameters.

U - Z

Underpeak Detector

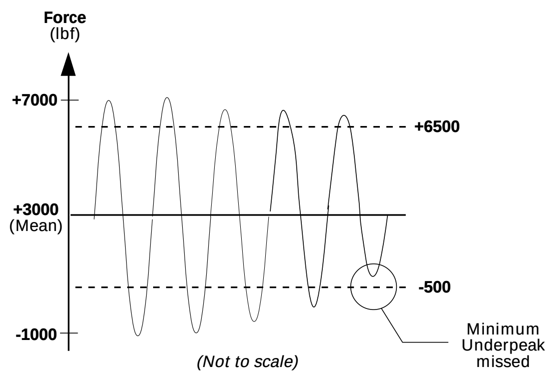
This function is used with cyclic tests to define an acceptable minimum operating range for an input channel.



As shown in the waveform above, the input signal at point A exceeds the Maximum Underpeak Setting—this is the desired result, so it is not an error. At B, the signal amplitude is insufficient to attain the Minimum Underpeak Setting—this generates an Underpeak Error.

For example, assume that you are running a fatigue test on a sample under the control of the strain control channel. After some preliminary investigation, you have determined that the desired strain will be achieved if the force is +7000, -1000 pounds.

You don't want to continue the test until the specimen breaks; instead, you have established that you consider that a failure has occurred if the force necessary to maintain constant strain falls off by 500 pounds from either peak.



As shown in the diagram, the test can continue indefinitely until the force necessary to maintain the strain becomes less than your threshold level. Whether or not the test ends depends upon the Detector Action you have selected.

See also: *Detector Actions 47*
Input Signals 94

Unit Assignment Set Editor

A utility program that permits establishing personalized sets of units (inches versus centimeters, etc.) that can be the used as the default dimension for the initial software values.

Utilities

The Utilities folder contains programs that perform various functions for TestStar, such as:

- Generating sensor calibration files
- Defining user access to TestStar
- Selecting a preferred set of unit dimensions
- Defining a load path stiffness set
- Diagnostic tools

See also: *Calibration 24*
Load Path Stiffness Editor 73
System Administration 138
Unit Assignment Set Editor 159

Valve

This is another name for servovalve or drive.

See also: *Drive 53*
Servovalve 125

Valve Balance

The process of adjusting the electrical input to a servovalve so that there is no hydraulic fluid flow when the error signal is at a null. This is the electronic equivalent of the mechanical valve balance described in each servovalve manual.

Valve Driver

An electronic device that takes the corrective (error) signal and generates the necessary current to drive the servovalve.

Zero

Zero is also called null.

See also: *Extensometers 61*
Offset 109
Sensor 121

Zeroing a Sensor

Each sensor used in a test should be zeroed before the test begins. However, each sensor should be zeroed at the right time.

Load

After installing a grip, you zero the force channel to remove the effects of the weight of a grip fixture on the force sensor output before the specimen is installed.

LVDT

Assume the LVDT is calibrated with the zero point at mid-actuator displacement. After a specimen is installed, the LVDT sensor output may not be zero. In this situation you would want to zero the output.

Displacement

Before installing an extensometer, use the zero pin or gage length fixture to establish the mechanical zero of the sensor. Use sensor zero if the sensor output is not zero

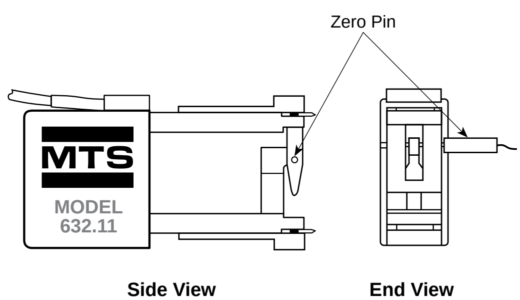
Zero Pin

The zero pin is used to obtain the mechanical zero point of an extensometer. It also protects the extensometer from damage if the arms should be flexed excessively while handling it.

When the extensometer is mechanically set up, it needs to be adjusted so that when it is sensing zero strain, then the output is zero volt.

To use the zero pin, install the extensometer on the specimen with the pin installed. Make sure to use the correct extensometer—its gage length should match the specimen's gage length. With the extensometer installed, zero its signal, and then remove the zero pin. Reinstall the pin before removing the extensometer after the test is done.

A zero pin is a necessary protective device for most extensometers.



See also: *Auto Zero 21*
Calibration 24
Extensometers 61

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