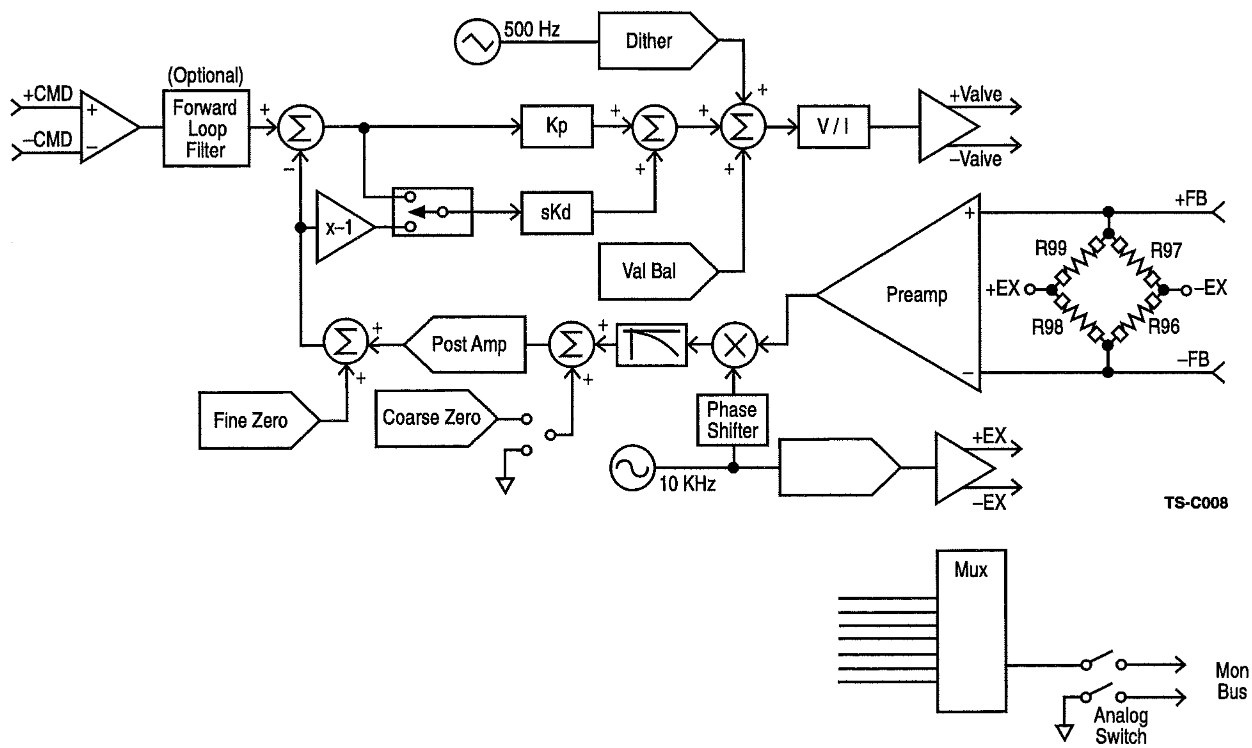
Chapter 7
Model 407.15 Three-stage Valve Driver

Description

The 407.15 Three-stage Valve Driver is a single-channel adjustable valve driver module specifically designed for user interactive applications using MTS Series 407 electronics. The Valve Driver provides programmable servovalve LVDT excitation, inner loop servo control, and valve drive current for a three-stage servovalve.

The Valve Driver includes a valve clamping circuit, used to clamp the valve current at a predetermined level in the event of a power supply failure.

The following is a simplified block diagram of the Valve Driver.



Monitor Output

The Three-stage Valve Driver output circuitry provides selectable monitor output signal selection. Signals can be monitored at either of the front panel BNC connectors. Any of the following signals can be selected for the monitor output:

- DEMOD—demodulator
- IL FDBK—inner loop feedback
- F ZERO—fine zero
- IL CMD—inner loop command
- IL ERR—inner loop error
- VLV BAL—valve balance
- VLV CUR—valve current
- GND—ground

Gain and Zero Offset

The Three-stage Valve Driver can be programmed to provide transducer output signal amplification within a range of 1 to 80. This provides compatibility with both low-level and high-level transducers. An adjustable zero offset voltage provides a dc offset of the conditioner output. This offset can be introduced either before or after the gain stage.

NOTE The actuator may exhibit a slight bump as the conditioner gain adjustment passes through the values 10 or 80. This unavoidable effect is caused by near-simultaneous changes in two internal values.

Two offset sources are available on the Three-stage Valve Driver: coarse zero and fine zero. The functions of these sources are determined by the installation of jumpers on the board.

Demodulator Phase

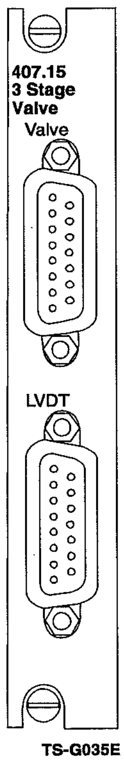
The Three-stage Valve Driver provides a demodulator phase adjustment within a range of ±90°.

Transducer Excitation

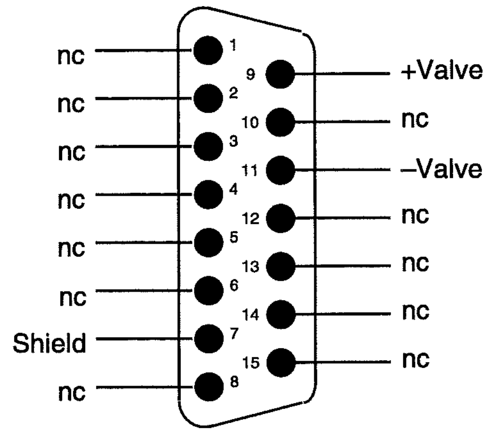
The Three-stage Valve Driver provides an amplitude adjustable 10 kHz excitation signal to the transducer. The excitation amplitude is adjustable within a range of 0 to 40 Vp-p (or ±20 V differential at the transducer).

Three-stage Valve Driver Panel

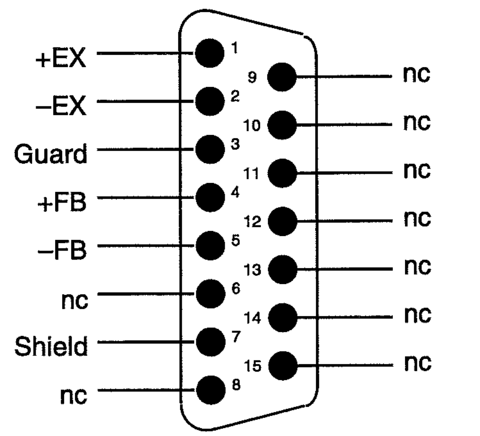
The Three-stage Valve Driver panel contains two 15 pin, female, D type connectors.



Valve



LVDT



Valve connector

The Valve 15-pin, female, D-type connector provides connections to the associated system servovalve.

LVDT connector

The LVDT 15-pin, female, D type connector provides connections to the associated system transducer, usually an LVDT (linear variable differential transformer).

Board Configurations

NOTE The following information is intended for qualified service personnel only. The Three-stage Valve Driver contains on-board jumpers and select resistors that are used to configure the module specifically for your application. These jumpers are typically installed by MTS prior to system installation for proper operation in your application. Do not change the position of any of these jumpers unless system requirements have changed.

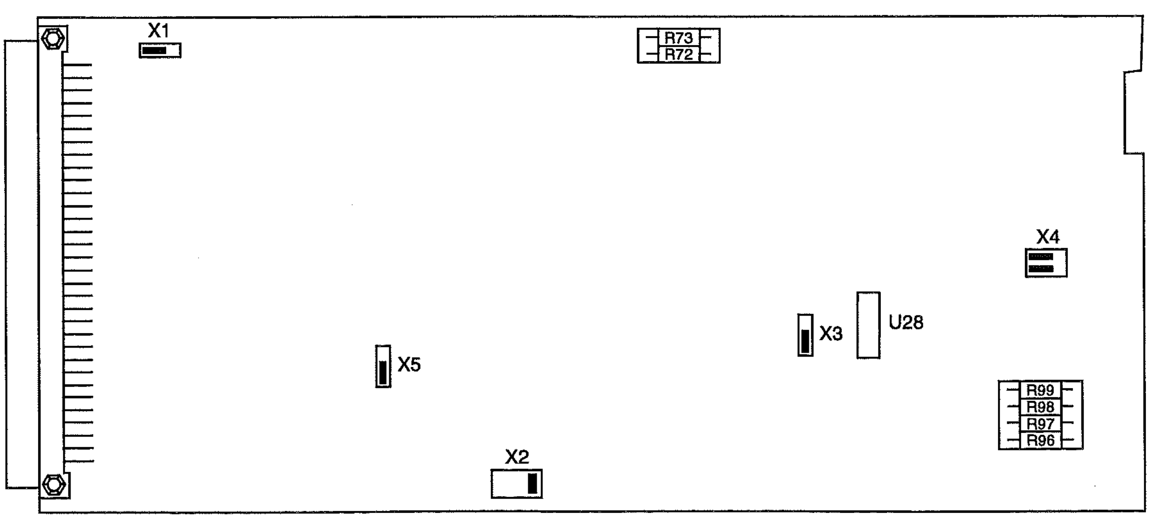
The following information is only necessary if you intend to change the operating configuration of the module from its original setup or if the module was not set up by MTS prior to shipment.

The jumpers and resistors are used to:

- disable or enable an optional circuit card
- select the preamp reference
- select the excitation frequency
- enable or disable valve clamping
- set the dither frequency
- set the full-scale current output

Jumper and Resistor Locations

The following figure shows the location of jumper and resistors on the Valve Driver circuit board.



407.15 Three-stage Valve Driver Jumper Summary

Jumper	Setting	Function
X1		Optional card selection
	1–2	Disable optional circuit card (default)
	2–3	Enable optional circuit card
X2		Excitation frequency selection
	1–8	10 kHz (standard)
	2–7	5 kHz
	3–6	2.5 kHz
	4–5	1.25 kHz
X3		Preamp zero reference. Connects coarse zero or ground (guard) into summation amplifier.
	2–3	Coarse zero (default)
	1–2	Analog ground (guard)
X4		Excitation selection. Selects voltage excitation source.
	5–6 and 1–2	Adjustable excitation
	4–5 and 2–3	Fixed ±15 Vdc excitation
X5		Valve clamping enable/disable
	1–2	Disable valve clamping (default)
	2–3	Enable valve clamping
U28		Demodulator filter (5 kHz default, MTS part number 477744-06). Should be changed if X2 is changed from 10kHz. The available filters are described in the Service chapter.

Excitation Frequency Selection (X2)

Excitation originates from an on-board digital 10 kHz carrier oscillator. The output frequency of the on-board oscillator can be divided down (by jumper X2) to smaller frequencies.

Jumper X2 is used to select the excitation frequency as follows:

10 kHz (default)	X2:	pins 1–8
5 kHz	X2:	pins 2–7
2.5 kHz	X2:	pins 3–6
1.25 kHz	X2:	pins 4–5

The excitation amplitude is determined by the software. The amplitude range is 0 to 40 Vp-p.

Valve Clamping (X5)

Jumper X5 enables or disables valve clamping as follows:

Clamp disable (default)	X5:	pins 1-2
Clamp enable	X2:	pins 2-3

Dither Oscillator Frequency (R73)

The Valve Driver channel provides an amplitude-adjustable dither signal to prevent servovalve silting and to overcome static friction that may reduce system resolution. The frequency of the on-board dither oscillator can be changed by replacing a single resistor on the module circuit board.

The dither oscillator frequency is established by the value of resistor R73. The standard dither oscillator frequency is 500 Hz. If another frequency is required, calculate the value of R73 according to the following formula:

$$F_{osc} = \frac{1}{2 \times R73 \times C15} \text{ Hz}$$

The default values are:

$$R73 = 100 \text{ k}\Omega$$
$$C15 = 0.01 \ \mu\text{F}$$

$$F_{osc} = \frac{1}{2 \times 100 \times 10^{3} \times 0.01 \times 10^{-6}} \text{ Hz}$$

$$F_{osc} = 500 \text{ Hz}$$

Full Scale Output Current (R72)

Full Scale Current Scaling

The full scale output current of each Three-stage Valve Driver channel can be modified by changing the value of resistor R72 on the 407.15 circuit board. The maximum output current is 100 mA.

The default full scale output current is 50 mA which is suitable for most applications. The following table lists the resistor values for other common full scale output currents.

Full Scale Current	Resistor	MTS Part Number
100 mA	10Ω, 1/4W, 1%	100005-14
50 mA	20Ω, 1/8W, 1%	100358-49
40 mA	24.9Ω, 1/8W, 1%	upon request
25 mA	40.2Ω, 1/8W, 1%	100358-75
15 mA	66.5Ω, 1/10W, 1%	upon request

If the full scale output current must be changed to a value that is not listed, use the following calculations to determine the required resistor value.

$$I_{out} = \frac{1V}{R_{scale}}$$

where:

I_{out} = the full scale output current (maximum 100 mA)
R_{scale} = R72

For example, a 20Ω resistor is used for the default full scale current of 50mA.

$$50\,mA = \frac{1V}{20\Omega}$$

Monitor Output Scaling

When current is selected to the Monitor BNC, the voltage output is proportional to the output current. The scale of this voltage is 10V output equals full scale current (standard 50 mA full scale, therefore 10V/50 mA).

Demodulator Filter Characteristics (U28)

The demodulator is a synchronous demodulator with a software-controlled ±90° phase adjustment and a five-pole Bessel filter. The filter characteristics are determined by an SIP filter module installed on the board. The default module is suitable for demodulation of a 10 kHz carrier frequency. To lower the high frequency noise, the filter cutoff frequency can be lowered (at the expense of decreased control bandwidth).

For optimum operation, the SIP filter module should be changed to match the carrier frequency whenever that frequency has been changed from the default (10 kHz).

The available filter modules, with their MTS part numbers and characteristics, are listed in the Service chapter of this manual. The SIP filter module is installed in location U28 on the Three-stage Valve Driver circuit board.

The following table lists the recommended demodulator filter cutoff frequency for various excitation frequencies.

Recommended Demodulator Filter Frequencies

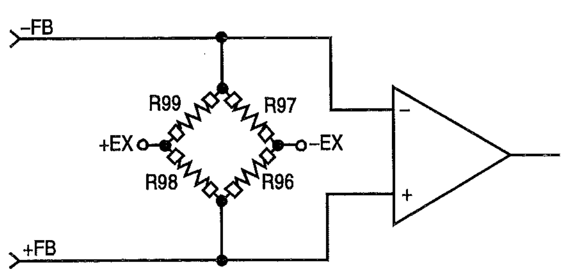
Excitation Freq	Cutoff Freq
10 kHz	5000 Hz
5 kHz	2000 Hz
2.5 kHz	1000 Hz
1.25 kHz	500 Hz

Valve Driver

The differential current valve driver provides an output current proportional to the inner loop PD sum. It also includes an amplitude programmable dither signal and valve balance offset. The dither frequency is resistor selectable. The standard dither frequency is 500 Hz.

Completion Resistors

The standard Three-stage Valve Driver has no completion resistors installed. Some applications may require this option. For example, some Hottinger LVDTs require completion resistors. This is accomplished by installing resistors R96 to R99.



Initial Setup of the Three-stage Valve Driver

⚠ WARNING

The following procedure produces immediate and unexpected actuator movement.

Unexpected actuator movement can result in personal injury and equipment damage.

Clear all personnel from the area before tuning the Three-stage Valve Driver inner loop. Uncouple any equipment that can be damaged by extreme movements.

Background

To get the best performance from the Three-stage Valve Driver, you must tune not only the control loop, but the valve inner control loop. Tuning the valve inner loop is like tuning any servo control loop. The only difference is that, in normal use during a test, the three-stage control loop is enclosed within an outer control loop.

Preparation

Before you begin to tune the inner loop, you must temporarily disable the outer loop control effects. Take the following steps:

1. **Save the outer loop control parameters and conditioner gain.** One way to do this is to open the menu for the control conditioner and select Setup to change the setup. The screen prompts you to save changes:

```
→Save cal and control
 loop settings?
 F1 = Save
 F2 = Discard
```

   Select Save (by pressing Alt Func, then F1) to save the existing setup of parameter values.

2. **Set the following parameters in the Three-stage Valve Driver menu:**

Gain	3.0 V/V
C Zero	0.0 V
F Zero	0.0 V
Excit	20.0 Vpp (for typical spool LVDT)
Phase	30 Deg
Fdbk Pol	NORMAL
P gain	1.0 V/V
D gain	0.0 ms
Balance	0%
Vlv Pol	NORMAL
Monitor	IL FDBK

Initial Setup of the Three-stage Valve Driver (continued)

Preparation (continued)

3. **In the Monitor menu, for Mon1 or Mon2, select VLV MON. Connect an oscilloscope to Mon 1 or Mon 2.**

4. **Set the gain for the control conditioner to zero.** Determine the conditioner selected for controller feedback (FdBack in the Controller menu). Open the menu for that conditioner and set the Gain to 0.0 V/V.

5. **In the Controller menu, set the outer loop gains.** Set the proportional gain to 2.0 and all other gains (integral, derivative, feedforward, delta P) to zero.

6. **In the Function Generator menu, set the following:**

Wvform	SQUARE
Freq	5Hz
Setpnt	0%
Span	5%

7. **In the Configuration menu, turn engineering units (Eng Units) OFF.**

8. **Zero the error.** Use the Set Point and DVM keys (as described in the Operation chapter under "Monitoring Adjustments") to minimize the dc error.

9. **Clear any active interlocks.** That is, if the interlock indicator is lit, check the Intlk status menu to determine which interlocks are active.

10. **Make sure that pilot pressure is applied to the three-stage valve but that hydraulic pressure is off to the main stage of the servovalve (use a hand shutoff valve or disconnect hoses to make sure main pressure is off).** Pilot pressure is normally present when the Hydraulic Power Supply is on.

11. **Press the Program Run key.**

Tuning and Feedback Setup

After the above preparation, take the following steps (using the 3-Stage Valv Drv menu unless otherwise specified):

1. **If the spool follows the inner loop command, change the valve polarity (Vlv Pol) so the spool moves to its absolute maximum displacement.** The valve control loop is deliberately reversed during the following steps, for setup purposes.

   While "in control," the spool will roughly follow the inner loop command which should be a square wave. When "out of control" the spool will move to its absolute maximum displacement in one direction.

2. **Adjust the Phase for a maximum in the inner loop feedback.**

Initial Setup of the Three-stage Valve Driver (continued)

Tuning and Feedback Setup (continued)

3. **Adjust the Gain until the *magnitude* of the inner loop feedback is about 10.0V.** (That is, if the feedback signal is positive, adjust until it is +10.0 V. If it is negative, adjust until it is –10.0 V).

4. **In the Function Generator menu, change the frequency to 0.1 Hz and the span to 100%.**

5. **In the 3-Stage Valv Drv menu, adjust the fine zero (F Zero) so that the spool feedback is symmetric.** If everything is working properly, the spool feedback should alternate between a positive and a negative value. Adjust the fine zero (F Zero) so that these two values are symmetric about zero. If necessary, re-adjust the Gain so that the values alternate between +10V and –10 V.

6. **In the Function Generator menu, change the span to 5% and the frequency to 2 Hz.**

7. **In the Controller menu, change the proportional gain to 1.**

8. **In the 3-Stage Valv Drv menu, switch the valve polarity so that the spool once again follows the inner loop command.**

9. **Adjust the proportional gain (P Gain) until the scope shows a slight overshoot (up to about 15%).**

10. **Increase the derivative gain (D Gain) to eliminate the overshoot.**

Restoring the Outer Loop

Restore the outer loop parameters by taking the following steps:

1. **Press the Hydraulic Off key.**

2. **Restore the outer loop control parameters and conditioner gain.** One way to do this is to open the menu for the control conditioner and select Setup to change the setup. The screen prompts you to save changes:

```
→Save cal and control
 loop settings?
 F1 = Save
 F2 = Discard
```

   Select Discard (by pressing Alt Func, then F2) to discard the existing setup of parameter values.

3. **If the outer loop remains unstable, try changing both polarities in the 3-Stage Valv Drv menu (Vlv Pol and Fdbk Pol).** But notice that if you change one, you MUST change both to maintain control of the inner loop.

Configuration Procedure (for a Two-stage Valve)

The Three-stage Valve Driver can also be connected to a conventional two-stage valve. In that case, tune the servo loop by taking the following steps (using the 3-Stage Valv Drv menu unless otherwise specified):

1. **Set the following parameters in this menu:**

P gain	1.0 V/V
D gain	0.0 ms
Gain	0.0 V/V
F Zero	0.0 V
Dither	(normal setting)
Balance	(normal setting)
	(settings for the remaining parameters don't matter)

2. **Tune the servo loop normally, as described in the Operation chapter of this manual.**

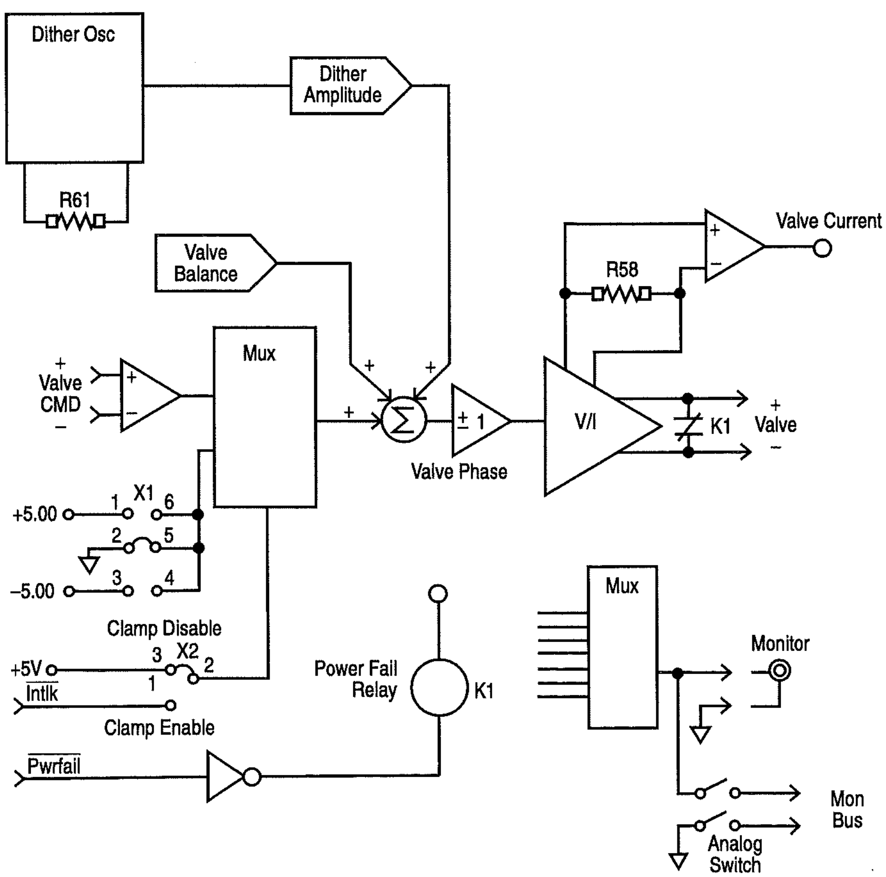
3. **If the outer loop remains unstable, try changing both polarities in the 3-Stage Valv Drv menu (Vlv Pol and Fdbk Pol).** But notice that if you change one, you MUST change both to maintain control of the inner loop.

Chapter 8
Model 407.16 Valve Driver

Description

The 407.16 Valve Driver is a single channel adjustable valve driver module specifically designed for user interactive applications using MTS Series 407 electronics. The following is a simplified block diagram of the 407.16 Valve Driver.

The Valve Driver includes a valve clamping circuit, used to clamp the valve current at a predetermined level in the event of a power supply failure.



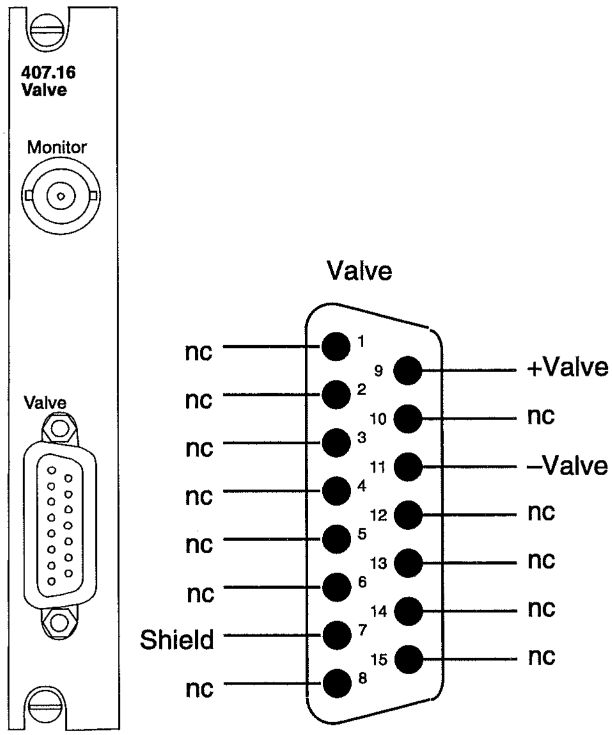
Monitor Output

The valve driver output circuitry provides selectable monitor output signal selection. Signals can be monitored at the rear panel BNC connector. Any of the following signals can be selected for the monitor output:

- GND—valve ground
- CUR—current
- VLV CMD—valve command signal
- VLV BAL—valve balance
- DITHER—dither amplitude
- +10.00 V—on-board reference

Valve Driver Panel

The Valve Driver panel contains a BNC connector for signal monitoring and a 15-pin, female, D-type connector.



Monitor BNC connector

The BNC Monitor connector provides connections to a readout device. The signal available on the Monitor connector is selected through the user interface display.

Valve connector

The Valve 15-pin, female, D-type connector provides connections to the associated system transducer.

Board Configuration

NOTE	The following information is intended for qualified service personnel only. The Valve Driver contains on-board jumpers and select resistors that are used to configure the module specifically for your application. These jumpers are typically installed by MTS prior to system installation for proper operation in your application. Do not change the position of any of these jumpers unless system requirements have changed.

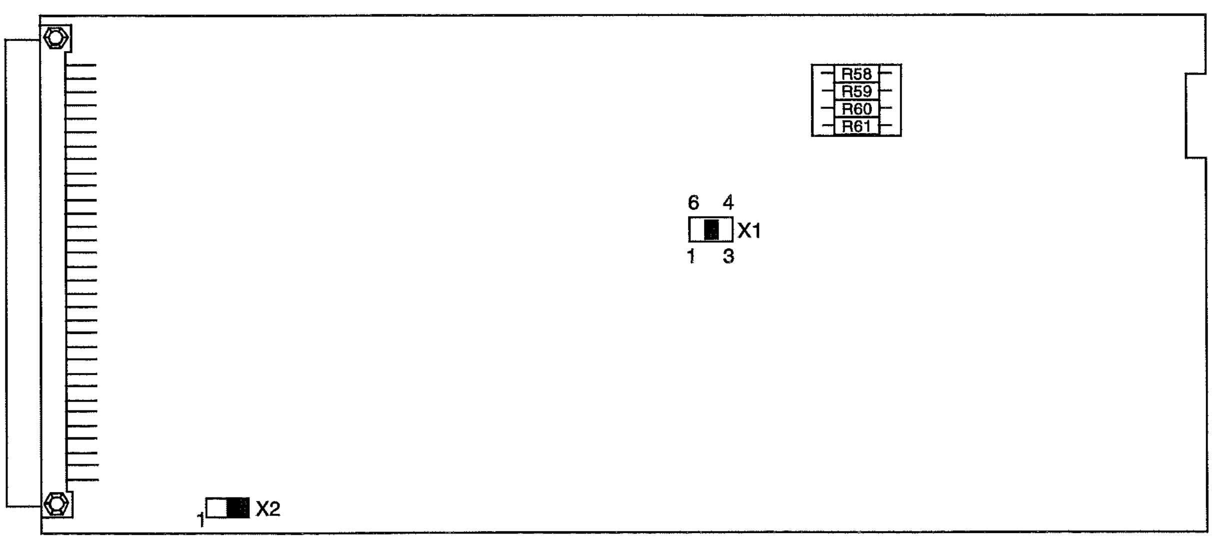
The following information is only necessary if you intend to change the operating configuration of the module from its original setup or if the module was not set up by MTS prior to shipment.

The jumpers and resistors are used to:

- select the valve clamping level for each channel (+50%, 0%, or –50% of full scale)
- enable or disable valve clamping
- determine the full scale output current

Component Locations

The following figure shows the locations of components on the Valve Driver circuit board.



407.16 Valve Driver Jumper Summary

Jumper	Setting	Function
X1		Valve clamping command selection
	1–6	Clamps at +50% of full scale
	2–5	Clamps at 0 command (default)
	3–4	Clamps at –50% of full scale
X2		Valve clamping enable/disable
	2–3	Clamping disabled
	1–2	Clamping disabled

Valve Clamping (X1 and X2)

Jumper block X1 and jumper block X2 are valve clamping jumpers. X1 is used to select the valve clamping command for the servovalve. Selections are +50% clamp, 0% clamp, and -50% clamp. X2 enables/disables valve clamping.

Valve clamping jumpers are used as follows:

+50% Clamp	X1:	pins 1-6
0% Clamp	X1:	pins 2-5 (default)
–50% Clamp	X1:	pins 3-4
Clamp disable	X2:	pins 2-3
Clamp enable	X2:	pins 2-1

Full Scale Output Current (R58)

Full Scale Current Scaling

The full scale output current of each Valve Driver channel can be modified by changing the value of resistor R58 on the 407.16 circuit board. The maximum output current is 100 mA.

The default full scale output current is 50 mA which is suitable for most applications. The following table lists the resistor values for other common full scale output currents.

Full Scale Current	Resistor	MTS Part Number
100 mA	10Ω, 1/4W, 1%	100005-14
50 mA	20Ω, 1/8W, 1%	100358-49
40 mA	24.9Ω, 1/8W, 1%	upon request
25 mA	40.2Ω, 1/8W, 1%	100358-75
15 mA	66.5Ω, 1/10W, 1%	upon request

If the full scale output current must be changed to a value that is not listed, use the following calculations to determine the required resistor value.

$$I_{out} = \frac{1V}{R_{scale}}$$

where:

I_{out} = the full scale output current (maximum 100 mA)
R_{scale} = R58

For example, a 20Ω resistor is used for the default full scale current of 50mA.

$$50\text{ mA} = \frac{1V}{20\Omega}$$

Monitor Output Scaling

When current is selected to the Monitor BNC, the voltage output is proportional to the output current. The scale of this voltage is 10V output equals full scale current (standard 50 mA full scale, therefore 10V/50 mA).

Dither Oscillator Frequency (R61)

The Valve Driver channel provides an amplitude-adjustable dither signal to prevent servovalve silting and to overcome static friction that may reduce system resolution. The frequency of the on-board dither oscillator can be changed by replacing a single resistor on the module circuit board.

The dither oscillator frequency is established by the value of resistor R61. The standard dither oscillator frequency is 500 Hz. If another frequency is required, calculate the value of R61 according to the following formula:

$$F_{osc} = \frac{1}{2 \times R61 \times C16} \quad \text{Hz}$$

The standard values are:

$$R61 = 100\ k\Omega$$
$$C16 = 0.01\ \mu F$$

$$F_{osc} = \frac{1}{2 \times 100 \times 10^{3} \times 0.01 \times 10^{-6}} \quad \text{Hz}$$

$$F_{osc} = 500\ \text{Hz}$$

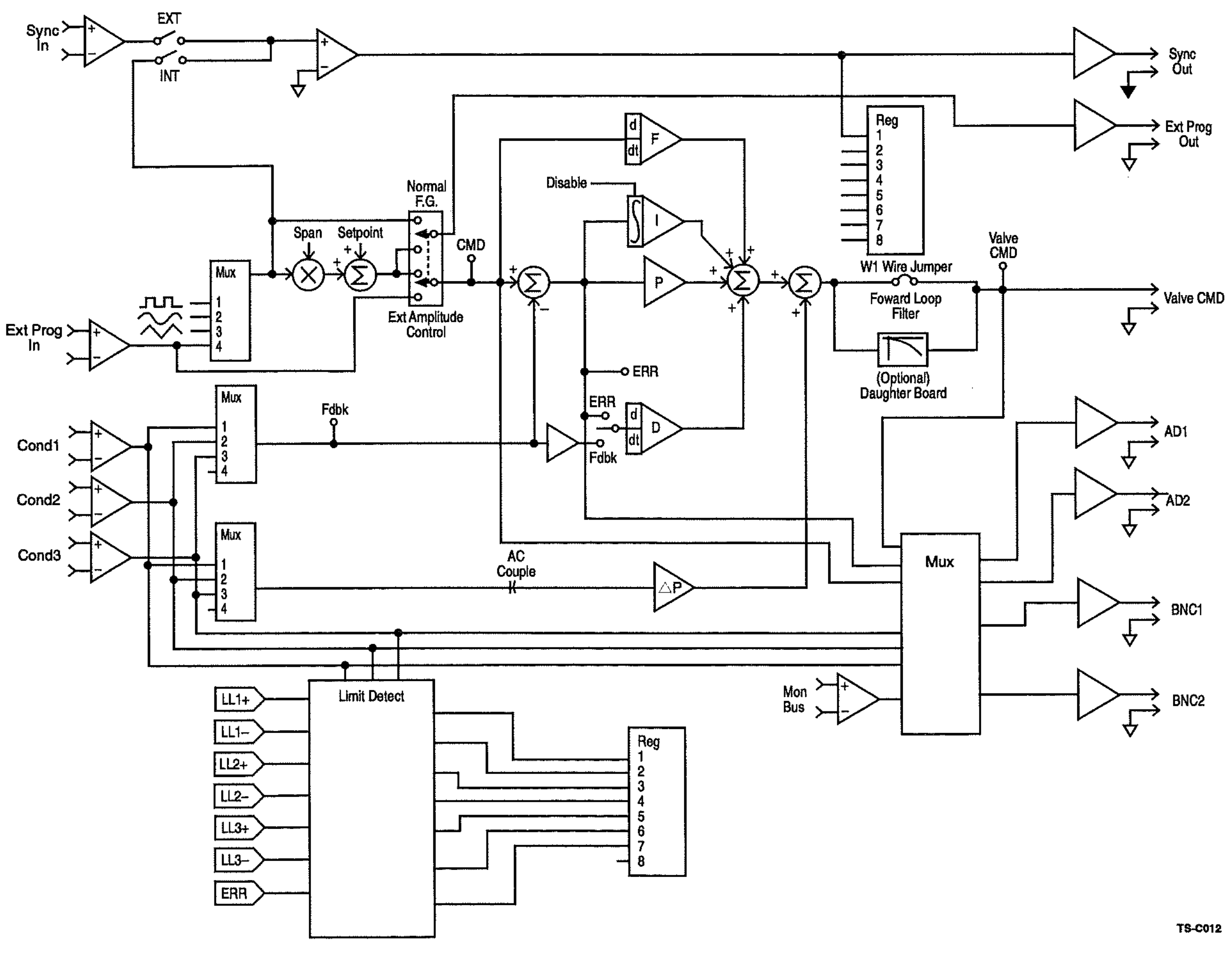
Model 407.18 Analog PIDF Controller

Description

The 407.18 Analog PIDF Controller is a module specifically designed for use in the 407 controller, where it provides the following functions:

- closed loop PIDF (proportional, integral, derivative, and feedforward) control
- simple function generation
- feedback selection
- limit checking

The Controller is a digitally-supervised analog device, that is, an analog controller whose PIDF gain elements are controlled digitally. The following is a simplified block diagram of the Controller board circuitry.

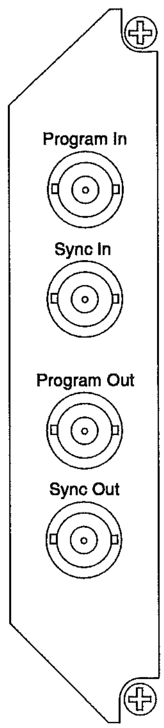


Analog PIDF Controller Panel

The Analog PIDF Controller panel contains four BNC connectors (Program In, Sync In, Program Out, Sync Out). These provide connections to an external program source.

The Program In and Sync In connectors receive program input and cycle count synchronization signals from an external program source or another 407 Controller in a multiple Controller configuration.

The Program Out and Sync Out connectors are used to pass the program and cycle count synchronization signal on to the next 407 Controller in a multiple Controller configuration. External program connections are shown in the following figure.



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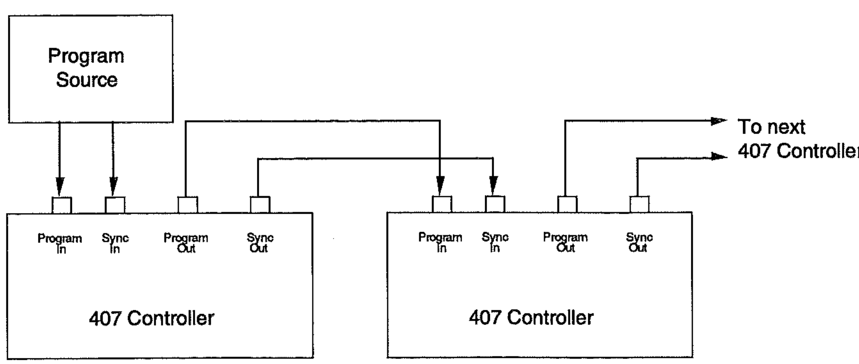


Board Configurations

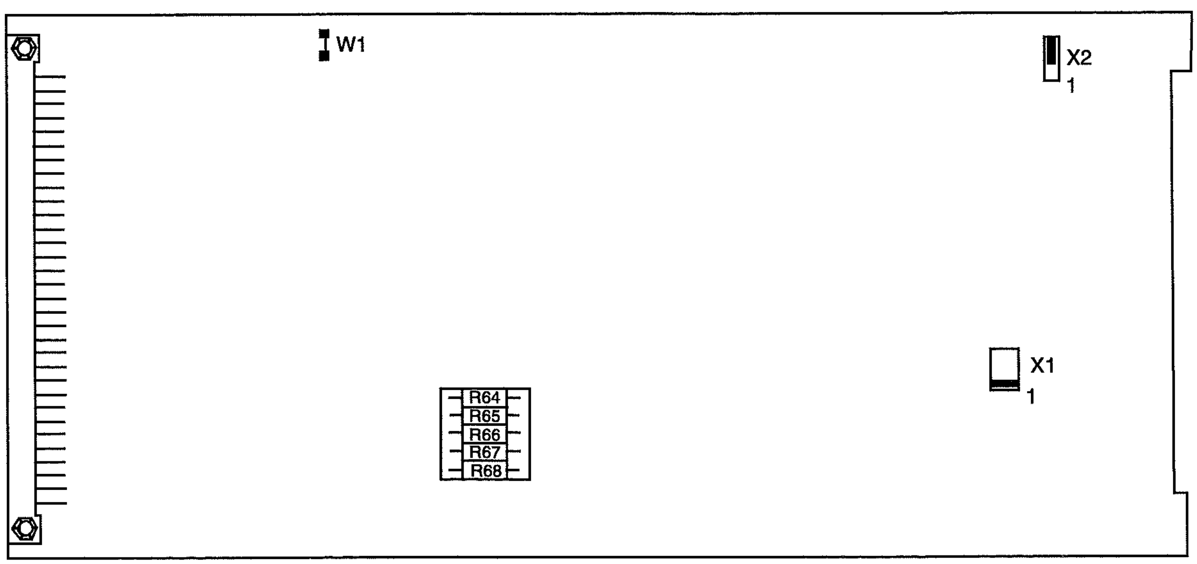
NOTE The following information is intended for qualified service personnel only.

The Controller board contains on-board jumpers and resistor networks that are used to configure the module specifically for your application. These jumpers and resistors are typically installed by MTS prior to system installation for proper operation in your application. *Do not change any of these components unless system requirements have changed.*

The following information is necessary only if you intend to change the operating configuration of the module from its original setup or if the module was not set up by MTS prior to shipment.

Jumper and Resistor Locations

The following figure shows the jumper and resistor locations on the Controller circuit board.



407.18 Analog PIDF Controller Jumper Summary

Jumpers X1 and X2 on the Controller board are not selectable. The following table is for reference only.

Jumper	Setting	Function
X1 & X2		Used for calibration of the sine wave source. These jumpers must always be configured as follows:
X1	1–6	Selects inputs for calibrating the on-board sine wave generator, the +10 V, or analog ground.
X2	2–3	Used for zeroing the on-board sine gain.
W1		Jumper W1 is a cut jumper. When installed, the jumper bypasses the optional daughter board.

Resistor Summary

The Controller board uses "select" resistors to set the full scale values for control loop gains. These resistors are installed on mounting posts in the locations indicated. They set full scale values for PIDF and Delta P gains. The following table shows the function of each resistor and the equation used to determine resistor size.

Resistor	Function	Equation
R61	Integral Gain proportional summing resistor, determines full scale value for I Gain	$I = \dfrac{R73/R61}{R56 \times C12}$ rps where: R56 = 100 kΩ (fixed) R73 = 200 kΩ (fixed) C12 = 0.01µF (fixed) R61 = 200 kΩ I = 1000 rps full scale
R62	Derivative Gain proportional summing resistor, determines full scale value for D Gain	$D = \left(\dfrac{R73}{R62}\right) \times R59 \times C8$ s where: R59 = 200 kΩ (fixed) R73 = 200 kΩ (fixed) C8 = 0.01µF (fixed) R62 = 10 kΩ D = 40 ms
R63	Proportional Gain proportional summing resistor, determines full scale value for P Gain	$P = \dfrac{R73}{R63}$ V/V where: R73 = 200 kΩ (fixed) R63 = 2 kΩ P = 100 V/V
R64	Feedforward Gain proportional summing resistor, determines full scale value for F Gain	$F = \left(\dfrac{R73}{R64}\right) \times R40 \times C4$ s where: R40 = 200 kΩ (fixed) R73 = 200 kΩ (fixed) C4 = 0.01µF (fixed) R64 = 10 kΩ F = 40 ms
R65	Differential Pressure (Delta P) Gain proportional summing resistor, determines full scale value for Delta P Gain	$\Delta P = \dfrac{R73}{R65}$ V/V where: R73 = 200 kΩ (fixed) R65 = 2 kΩ ΔP = 10 V/V

Chapter 10
Service

Routine Maintenance

Routine maintenance consists of visually inspecting the chassis and circuit cards. Inspection should include the following:

- Check all wires and cables for cracked or scraped insulation
- Check all wires, cables and electrical components for signs of overheating
- Check the chassis for dirt, oxidation, or damage
- Check to see that vent holes in chassis are not plugged
- Remove dust and dirt from assembly (See *Cleaning*, below)

Cleaning

When cleaning the 407 Controller, use a soft bristled brush or vacuum to remove surface dust and dirt.

⚠ CAUTION

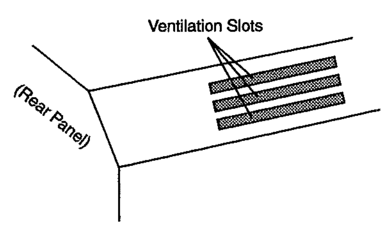
Do not clean the 407 Controller front panel with cleaners or solvents other than those recommended.

The use of cleaners or solvents other than those recommended can cause electrical damage, damage to surface areas, or dissolve plastic components used in keypad and indicator surfaces.

Clean assemblies using only recommended methods and materials.

Use a soft cloth, cotton swab or tissue, moistened with isopropyl alcohol to clean the 407 Controller. Other solvents or cleaners are not recommended.

Serial Number



The serial number of the 407 Controller can be viewed through the ventilation slots at the rear of the chassis on the power supply side (two numbers appear: the *lower* number is the serial number).

Power-up Self-test

At power-up, the 407 Controller performs a self-test of the following functions:

ROM	Performs a CRC (cyclic redundancy check) on the ROM and compares the value to a similar value computed earlier when the ROM program was compiled. A failure means either a connectivity problem on the chip or an improperly programmed ROM.
Power Check	Checks the status of the power supply power fail signal. This signal is set if any of the dc voltages are not within certain tolerances. When this tests fails one or more of the Power Supply OK LEDs[1] will remain unlit.
Scanning slots	Scans all of the plug-in module slots (controller, conditioner and valve driver). The initialization halts if the controller module is not found. For the other slots the type of card installed is indicated.
Keypad	Checks the pad for stuck keys. If any failures are found they are indicated and the initialization halts. While this test is running none of the front panel keys should be pressed or false failures will be detected. Notice that this test can only detect keys that are stuck closed (down) but not keys that are stuck open (up).
LEDs	Simultaneously turns on all front panel LED (light emitting diodes) and then turns them all off. You can watch the LEDs while this test is running to make sure all of them are functioning.
A/D	Checks the gain and offset of the A/D (analog to digital converter). • The calibration gain computed at power-up is compared to a nominal gain of 1.343e-3. • The calibration offset computed at power-up is compared to a nominal offset of 0.0. When a parameter fails, it is displayed with the message "Use defaults? 1=Yes 2=No." You can then press the 1 key to use the nominal values (gain = 1.343e-3, offset = 0.0) or press 2 to use the computed values. In either case, if this test fails, the internal DVM readings are not reliable.
BRAM	Checks the version number stored in battery-backed memory (BRAM). This check fails if an unknown version number is read. An unknown version number means either battery failure (losing all settings), or a version number is not recognized by this firmware. Usually the firmware is forward-compatible but not necessarily backward-compatible (an old ROM in a new unit may produce this failure). If this test fails after reinitialization, the battery RAM has probably failed.

1 Four supply OK LEDs are visible through the left side panel vent holes. In order from front to rear they are for the -15V, +15V, +5V and +24V supplies. If any of these LEDs is not lit, the associated supply is less than the minimum threshold. The +5V supply is also inhibited when the +15V supply is not OK.

Troubleshooting

Indication	Probable Cause	Remedy
No display	Power supply failure	See power supply failure
	Front panel display cable is not attached	Call MTS service or remove cover and check cable to display
	Hardware failure	Call MTS service
Power supply failure[1]	+24V power supply shorted	Check for shorts on the +24V supply at the DIO connector
	±15V power supply shorted	Check for shorts on the ±15V supplies at the conditioner transducer connectors
	Internal fuse has blown	Remove cover and check fuse
	Misadjusted power supply or hardware failure	Call MTS service
Display continues to recycle through self tests	Firmware or hardware failure	Call MTS service
BRAM (battery backed RAM) self test fails	A new version of firmware has been installed whose memory map is incompatible	Reinitialize the BRAM and reenter all settings
	The battery on the BRAM chip has failed	Call MTS service
Hydraulic power supply (HPS) does not turn on	No cable or jumper plug installed in Hyd Out connector	Add jumper plug to the last 407 in the hydraulic chain
	Hyd Config is set for HSM or NONE	Set Hyd Config to HPS or HPSHSM
Controller does not reset	No cable or jumper plug installed in Remote Emergency Stop connector	Add jumper plug (MTS p/n 491695-01)
External Interlock not cleared by reset	No cable in Intlk In but unit is set up as an interlock slave	Change configuration to interlock master
	No cable or jumper installed in Intlk Out connector	Add jumper plug (MTS p/n 496359-01)

1 Four supply OK LEDs are visible through the left side panel vent holes. In order from front to rear they are for the -15V, +15V, +5V and +24V supplies. If any of these LEDs is not lit, the associated supply is less than the minimum threshold. The +5V supply is also inhibited when the +15V supply is not OK.

Troubleshooting (continued)

Indication	Probable Cause	Remedy
Setpoint and Span have no effect.	Amplitude controller configuration is set for EXTERN, but no external amplitude controller is connected	Check amplitude controller configuration
Cannot change peak/valley parameter displayed on DVM line 2	A signal name has been selected for UPk Sig in Limit Settings menu	Set UPk Sig to NONE.
Excitation output changes when cable is plugged in	458/406 style cable is in use	Remove jumper X4 on DC conditioner module
Excitation remains at ±15 V. Does not change when adjusted in software	High level excitation is selected	Select adjustable excitation

MTS Part Number Reference

Item	Description	Assembly Number
407 Controller:		
407.01	407 stock chassis with 2-stage valve driver	487225-02
	407 stock chassis with 3-stage valve driver	487225-03
407 Kit	407 Handle Kit	487223-01
407.PS	Power Supply	493330-01
407.02	Processor	493343-01
407.05	Pump Interface Box (dc)	502235-02
	Pump Interface Box (ac)	502235-03
407.12	DC Conditioner	493341-01
407.14	AC Conditioner	493340-01
407.15	Three-stage Valve Driver	493345-01
407.16	Valve Driver	493342-01
407.18	Analog PIDF Controller	493344-01
407.BP	Backplane	487637-01
Extender board	Extender bd, 3U, 96 pin DIN	119506-48
Extender board	Extender bd, 3U, 128 pin DIN	119506-76

MTS Part Number Reference (continued)

Item	Description	Assembly Number
Configuration Drawings:		
407.01	407 Controller	497200-01
407.12	DC Conditioner	496356-01
407.14	AC Conditioner	496355-01
407.15	Three-stage Valve Driver	500210-01
407.16	Valve Driver	496357-01
407.18	Analog PIDF Controller	496358-01
Mounting Shelf—Rack Mount:		
	Shelf for one 407 Controller	494114-01
	Shelf for two 407 Controllers	494114-02
Remote E-Stop Box:		
	English Label	464872-01
	German Label	464872-02
	French Label	464872-03
Cables, Connectors, Jumpers:		
Servovalve (SV)	252 SV Cable	464401-xx [2]
	252 SV Cable, Dual, Out of Phase	464404-xx
	252 SV Cable, Dual, In Phase	464405-xx
	256 SV Cable (same as 252)	464401-xx
	256 Valve LVDT	464408-xx
Conditioner	Load Cell, PT connector	464402-xx
	Load Cell, MS connector	464406-xx
	LVDT	464403-xx
	Extensometer	501200-xx
	Delta P cell single	479276-xx
	Delta P cell dual	480496-xx
Remote E-Stop	Cable	494746-xx
	Jumper Connector	491695-01
User DIO	Mating Connector	113282-47
Shunt Cal	Shunt Cal Header (w/o resistor)	118719-14
230 Vac power cord kits[1]	U.S.	497020-01
	Schuko	497020-02
Power Line Filter	4-circuit Shuko	119600-15

1 The 407 Controller needs no configuration changes (except power plug) to accept 230 Vac input power.
2 xx denotes a tabbed drawing including multiple cable lengths. Consult MTS for ordering information.

MTS Part Number Reference (continued)

Item	Description	Assembly Number
Cables, Connectors, Jumpers (continued):		
Box to Box Interconnect	Program Interconnect Cable or Sync Interconnect Cable	494749-xx
Hydraulic Interconnect	Hydraulic Interconnect Cable	495400-xx
Interlock	Interlock Interconnect Cable	495400-xx
	Interlock Hydraulic Jumper	496359-01
HSM		
298 HSM	on/off valve	497403-xx
298 HSM	proportional valve	494743-xx
292 HSM	proportional valve	494742-xx
290/293 HSM	24 Vdc hi/low	494744-xx
	115 Vac hi/low	494745-xx
	115 Vac off/on	397182-xx
HSM Adapter (1 ft)	7-pin CPC to 4-pin CPC	495385-01
HPS	Defeat Jumper (D-15)	495384-01
	Defeat Jumper (CPC)	397199-01
	HPS w/PLC, 24 Vdc without solenoids (no interface req.)	494747-xx
	24 Vdc (req. 407.05 Interface)	397087-xx
	115 Vac (req. 407.05 Interface)	397088-xx
(MS style HPS 24 V)	24 Vdc (req. 407.05 Interface)	054075-xx
	24 Vdc Cable Interface Adapter	494741-01
(MS style HPS 115 V)	115 Vac (req. 407.05 Interface)	054001-xx
	115 Vac Cable Interface Adapter	493910-01
407 to 406 Cable Adapters (1 ft each)	HSM to 115Vac, MS style	500947-01
	HSM to 24Vdc, MS style	500948-01
	Servovalve, MS style	500949-01
	Transducer, MS style	501600-01
	Delta P, MS style	501601-01
SIP Filter Modules:	Used on 407.12, 407.14, and 407.15	
	50 Hz Bessel	477744-01
	100 Hz Bessel	477744-02
	200 Hz Bessel	477744-03
	500 Hz Bessel	477744-04
	1000 Hz Bessel	477744-05
	2000 Hz Bessel	477744-06
	5000 Hz Bessel	477744-07

Proportional HSM Driver Adjustment

NOTE The following information is intended for qualified service personnel only. The procedure requires the removal of the controller cover and describes adjustments made to the internal controller circuitry.

The proportional HSM driver circuit of the 407 Controller is adjusted at the factory for operation with an MTS Series 298 HSM. Other models of proportional type HSMs may require that the proportional driver circuit be adjusted to attain the proper high and low pressure outputs. The following procedure assumes that the controller is installed in the system and that system hydraulics are operational.

⚠ WARNING

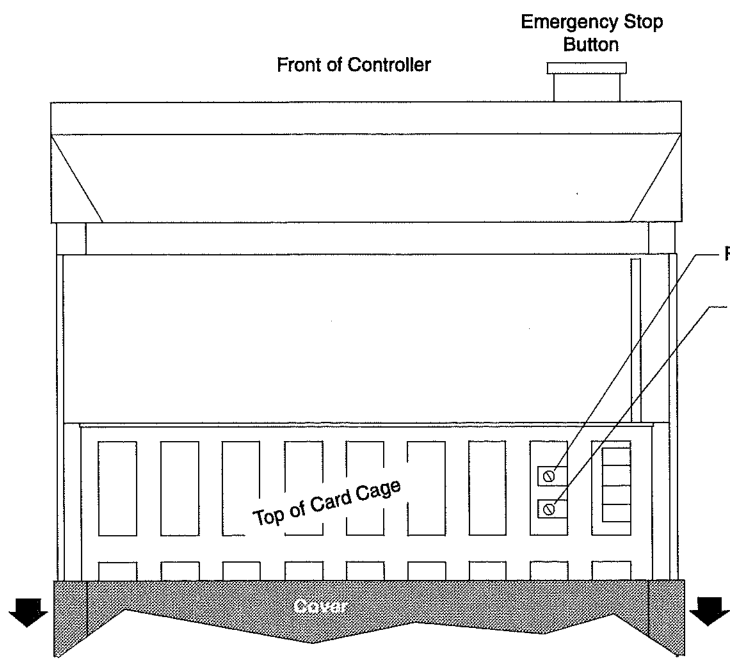
High voltage is present inside the 407 Controller chassis.

Touching any of the components inside the chassis while electrical power is applied can cause death or severe injury.

Turn off the 407 Controller before removing the top cover of the chassis.

1. If the 407 Controller includes a handle, remove the handle.

2. Remove the two Phillips screws from each side of the Controller. Slide the cover toward the rear of the unit to expose the adjustment potentiometers R1 and R2 shown in the following figure (top view).



WARNING

Uncontrolled actuator movement can result from applying hydraulic pressure to the system when the servovalve command (dc error) has not been zeroed.

If the servovalve command (dc error) does not equal zero when hydraulic pressure is applied to the system, equipment damage and/or personal injury can result.

Make sure that the servovalve command is zero before applying hydraulic pressure to the system.

3. Apply high hydraulic pressure to the system.
4. Adjust R1 to attain the desired high pressure output from the HSM.
5. Apply low hydraulic pressure to the system.
6. Adjust R2 to attain the desired low pressure output from the HSM.

Replacing a ROM on the 407.02 Processor

For firmware upgrades, you must replace the U53 ROM on the Model 407.02 Processor board.

The tools you need are a Phillips screwdriver and a PLCC extractor tool such as:

- MTS (part number 119607-14)
- Methode Electronics (part number CT2101)
- Techni-Tool (part number 560PR291)
- Newark Electronics (part number 51F1162)

If no extractor tool is available, an experienced installer can use a fine-tipped tweezers, a dental pick, or equivalent.

⚠ CAUTION

Make sure you have the experience and proper tools to perform this procedure, then proceed with caution.

Inexperienced personnel or inadequate tools can cause damage to the 407 Controller. MTS is NOT responsible for any damage to the 407 Controller during the upgrade procedure.

If you do not have the experience or tools to perform this task, send the 407 Controller to MTS for the upgrade or call your MTS field service representative.

⚠ CAUTION

Do not work with the power on.

Connecting or disconnecting components while power is applied can cause severe equipment damage.

Make sure the power switch is off before opening the 407 Controller or removing any module.

⚠ CAUTION

Guard against static discharge, which can damage circuit components:

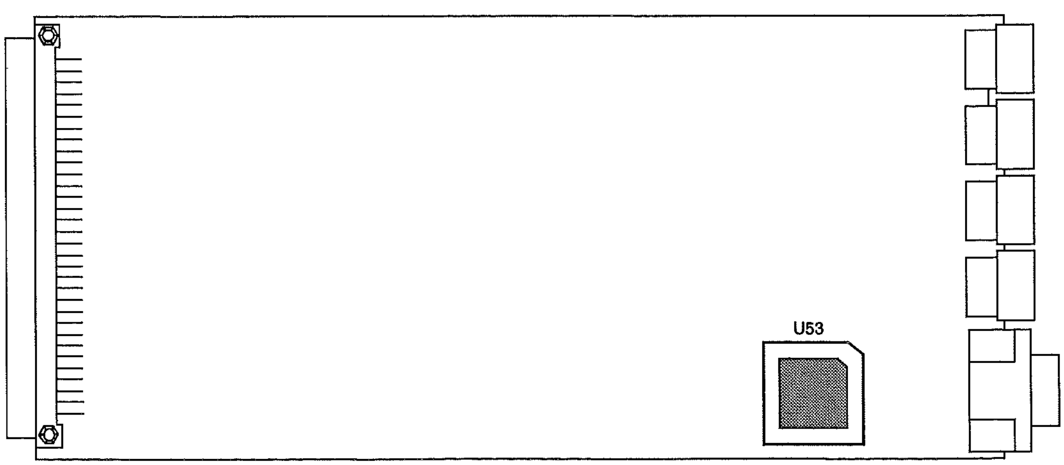
- **If the Controller power cord is plugged in (so the chassis is grounded) you can then touch the chassis before touching any component or conductive path.**
- **Alternatively, you can work at an anti-static work station, or use anti-static wrist or ankle bands.**
- **Do not take a new component out of its anti-static packaging until you are ready to install it.**
- **After removing a component, place it on a non-static surface.**
- **Except where necessary, avoid touching components or conductive paths on the circuit card.**

In general, use all reasonable anti-static precautions.

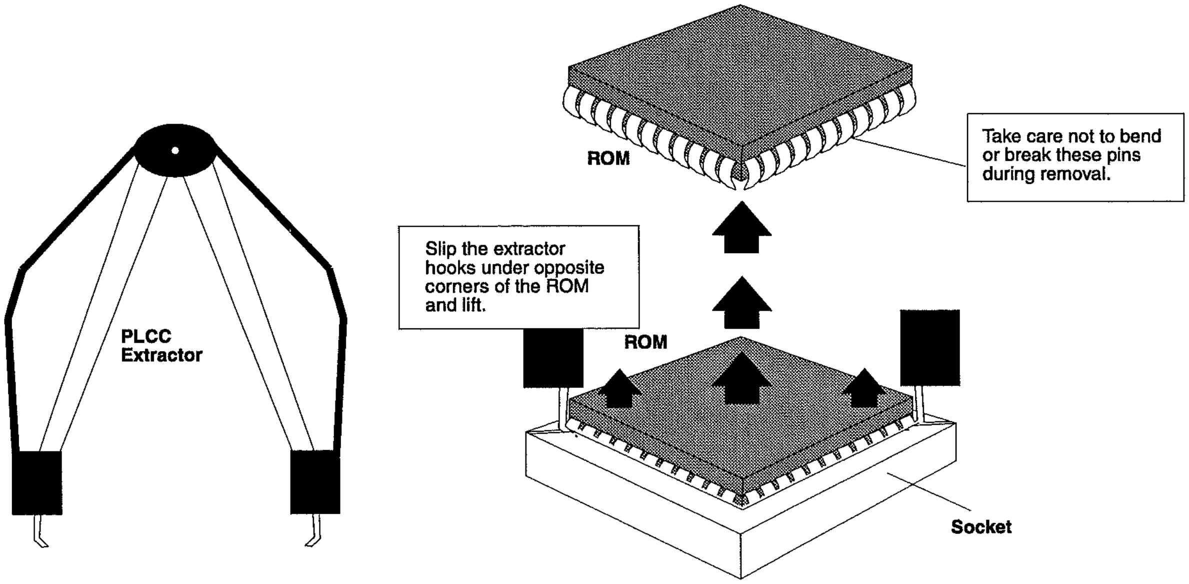
Removing the Processor Module from the Chassis

Take the following steps:

1. Turn off power to the 407 Controller.
2. Remove the two Phillips screws holding the processor in place on the rear panel.
3. If an HPS cable connector or jumper plug is firmly attached to the D connector, pull on that plug to remove the processor board. If you need more leverage, you can remove the blank panel next to the processor module. Carefully pull on the processor board to free it from its large (128-pin) bus connector. Slide it from the chassis. You may need to rock it up and down slightly to free it from the connector.
4. Use this figure to locate U53 (a PLCC in a socket) on the board:



Removing the ROM with an Extractor



Take the following steps:

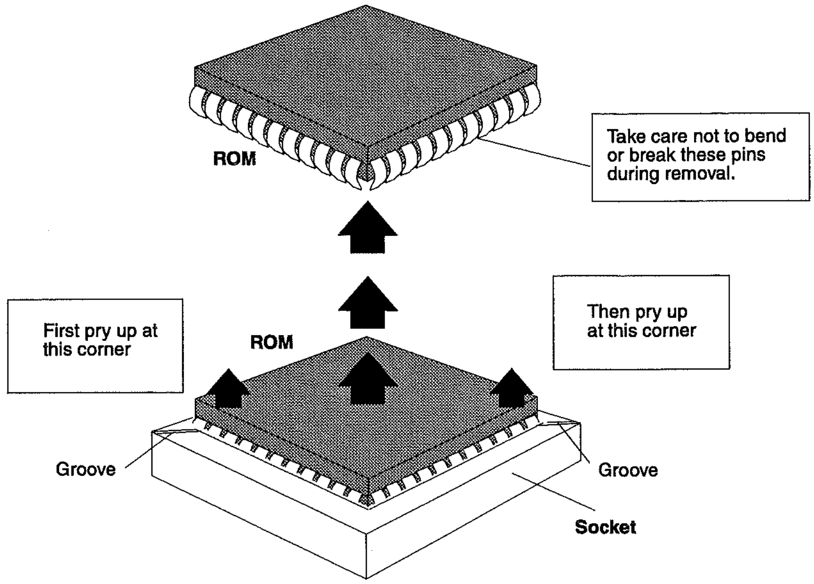
1. Place the module on a firm, flat surface. The module panel should overhang the edge of the surface, so the circuit board lies flat on the surface.

2. Carefully slip the hooks of the tool down between the ROM and the socket, at the opposite corners of the ROM. Press the extractor arm down firmly and listen for a click, to make sure the extractor hooks are below the ROM.

3. Be sure the tool is not touching any pins, then squeeze to grip the ROM and lift it free. Be careful not to damage pins on the ROM, which may be needed later.

4. Place the ROM on a non-static surface. If the replacement is not functional, you may need to put this one back in place. (In that unlikely event, consult MTS for a replacement.)

Removing the ROM with a Pick



Take the following steps:

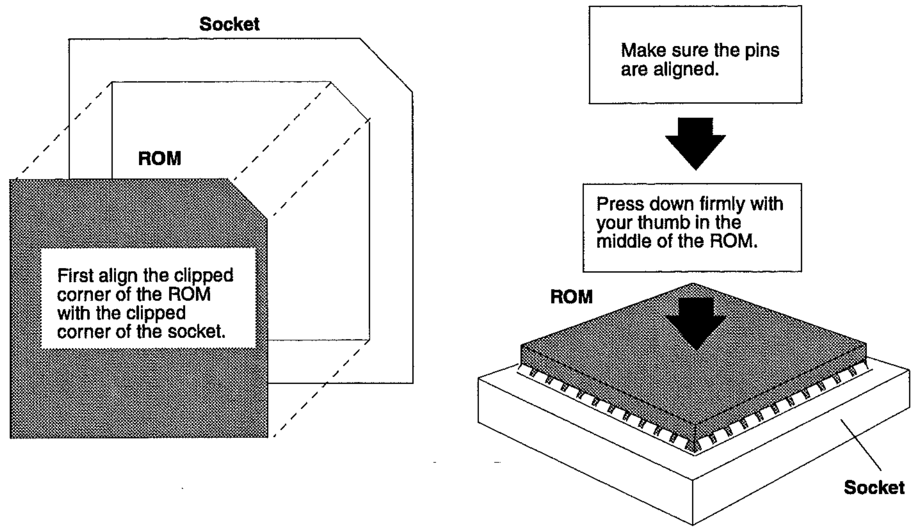
1. Place the module on a firm, flat surface. The module panel should overhang the edge of the surface, so the circuit board lies flat on the surface.

2. Using the groove in one corner of the socket as a guide, insert the extractor tool under one corner of the ROM, between the ROM and the socket. Make sure the tool is not in contact with any pins. (One way to do this is to pry against the top layer of the ROM, above the pins.) Pry up gently until the corner of the ROM corner raises slightly.

3. In the same way, pry up at the opposite corner of the ROM. Repeat this process until the ROM comes free of the socket. Be careful not to damage pins on the ROM, which may be needed later.

4. Place the ROM on a non-static surface. If the replacement is not functional, you may need to put this one back in place. (In that unlikely event, consult MTS for a replacement.)

Installing the New ROM



Take the following steps:

1. Place the module on a firm, flat surface. The module panel should overhang the edge of the surface, so the circuit board lies flat on the surface.

2. To install a new ROM, first align the angled or "clipped" corner of the ROM with the clipped corner of the socket. Set the ROM in place, making sure the pins align correctly.

3. With your thumbs centered on the ROM, press down firmly. Taking care not to rock the ROM or let it slip out of alignment, snap it into place in the socket.

Replacing the Module

Slide the module back into place in the 407 Controller chassis, and secure it with two Phillips screws.

Troubleshooting the New ROM

After you install a new ROM, you can check it by:

- Powering up the 407 Controller and observing its self-test.
- Using the 407 Controller normally.

If the new ROM does not work properly, take the following steps:

1. Use the procedure above to remove the processor module from the 407 chassis.

2. Check that the new ROM is seated tightly in its socket, and that it is oriented properly. If not, try reinstalling it.

3. If the new ROM, properly installed, still does not work properly, remove it and return it to your supplier. You may want to replace it with the original ROM.

Chapter 11 Specifications

Parameter	Specification
Physical	
Height	5.2 in. (132 mm)
Width	8.8 in. (224 mm)
Depth	16.5 in. (419 mm)
Weight	15 lbs (6.8 kg)
Environmental	
Ambient temperature	10°C(50°F) to 40°C(104°F)
Relative humidity	0 to 85%, noncondensing
Power supply	
Line voltage	90 to 250 Vac
Line frequency	47 to 440 Hz
Inrush current	10 A max, 5 A pk typical @ 115 Vac
Operating power	125 W max, 75 W typical
Line transient immunity	Exceeds IEC 801-4 Level 4
Controller	
Proportional range	0 to 100V/V
Proportional resolution	0.025 V/V (12 bits)
Proportional bandwidth	5 kHz min
Integrator range	0 to 1000 rps
Integrator resolution	0.244 rps (12 bits)
Differentiator range	0 to 40 ms
Differentiator resolution	0.0098 ms (12 bits)
Differentiator break frequency	5 kHz
Feedforward range	0 to 40 ms
Feedforward resolution	0.0098 ms (12 bits)
Feedforward break frequency	5 kHz
Delta P gain range	10 V/V
Delta P gain resolution	0.00244 V/V (12 bits)
External program input	
R_{in}	20 kΩ differential
V_{in}	±10 V operation, ±15 V max w/o damage
External program output	
R_{load}	1 kΩ min
C_{load}	0.01 µF max
V_{out}	±10 V min

Parameter	Specification
Controller (continued)	
External sync input	
R_{in}	20 kΩ differential
V_{in}	0 to 5 V operation, ±15 V max w/o damage
V_{IL}	1.5 V max
V_{IH}	4.0 V min
Minimum pulse width	5 ms
External sync output	
V_{OL}	1.0 V max with 5kΩ load
V_{OH}	4.0 V min with 5kΩ load
Waveform	Square wave, 50% duty cycle (when generated internally)
Monitor outputs	
R_{load}	1 kΩ min
C_{load}	0.01 µF max
V_{out}	±10 V min
Limit Detectors	
Conditioner limit range	± 15 V
Conditioner limit resolution	7.3 mV
Error limit range	0 to 15 V
Error limit resolution	3.7 mV
Underpeak detector range	±15 V
Underpeak detector resolution	10 mV
Peak detector accuracy	0.5% of F.S. (50 mV)
Peak detector input frequency	50 Hz max
Function generator	
Waveforms	sine, square, triangle, external input
Setpoint:	
range	–100% to 100%
resolution	0.0031% (16 bits)
Span:	
range	0 to 100%
resolution	0.0061% (14 bits)
Maximum cycle count	9,999,999
Amplitude accuracy	0.1% of F.S. (10mV)
Sine distortion	0.5% max THD
Frequency	
range	0.1 to 100 Hz
resolution	0.01 Hz (14 bits)
Frequency accuracy	5%
Start mode	soft start with adjustable ramp rate

Parameter	Specification
HPS	
Input power	26 V max
Outputs	Start, Low, High
Inputs	On, Intlk1, Intlk2
DVM	
Screen update rate	≈0.3 s
Range	≈-11 V to +11 V
Resolution	1.3 mV (14 bits)
Accuracy	0.3% of reading or 5 mV (whichever is greater)
DIO	
Contact outputs	Max switched current = 3 A Max switched power = 100 W Max switched voltage = 30 Vdc or 120 Vac
Optical inputs	V_{IL} = 2 V max V_{IH} = 10 V min V_{in} = 30 V w/o damage R_{in} = 1.8 kΩ
Model 407.12 DC Conditioner	
Differential dc excitation:	
Range	0 to 20 V differential (programmable)
Resolution	5 mV (12 bits)
Current	100 mA max
Stability	±5 ppm/°C
Load regulation	0.05% min load to max load
Compatible transducer bridge range	120 to 1000Ω (de-rated excitation under 200Ω)
Capacitive load	0.01 µF max
Zero:	
Coarse zero range	-5 to +5 V (before postamp)
Coarse zero resolution	2.5 mV (12 bits)
Fine zero range	-2 to +2 V
Fine zero resolution	1.0 mV (12 bits)
Supported transducer configurations	4- through 9-wire full bridges (configurable), half bridge (configurable completion resistors), quarter bridge (configurable completion resistors)

Parameter	Specification
Model 407.12 DC Conditioner (continued)	
Amplifier	
Input impedance	1 MΩ min
CMRR	100 dB min dc to 100 Hz (gain = 500) 350 Ω with 1% imbalance
Preamp gain ranges	1, 8, 64, and 512 V/V
Post amp gain range	0 to 10 V/V
Postamp gain resolution	0.0025 V/V
Delta K range	0.95 to 1.05 V/V
Delta K resolution	0.000024 V/V (12 bits)
Noise	2 mV p-p max, dc to 500 Hz (gain=500)
Calibration check modes	Shunt calibration (rear panel or external shunt resistor)
Model 407.14 AC Conditioner	
Differential ac excitation:	
Voltage range	0 to 40 Vp-p
Resolution	10 mV
Frequency	10 kHz standard (1.25, 2.5, 5.0 10 jumper selectable)
Capacitive load	0.01 µF max
Demodulator	
Phase range	–90° to +90°
Resolution	0.7 ° (8 bits)
Amplifier:	
Input impedance	1 MΩ min
CMRR	95 dB typical from dc to 60 Hz (350 Ω with 1% imbalance), 60 dB typical at 10 kHz (gain = 1)
Preamp gain ranges	1 and 8
Postamp gain range	0 to 10 (adjustable)
Postamp gain resolution	0.0025 min
Delta K range	0.95 to 1.05 V/V
Delta K resolution	0.000024 V/V (12 bits)
Noise	2 mVp-p max (dc to 500 Hz, G = 10)
Zero:	
Coarse zero range	-5 to +5 V (before postamp)
Coarse zero resolution	2.5 mV (12 bits)
Fine zero range	-2 to +2 V
Fine zero resolution	1.0 mV

Parameter	Specification
Model 407.15 Three-stage Valve Driver	
Inner loop command:	
Input type	voltage
Input impedance	20 kΩ
Voltage range	±10 V full scale
AC conditioner:	
Input impedance	1 MΩ
Input range	±10 V (operating), ±14 V (no damage)
Zero:	
Coarse zero range	-5 to +5 V (before postamp)
Coarse zero resolution	2.5 mV (12 bits)
Fine zero range	-2 to +2 V
Fine zero resolution	1.0 mV
AC CMRR (G = 1)	70 dB minimum (dc to 120 Hz), 50 dB minimum (10 kHz)
Excitation voltage range	0 to 40 Vp-p (programmable)
Excitation voltage resolution	12 bits
Excitation frequency	10 kHz standard (jumper selectable for 1.25, 2.5, 5, or 10 kHz)
Demodulator filter	5 MHz SIP module for 10 kHz excitation (standard)
Phase adjustment range	-90° to + 90°
Phase adjustment resolution	0.7° (8 bits)
Noise (G = 80)	1 mVpp maximum (0.1 to 10 Hz) 10 mVp-p maximum (dc to 1 MHz)
Bandwidth	2 kHz minimum at ±3 dB
Controller:	
Type	Proportional and derivative
Proportional range	0 to 100 V/V
Proportional resolution	0.024 V/V (12 bits)
Derivative range	0 to 40 ms
Derivative resolution	0.0098 ms (12 bits)
Valve Driver:	
Type	differential current driver
Current range	±50 mA full scale standard (±100 mA max with resistor change)
Dither frequency	500 Hz standard (resistor selectable)
Dither amplitude range	20% p-p of full scale
Dither amplitude resolution	0.005% of full scale (12 bits)
Valve balance range	±20% of full scale
Valve balance resolution	0.010% of full scale (12 bits)
Input (valve command)	±10 V full scale

Parameter	Specification
Model 407.16 Valve Driver	
Dither frequency	500 Hz standard (resistor selectable)
Dither amplitude range	20% p-p of full scale
Dither amplitude resolution	0.005% of full scale (12 bits)
Valve balance range	±20% of full scale
Valve balance resolution	0.010% of full scale (12 bits)
Valve clamping	zero, +50%, -50% (configurable)
Current range	±50 mA full scale standard (±100 mA max with resistor change)
Input (valve command)	±10 V full scale

Specifications are subject to change. Contact MTS for verification of critical specifications.

Appendix A
Acronyms/Abbreviations

List of Acronyms and Abbreviations

The following list contains acronyms, abbreviations, or terms that are used in this manual or that appear on the 407 Controller display.

%	percent
%/s	percent per second
+ EX or - EX	plus excitation or minus excitation
+EXS or - EXS	plus excitation signal or minus excitation signal
+FB or - FB	plus feedback or minus feedback
+FBR or -FBR	plus feedback return or minus feedback return
ACx Cond	ac conditioner in slot x (x1, 2, or 3)
ACx Cond Max/Min	ac conditioner x max/min limits
ACx Cond Pk/Vly	ac conditioner x peak/valley settings
ACx Lo	ac conditioner x lower limit (x = 1, 2, or 3)
ACx Up	ac conditioner upper limit
Ampl Cntrl	external amplitude control
Balance	valve spool balance
bar	bar (pressure)
BRAM	battery-backed RAM (memory)
C	degrees Celsius
C Zero	coarse zero offset
ChngPswd	change password
cm	centimeters
Cmd	command signal
Cmd Max/Min	command max/min limits
Cmd Pk/Vly	command peak/valley settings
CRC	cyclic redundancy check (a ROM self-test)
Cyc Cnt	cycle count
Cyc Src	cycle counter source
D Gain	derivative gain (rate)
D src	input to the differentiator
DCx Cond	dc conditioner in slot x (x1, 2, or 3)
DCx Cond Max/Min	dc conditioner x max/min limits
DCx Cond Pk/Vly	dc conditioner x peak/valley settings

DCx Lo	dc conditioner x lower limit (x = 1, 2, or 3)
DCx Up	dc conditioner upper limit
deg	degrees (angular)
Delta	in shunt calibration, the difference between the shunted conditioner output and the pre-shunt output
Delta K	the conditioner output divided by the conditioner input (from the transducer)
Delta P	differential pressure
demod	demodulator (as in demodulator output)
DigIn	digital input interlock
Din1	digital input 1
Din1Pol	polarity for digital input 1
Din2	digital input 2
Din2Pol	polarity for digital input 2
DIO	digital input/output
Dither	oscillating signal used to prevent servovalve silting and to overcome static friction
Dout1	digital output 1
Dout1Pol	polarity for digital output 1
Dout2	digital output 2
Dout2Pol	polarity for digital output 2
dP Cond	differential pressure (Delta P) conditioner
dP	differential pressure (Delta P)
dP Gain	differential pressure (Delta P) gain
Eng Units	engineering units display feature
Enter Lvl	enter a security level
EOC Act	action to be taken at end of count
EOC	end-of-count interlock
ErrLim	error limit
Error	interlock caused by exceeding the error limit
Error Max/Min	error max/min limits
Error Pk/Vly	error peak/valley settings
ESTOP	emergency stop interlock
EU	undefined engineering units
Excit	excitation
Extern	interlock cause by external 407 Controller
F	degrees Fahrenheit
F Gain	feedforward gain
F Zero	fine zero offset,
F.S. Val	full scale value
FdBack	feedback conditioner

Fdbk	feedback signal
Fdbk Pol	polarity of conditioner feedback
Freq	function generator frequency
G	gravitational accelerations
Gain	conditioner gain
gnd	ground
HPS	hydraulic power supply
HPS1	interlock, typically, low hydraulic fluid level
HPS2	interlock, typically, overtemperature hydraulic fluid
HSM	hydraulic service manifold
Hyd Config	hydraulic configuration
hyd	hydraulic
I Gain	integral gain
ilb	inch-pounds torque
in	inches
Intlk Config	interlock configuration
Intlk	interlock
kg	kilograms
kgm	kilogram-meters (torque)
kip	thousand pounds force
kN	kiloNewtons
lb	pounds force
LVDT	linear variable differential transformer
m	meters
m/s	meters per second
Max Val	maximum valley
Min Pk	maximum peak
mm	millimeters
Mon1	monitor 1 (BNC connector on front panel)
Mon2	monitor 2 (BNC connector on front panel)
Monitor	valve signal selected for readout
MT	metric tons
N	Newtons
N-m	Newton-meters
P Gain	proportional gain
P/V Sens	peak/valley sensitivity level
Pa	Pascals
Phase	phase (in degrees) of the ac conditioner demodulator
PID	proportional, integral, and derivative
PIDF	proportional, integral, derivative, and feedforward

PLC	programmable logic controller (PLC is a registered trademark of Allen-Bradley Corporation.)
Polarity	feedback polarity or valve command polarity
ppm/°C	parts per million per degree Celsius
Pre-Shunt	output from the dc conditioner before a shunt is activated
Preset	maximum cycle count
Prop	proportional valve HSM
psi	pounds per square inch (pressure)
rad	radians
RAM	random access memory
RCOM	resistor common—specifically, external shunt calibration resistor common
ROM	read-only memory
rps	repetitions per second
Setpnt	setpoint (mean level) of the function generator waveform
SetPt R	setpoint ramp rate
SIP	single in-line package
Span	span (amplitude) of the function generator waveform
Span R	span ramp rate
ue	microstrain units (με)
Units	engineering units for display
UPk Sig	signal selected for underpeak detection
UpkPeak	interlock, underpeak peak
UpkVly	interlock, underpeak valley
V	volts
V/V	volts per volt, a measure of voltage gain
Vlv Bal	valve balance
Vlv Cmd Max/Min	valve command max/min limits
Vlv Cmd Pk/Vly	valve command peak/valley settings
Vlv Cmd	valve command
Vlv Mon	valve readout signal selected in valve driver menu
Vlv Mon Max/Min	valve monitor max/min limits
Vlv Mon Pk/Vly	valve monitor peak/valley settings
Vlv Pol	valve command polarity
Wvform	waveform
XDCR	transducer

Appendix B
Control Principles

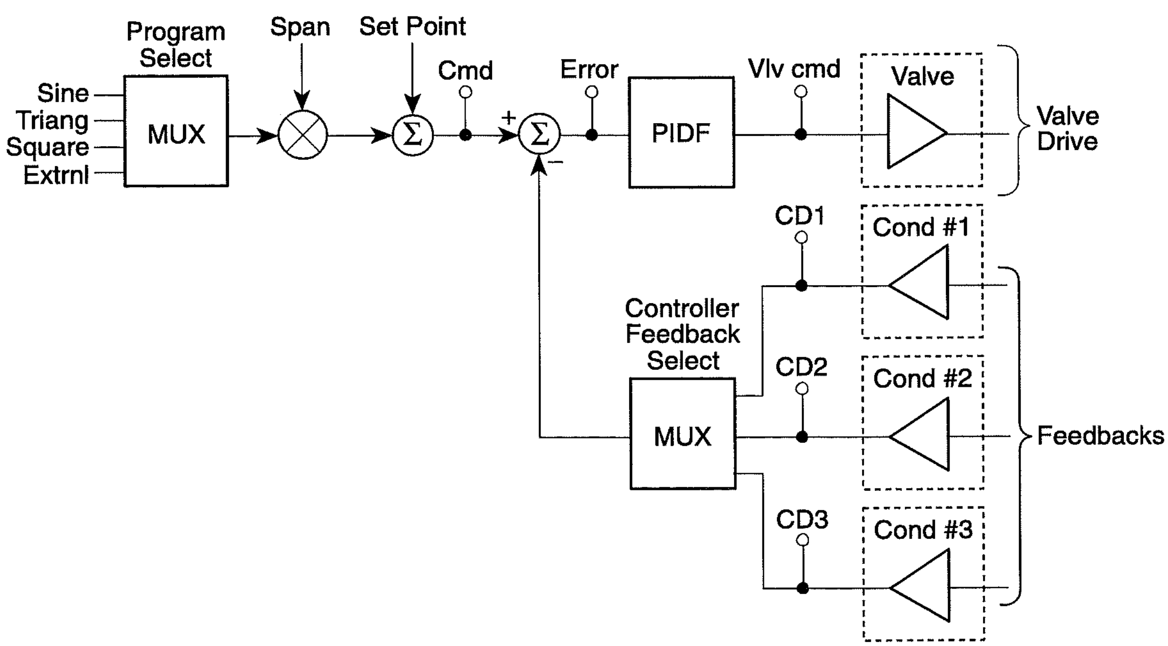
Overview

This appendix explains the control principles used in the 407 Controller, including basic closed-loop servo control and the following additional topics:

- Control signal generation
- Calibrated ranges
- Limit detection
- Span adjustments
- Setpoint adjustments
- Servo loop adjustments (proportional, integral, derivative, feedforward)

Because of the flexibility of 407 Controller, this appendix describes these topics in a general manner. These principles apply, however, whether you are configuring your own test system or using a pre-configured system supplied by MTS.

It is important to fully understand these control principles before setting up or executing a test. The following is a simplified block diagram of the 407 Controller.

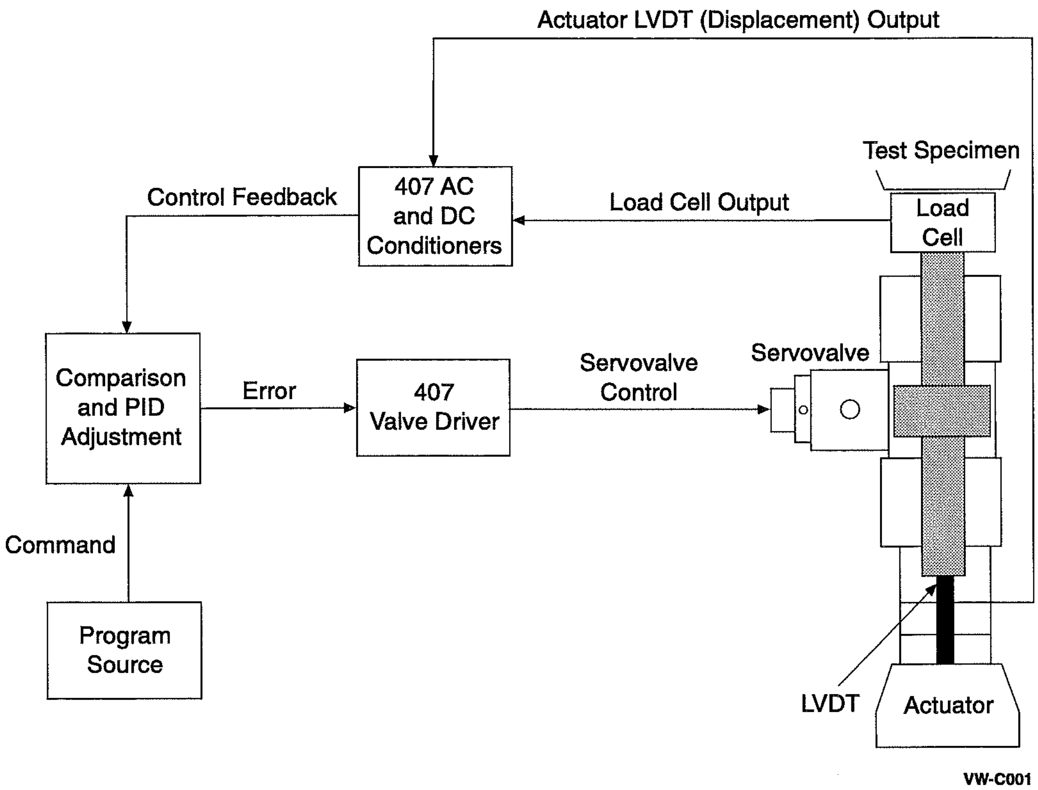


MP-C013

System Control Theory

Control of each actuator in the test system is provided by a "loop" of electronic and servo hydraulic components. As shown in the following figure, the 407 Controller provides a means of comparing the command signal with a feedback signal to generate a signal that controls the servovalve. The servovalve controls hydraulic flow to the actuator which moves the actuator piston rod. The actuator piston rod applies the force required to load or displace the specimen being tested.

This control method is referred to as "closed-loop control" because the process of command, feedback, comparison, and servovalve control is totally a function of the control circuitry and occurs without operator interaction.



Control Signal Generation

The four major signals in the control system are:

- Command
- Control feedback
- Error
- Servovalve control signal

Command

The command signal begins in the program source, which is either the internal 407 Controller function generator or an external program input. The source is user-selectable through the 407 user interface.

Setpoint and span adjustments are added to the program signal to generate the command signal. The program signal, scaled by span and offset by setpoint is referred to as "composite command."

Control Feedback

The control feedback signal begins as an output signal from a transducer, such as a load cell or linear variable differential transformer (LVDT). The ac and/or dc conditioner modules in the 407 Controller amplify and condition this transducer output signal to produce the control feedback signal. The control feedback signal is then sent to the 407 processor for comparison with command.

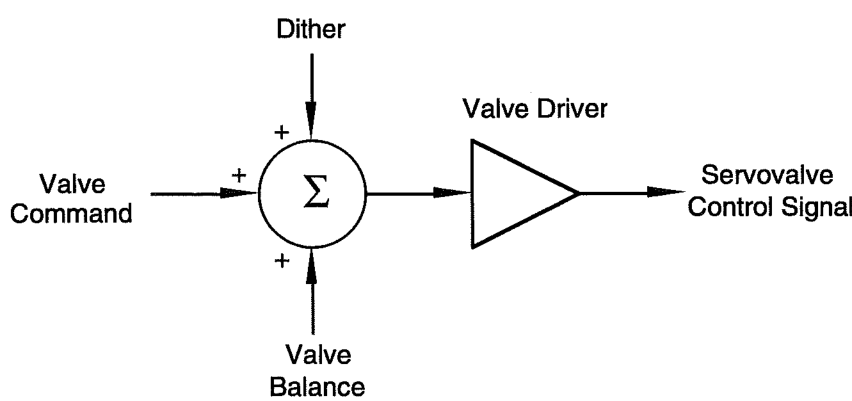
Error

Error is the difference between command and control feedback. The error signal, which is calculated in the 407 Controller, is scaled by the PIDF controller and then sent to the valve driver module.

Servovalve Control Signal

The valve driver module converts the scaled error signal into a current that is used to control the servovalve. This is the servovalve control signal.

As shown in the following figure, dither and valve balance signals are added to the error signal to generate the servovalve control signal.



Calibrated Range

To maintain accuracy over the entire testing range, the transducer feedback signal may be scaled to take advantage of the entire ±10 volt signal range.

For each test conducted using the 407 Controller, you must determine the range of force, acceleration, displacement, etc., that the test system will need to monitor and control. When this range represents the minimum and maximum values to be measured during the test, it is referred to as the "testing range."

The full-scale value covers both the positive and the negative range of the transducer feedback signal. For example, if a transducer is calibrated using a full-scale value of 15 kN, the calibrated range is ±15 kN, and when this calibrated range is in use, 10 volts is equivalent to 15 kN.

NOTE It is important to understand that the full-scale value does not reduce the static force capability of the associated actuator, but only increases the sensitivity of the electronic control and readout components.

Limit Detection

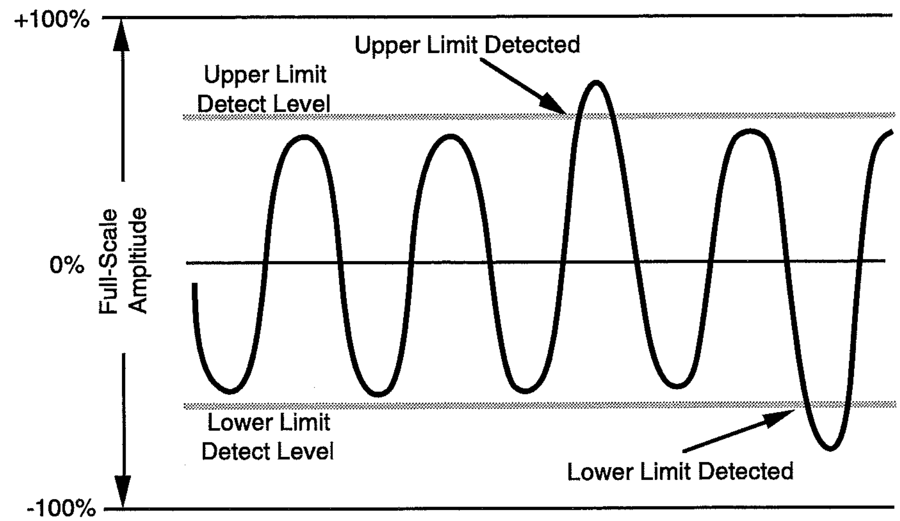
The 407 Controller provides three types of limit detectors:

- Feedback limit detectors—monitor the control and feedback signals to detect if the signals exceed or fall below specified upper and lower levels. The upper and lower levels are specified independently.
- Error detectors—monitor the error signal to detect if it exceeds a specified absolute level.
- Underpeak detectors —sense when a signal fails to reach a specified level. Upper and lower underpeak levels (minimum peak and maximum valleys) are specified independently.

The Reset button on the 407 Controller front panel clears the limit indicators and resets the interlocks after a hydraulic shutdown resulting from an out-of-limits condition. Reset must be used before hydraulic pressure can be applied to the test station after the shutdown.

Feedback Limit Detectors

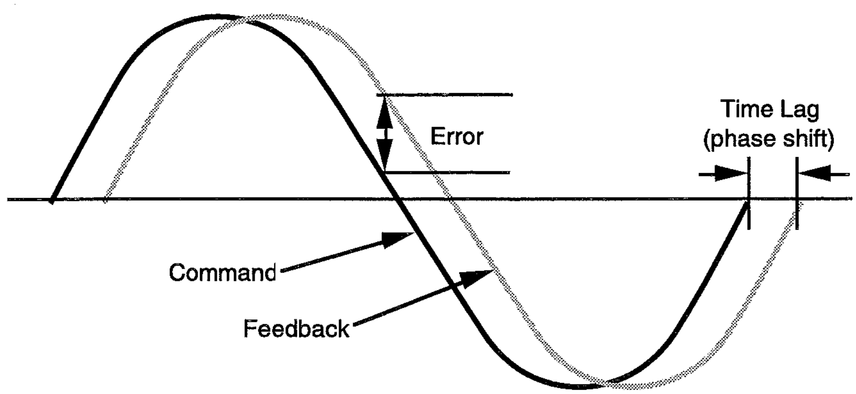
Limit detectors monitor the transducer conditioner feedback signals. As shown in the following figure, when a feedback signal exceeds either its preset upper limit or falls below its preset lower limit, the corresponding limit detector can remove hydraulic pressure from the test system.



The limit detectors should be set to minimize the chances of accidental damage to test specimens and test equipment. They are set to shut down the test if the specimen fails in order to prevent damaging the fixture or equipment. *Under no circumstances should the limit detectors be relied on to protect personnel.*

Error Detector

The error detector monitors the difference between the command and control feedback (error), as shown in the following figure. It is used to detect excessive error during testing, and is typically set to detect the loss of closed-loop control. An error detector causes hydraulic pressure to be removed from the associated test station if it detects an error in excess in the preset level.

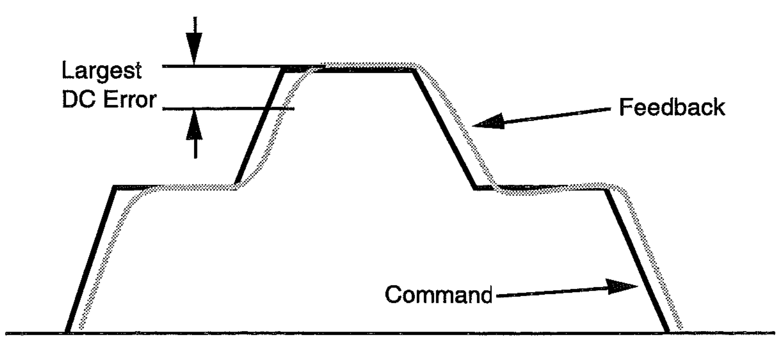


Determining Acceptable Error

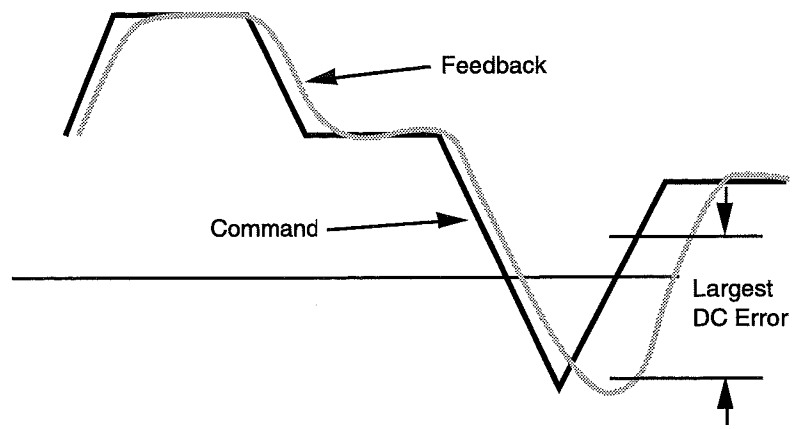
The level of acceptable error depends directly on the accuracy requirements of each testing situation.

In higher frequency tests, the instantaneous error increases in proportion to command frequency and the error detectors have to be adjusted to higher levels. This is due to the time lag, or phase shift, between the program command and system response. Therefore, the error detectors are generally set to sense a loss of closed-loop control at higher command frequencies.

In the following low-frequency example, the error detector can be set to a relatively small level because the feedback tracks the command so closely.



However, if a higher frequency content were added to the program command, as shown below, the error detector would have to be adjusted to a higher level to avoid setting the system interlock.



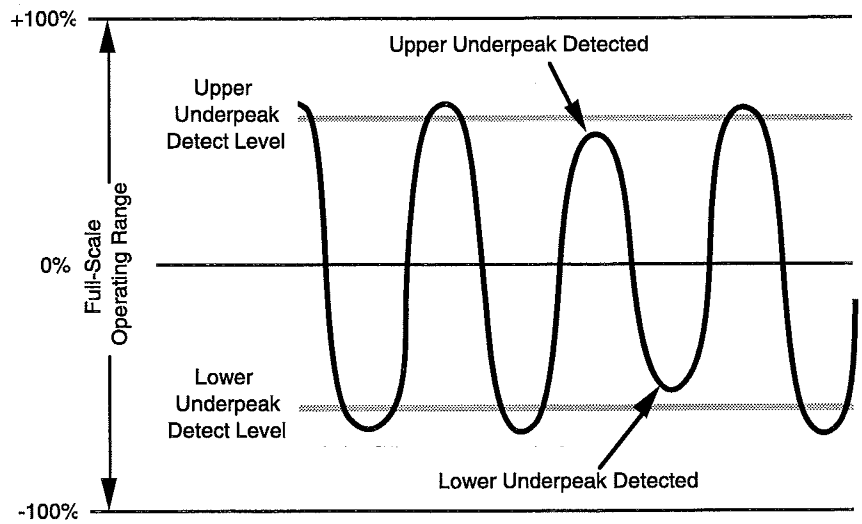
Setting Error Limits

The error limit setting specifies the acceptable maximum positive or negative error level (the absolute value of the difference between command and feedback). For static and low frequency testing, the initial error detector levels can be determined before beginning test set up. The level selected should reflect the response requirements of the specific test. For example, if the test can tolerate up to 25% deviation from the program signal, the error detector level can be set to 25%.

The error detector level can also be adjusted during testing if desired. The best guide for adjusting the error detectors for high frequency testing is operator experience.

Underpeak Detection

The underpeak detectors sense when a signal fails to reach a specified upper or lower level. Underpeak detection is typically used to stop a test at the onset of failure in a fatigue test. As shown in the following figure, two levels are specified for underpeak detection; an upper underpeak level (minimum peak) and a lower underpeak level (maximum valley). Underpeak levels can be established for any feedback signal.



When the signal input to the underpeak detector does not reach the preset upper detect level, the underpeak detector will stop the test through the system interlock and provide an indication (if the underpeak interlock is enabled). Likewise, if the signal does not reach the preset lower detect level, the underpeak detector will also stop the test and provide an indication.

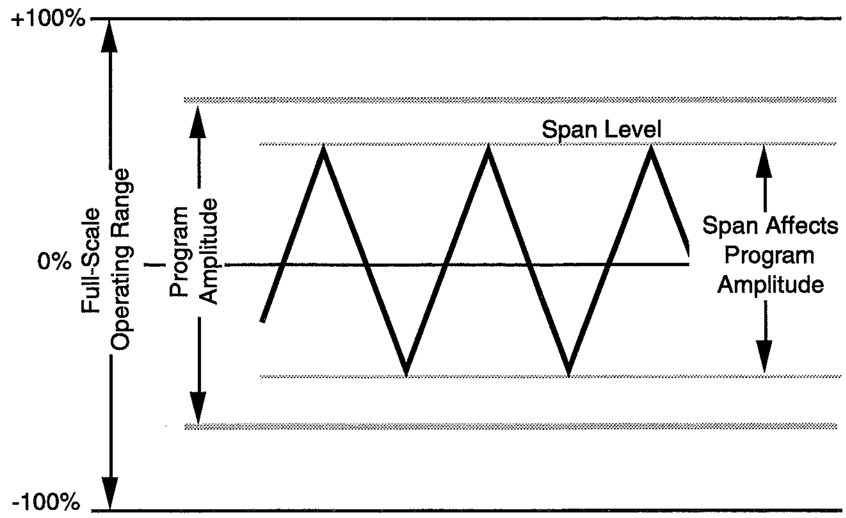
Setting Underpeak Levels

The upper underpeak level (minimum peak) will typically be set at a level 5% to 10% less positive (more negative) than the anticipated peak level of the selected input signal. The lower underpeak level (maximum valley) will typically be set at a level 5% to 10% less negative (more positive) than the anticipated valley level of the selected signal.

Span Adjustments

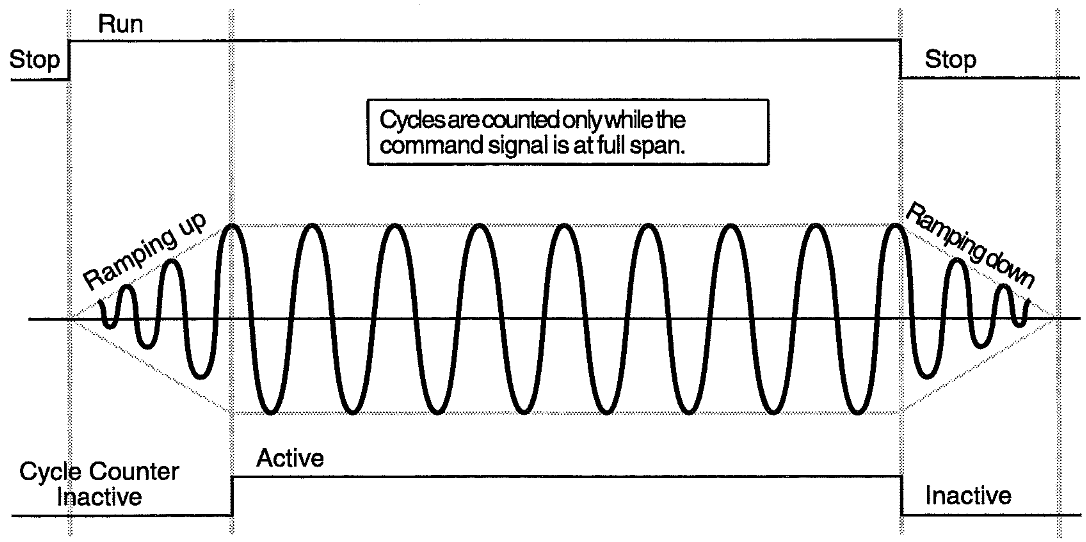
Effect on Amplitude

The maximum/minimum amplitude of a waveform output by a program source is ±10 volts, which represents ±100% of the selected operating range. As is demonstrated by the following figure, the Span control determines the amplitude of the command signal. If the span is 0, then no program signal is sent to the actuator. If the span is 100, 100% of the program signal is sent to the actuator.



While Span is ramping up or down, the cycle counter is disabled. When in the run state, the cycle counter counts cycles only when Span is fully ramped up.

When external program is selected, the cycle counter input is a version of the external program signal. The cycle counter counts the zero crossings of the program signal.



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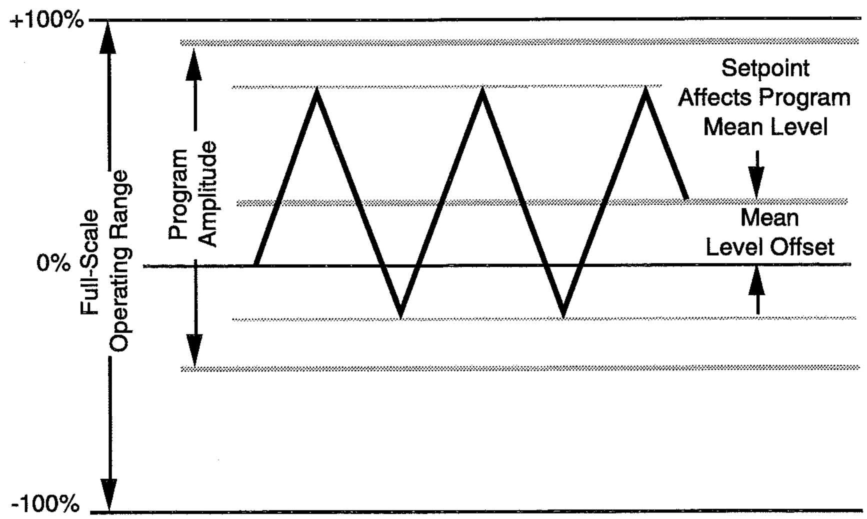
Setpoint Adjustments

Mean Level Offset

The maximum/minimum amplitude of a waveform output by a program source is ±10 volts, which represents 100 percent of the selected operating range. The setpoint control, demonstrated in the following figure, changes the mean level offset of the program command signal. This is the position about which the actuators will move during testing.



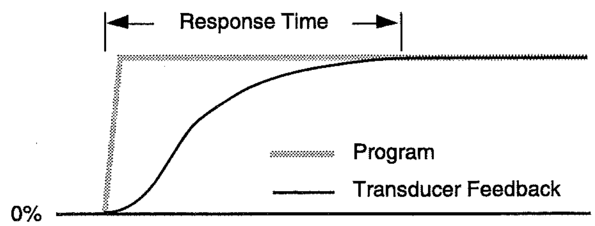
Servo Loop Adjustments

The servo loop adjustments establish the response and stability of the servo control loop. Servo loop adjustments are experimental and you should become familiar with the effects of these adjustments while using dummy specimens during both dynamic and static system operation.

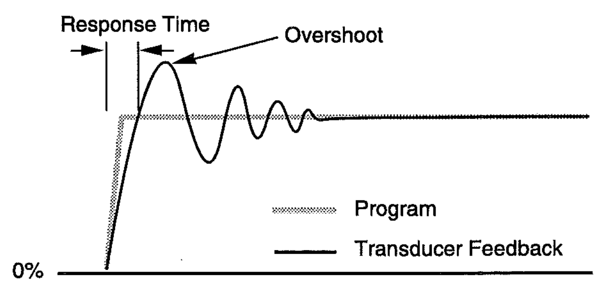
The following paragraphs explain how the servo loop controls affect the error signal.

Proportional Gain

The proportional gain adjustment determines how closely the feedback signal will follow the program. The greater the gain, the more the servovalve opens for a given error. As proportional gain is increased, the error decreases, indicating closer tracking of the feedback to the command. The following figure shows the program and resulting transducer feedback signal with a small gain.



Increasing the proportional gain decreases the stability margin of the system, increases the amplitude and frequency of oscillation, and decreases response time. The following figure shows the effect on the transducer feedback of increasing the gain adjustment.



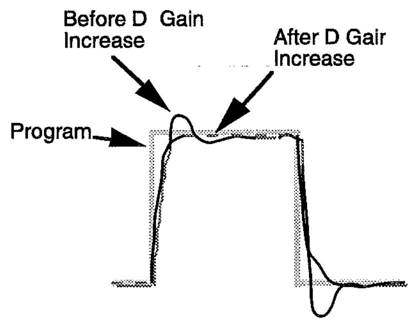
If the proportional gain is set too high, unstable system operation can result. This instability may cause specimen damage. Consequently, gain should be set as high as possible while maintaining stable system operation.

Integral Gain (Reset)

The integral gain adjustment increases system accuracy during static or low-frequency operation, when the actuator cannot hold the commanded position. It reduces the error between command and feedback by integrating out offsets in the dc portion of the feedback.

Derivative Gain (Rate)

The derivative gain adjustment improves the servo control loop dynamic stability by reducing the overshoot at higher proportional gain settings. It reduces the system bandwidth, closing the servovalve in anticipation of achieving the commanded position through the rate of change in feedback. The following figure shows the effect of adding derivative gain to a transducer feedback signal that has already been adjusted for gain.



Feedforward Gain

Sometimes it is necessary to enhance system response time even though the maximum amount of proportional gain has already been applied that can be applied to the control loop while maintaining system stability. In these cases, feedforward is used. The feedforward term is multiplied by the rate of change in the command signal with respect to time, and the result is added directly to the actuator control signal.

Delta P

Delta P (differential pressure) is an optional control that introduces a signal that stabilizes displacement control in systems with large, moving masses. By monitoring pressure across the actuator cylinder, it anticipates the motion that will be caused by the potential energy available in the actuator. It changes the servovalve command in anticipation of load reversals.

NOTE To use this control option, an actuator fitted with a delta P transducer is required.

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Appendix C
Test Configuration Notes

407 Controller Serial No.	
Test Name	
Date	
Test Article	
Test Engineer	
Operator	
Remarks	

Configuration

Parameter	Setting
Eng Units	
EOC Act	
Cyc Src	
SetPt R	
Span R	
Hyd Config	
Intlk Cnfg	
P/V Sens	
Ampl Cntrl	

Function Generator

Parameter	Setting
Wvform	
Freq	
Setpnt	
Span	
Preset	

PIDF Controller

Parameter	Setting
FdBack	*
P Gain	*
I Gain	*
D Gain	*
D src	*
F Gain	*
dP Cond	*
dP Gain	*

* This value depends upon the setup (Setup1 or Setup2) selected for the control conditioner.

Limits

Parameter	Setting
ACx Up	
ACx Lo	
DCx Up	
DCx Lo	
ErrLim	
UPk Sig	
Min Pk	
Max Val	

Digital I/O

DIN1 Definition:

Parameter	Setting
Din1	
Din1Pol	

DIN2 Definition:

Parameter	Setting
Din2	
Din2Pol	

DOUT1 Definition:

Parameter	Setting
Dout1	
Dout1Pol	

DOUT2 Definition:

Parameter	Setting
Dout2	
Dout2Pol	

Slot 1 Conditioner Type:

Definition:		Xducer ID:
Parameter	**Setup 1**	**Setup 2**
Conditioner Setup		
Units		
F.S. Val		
Gain		
Delta K		
C Zero		
F Zero		
Excit		
Phase (AC Cond. only)		
Polarity		
Monitor		
Shunt Cal Chk (DC Cond. only)		
Pre-Shunt		
Delta		

Slot 2 Conditioner Type:

Definition:		Xducer ID:
Parameter	**Setup 1**	**Setup 2**
Conditioner Setup		
Units		
F.S. Val		
Gain		
Delta K		
C Zero		
F Zero		
Excit		
Phase (AC Cond. only)		
Polarity		
Monitor		
Shunt Cal Chk (DC Cond. only)		
Pre-Shunt		
Delta		

Slot 3 Conditioner Type:

Definition:		Xducer ID:
Parameter	**Setup 1**	**Setup 2**
Conditioner Setup		
Units		
F.S. Val		
Gain		
Delta K		
C Zero		
F Zero		
Excit		
Phase (AC Cond. only)		
Polarity		
Monitor		
Shunt Cal Chk (DC Cond. only)		
Pre-Shunt		
Delta		

2-Stage Valv Drv

Definition:

Parameter	Setting
Dither	
Balance	
Polarity	
Monitor	

3-Stage Valv Drv

Definition:	Xducer ID:
Parameter	**Setting**
Gain	
C Zero	
F Zero	
Excit	
Phase	
Fdbk Pol	
P Gain	
D Gain	
Dither	
Balance	
Vlv Pol	
Monitor	

Appendix D
Product Options

Use this appendix to save service bulletins and other information on product options.

Index

* on screen 2-5
@ on screen 2-35

2-Stage Valv Drv menu 2-37
2-stage valve driver balance 2-37
2-stage valve driver dither 2-37
2-stage valve driver monitor signals 2-38
2-stage valve driver polarity 2-38
2-stage valve with 3-stage driver 7-12
3-stage conditioner gain 2-39
3-Stage Valv Drv menu 2-39
3-stage valve conditioner coarse zero 2-39
3-stage valve conditioner excitation 2-40
3-stage valve conditioner fine zero 2-39
3-stage valve conditioner gain 2-39
3-stage valve conditioner phase 2-40
3-stage valve driver balance 2-41
3-stage valve driver dither 2-40
3-stage valve driver gain 2-40
3-stage valve driver monitor signals 2-41
3-stage valve driver polarity 2-41
3-stage valve feedback polarity 2-40
407 configurations 4-11, 4-12
407 connections, multiple 4-11, 4-12
407 Controller configuration 2-9
407 Controller rear panel connections 4-1
407 Controller, defined 1-1
407 Controller, installing 4-20
407 Controller, mounting 4-20
407 module, installing 4-4
407 module, removing 4-4
407 power 4-2
407.02 Processor, replacing ROM 10-9
407.05 Pump Interface 4-7
407.05 Pump Interface, E-stop 4-14
407.12 DC Conditioner connections 4-16
407.12 DC Conditioner parameters 2-29
407.12 DC Conditioner, defined 5-1
407.12 DC Conditioner, specifications 11-3, 11-4
407.14 AC Conditioner parameters 2-29
407.14 AC Conditioner, defined 6-1
407.14 AC Conditioner, specifications 11-4
407.15 Three-stage Valve Driver connections 4-16, 4-17
407.15 Three-stage Valve Driver parameters 2-39
407.15 Three-stage Valve Driver, defined 7-1
407.15 Three-stage Valve Driver, specifications 11-5
407.16 Valve Driver connections 4-17
407.16 Valve Driver parameters 2-37
407.16 Valve Driver, defined 8-1
407.16 Valve Driver, specifications 11-6
407.18 Analog PIDF Controller, defined 9-1

A/D self-test 10-2
ac conditioner
- board 6-4
- completion resistors 6-8
- excitation mode 6-6
- excitation, adjustable 6-6
- filter 6-7
- jumpers 6-5
- monitor output 6-2
- phase 2-34, 2-40
- resistors 6-5, 6-6
- resistors, floating source 6-9
- specifications 11-4

ac conditioner, defined 6-1
ac conditioner, demodulator filter 6-8
access level 1-3
access level, security 2-14
action, Din1 2-26
action, Din2 2-27
action, EOC 2-10
actions, digital inputs 2-26
active shunt indication 2-35
ACx COND Setup 2-30, 3-6
ACx COND signal 2-23
ACx Conditioner menu 2-29
ACx Lo 2-21, 2-24
ACx Up 2-21, 2-24
adjusting HSM driver 10-7
adjusting values 2-7
adjustment knob 2-7
adjustment knob and DVM 3-3
adjustments, monitoring 3-3
Alt Func Enter keys 2-6
Alt Func key 2-5
alternate function key 2-5
Ampl Cntrl 2-13
amplitude control 2-13
analog controller board 9-3
analog controller connectors 9-2
analog controller jumpers 9-4
analog controller rear panel 9-2
analog controller resistors 9-5
analog controller, defined 9-1
analog ground reference 5-7, 6-5, 7-5
arrow keys 2-5
arrow keys in menus 2-6
asterisk on screen 2-5
at sign (@) on screen 2-35

Back Space key 2-5
Balance 2-37, 2-41
battery, self-test 10-2
block diagram
- ac conditioner 6-1
- dc conditioner 5-1
- PIDF controller 9-1
- three-stage valve driver 7-1
- valve driver 8-1

BNC connectors (front panel) 2-3
board configurations, ac conditioner 6-4
board configurations, analog controller 9-3
board configurations, dc conditioner 5-5, 5-11
board configurations, PIDF controller 9-3
board configurations, three-stage valve driver 7-4
board configurations, valve driver 8-4
BRAM, self-test 10-2
bridge arm selection 5-7
bridge balance resistor 5-12
bridge balancing, dc conditioner 5-9
bridge completion configurations 5-15

bridge completion resistors 5-12
bridge configuration
full bridge 4-wire 5-17
full bridge 8-wire 5-18
full bridge 9-wire 5-19
half bridge 3-wire 5-16
quarter bridge 3-wire 5-15
bridge configurations 5-15
button, E-stop 2-2

C Zero 2-33, 2-39
C Zero, default 2-31, 3-7
calibrated range, defined B-4
calibration resistor, dc conditioner 5-4
calibration, dc conditioner 5-3
calibration, delta P transducer 5-20
calibration, differential pressure transducer 5-20
calibration, force transducer 5-20
calibration, load cell 5-20
calibration, LVDT 6-10
calibration, strain gage 5-24
calibration, torque cell 5-20
changing password 2-14
changing security level 2-14
chassis common 4-2
checking interlocks 2-19
Chng Pswd 2-14
choosing item 2-6
cleaning the 407 Controller 10-1
Clear Entry key 2-5
closed-loop control, defined B-2
CMD signal 2-23
coarse zero 5-2, 6-2, 7-2
coarse zero reference 5-7, 6-5, 7-5
coarse zero, 3-stage valve conditioner 2-39
coarse zero, conditioner 2-33
command 2-42, 3-2
command max/min 2-42, 3-2
command peak/valley 2-42, 3-2
command signal, defined B-3
common, 407 chassis 4-2
common, 407 signal 4-2
completion resistors, ac conditioner 6-8
completion resistors, three-stage 7-8
composite command, defined B-3
conditioner
coarse zero 2-33
delta K 2-33
delta P 2-18
excitation output 2-33
feedback polarity 2-34
fine zero 2-33
full scale value 2-32
gain 2-33
max/min 2-42, 3-2
monitor signals 2-34
output 2-42, 3-2
peak/valley 2-42, 3-2
selecting feedback 2-17
setup, saving 2-30, 3-6
setup, switching 2-30, 3-6
conditioner filter header 5-7, 6-5
configuration 3-stage driver for 2-stage valve 7-12
Configuration menu 2-9
configuration, shunt cal 5-10
connections
external interlock 4-12
external program 4-10
HPS 4-6
HSM 4-5
Hyd In/Hyd Out 4-11
hydraulic power supply 4-6
hydraulic service manifold 4-5
Intlk In/Intlk Out 4-12
multiple 407 4-11, 4-12
rear panel 4-1
remote E-stop 4-13
transducer 4-16
user I/O 4-15
connections, servovalve 4-17
connector, ac conditioner 6-3
connector, dc conditioner 5-4
connector, LVDT 7-3
connectors, analog controller 9-2
connectors, BNC 2-3
connectors, PIDF controller 9-2
connectors, three-stage valve driver 7-3
connectors, two-stage valve driver 8-3
control feedback signal, defined B-3
control keys, hydraulic pressure 2-2
control keys, program 2-3
control signal generation, defined B-3
control, hydraulic 2-11
controller board 9-3
controller jumpers, PIDF 9-4
Controller menu 2-17
controller resistors 9-5
controller specifications 11-1
controller, analog PIDF, defined 9-1
Controller, defined 1-1
controller, mounting 4-20
counter, using cycle 3-4
current excitation 5-7
Cyc Cnt 3-2
Cyc Src 2-10
cycle count (on DVM) 3-5
cycle count, function generator 3-2
cycle counter source 2-10, 3-4
cycle counter, setting maximum 3-4
cycle counter, using 3-4
cycle source off 2-10
cycle source program 2-10
cycle source sync 2-10

D Gain 2-18, 2-40
D Gain, default 2-31, 3-7
D Src 2-18
D Src, default 2-31, 3-7
daisy chain connections 4-11, 4-12
dc conditioner
board 5-5, 5-11
bridge balancing 5-9
excitation mode 5-8
excitation sensing 5-8
excitation, adjustable 5-9
filter 5-11
jumper settings 5-7
jumpers 5-6, 5-7
monitor output 5-2
resistors 5-9
shunt calibration 5-13
dc conditioner shunt calibration 2-35
dc conditioner, defined 5-1
dc conditioner, specifications 11-3, 11-4
DCx COND Setup 2-30, 3-6
DCx COND signal 2-23
DCx Conditioner menu 2-29
DCx Lo 2-21, 2-24
DCx shunt cal check 2-35
DCx Up 2-21, 2-24
deactivating shunt cal 2-35
default parameters 2-31, 3-7
Delta K 2-33
delta K, conditioner 2-33

Delta K, default 2-31, 3-7
delta P conditioner 2-18
delta P gain 2-18
delta P gain resistor 9-5
delta P transducer calibration 5-20
delta P, defined B-12
demodulator filter header 6-5, 7-5
demodulator filter, ac conditioner 6-7, 6-8
demodulator phase 2-34, 2-40
derivative gain 2-18
derivative gain resistor 9-5
derivative gain, 3-stage valve driver 2-40
derivative gain, defined B-12
differential pressure conditioner 2-18
differential pressure gain 2-18
differential pressure transducer calibration 5-20
differentiator source 2-18
DigIn 2-22
digital I/O
  example 4-15
  input 1 action 2-26
  input 1 polarity 2-27
  input 2 action 2-27
  input 2 polarity 2-27
  input actions 2-26
  input interlock 2-22
  output 1 event 2-27
  output 1 polarity 2-28
  output 2 event 2-28
  output 2 polarity 2-28
  wiring 4-15
Digital I/O menu 2-26
digital voltmeter 2-5, 2-42, 3-2
digital voltmeter specifications 11-3
Din1 2-26
Din1 interlock 2-22
Din1Pol 2-27
Din2 2-27
Din2 interlock 2-22
Din2Pol 2-27
DIO connections 4-15
DIO example 4-15
display screen 2-4
display, digital voltmeter 2-42, 3-2
Dither 2-37, 2-40
dither amplitude 2-37, 2-40
dither frequency, three-stage valve driver 7-6
dither frequency, valve driver 8-7
Dout1 2-27
Dout1Pol 2-28
Dout2 2-28
Dout2Pol 2-28
down arrow key 2-5, 2-6
dP Cond 2-18
dP Cond, default 2-31, 3-7
dP Gain 2-18
dP Gain, default 2-31, 3-7
DVM 2-5
  monitoring adjustments 3-3
  resetting max/min limits 3-3
DVM signals 3-2
  command 3-2
  command max/min 3-2
  command peak/valley 3-2
  conditioner max/min 3-2
  conditioner output 3-2
  conditioner peak/valley 3-2
  error 3-2
  error max/min 3-2
  error peak/valley 3-2
  valve command 3-2
  valve command max/min 3-2
  valve command peak/valley 3-2
  valve commandpeak/valley 3-2
  valve monitor max/min 3-2
  valve monitor peak/valley 3-2
  valve monitor peak/valley 3-2
DVM specifications 11-3
DVM, using 2-42, 3-2
DVM/Menu key 2-5, 2-42, 3-2

E-stop button 2-2
E-stop connections, remote 4-13
E-stop interlock (ESTOP) 2-20
E-stop to 407 controller, remote 4-13
E-stop to 407.05 4-14
emergency stop button 2-2
emergency stop connections, remote 4-13
emergency stop interlock (ESTOP) 2-20
end-of-count (EOC) action 2-10
end-of-count (EOC) interlock 2-20
Eng Units 2-9
engineering units 2-9, 2-32
Enter key 2-5, 2-6
Enter key in menus 2-6
Enter Lvl 2-14
entering value 2-7
EOC 2-20
EOC Act 2-10
EOC action 3-4
EOC reset 3-5
EOC, checking 3-5
ErrLim 2-24
Error 2-21, 2-42, 3-2
error detector, defined B-6
error interlock 2-21
error limit 2-24
error limits, setting B-7
error max/min 2-42, 3-2
error peak/valley 2-42, 3-2
ERROR signal 2-23
error, determining acceptable B-6
ESTOP 2-20
event, Dout1 2-27
event, Dout2 2-28
example, digital I/O 4-15
example, user digital I/O 4-15
Excit 2-33, 2-40
Excit, default 2-31, 3-7
excitation
  3-stage valve conditioner 2-40
  ac conditioner 6-6
  adjustable 5-7, 6-5, 7-5
  adjustable ac conditioner 6-6
  adjustable dc conditioner 5-9
  conditioner 2-33
  current 5-7
  dc conditioner 5-8
  fixed 5-7, 6-5, 7-5
  internal/external 5-7
  sense 5-7
  three-stage valve conditioner 2-40
excitation frequency selection 6-5, 7-5
excitation frequency, three-stage valve driver 7-6
excitation mode, ac conditioner 6-6
excitation mode, dc conditioner 5-8
excitation selection 5-7, 6-5, 7-5
excitation sensing, dc conditioner 5-8
Extern 2-22
external 407 interlock 2-22
external guard 5-7, 5-10
external Hyd connections 4-11
external interlock connections 4-12
external Intlk connections 4-12

external program connections 4-10
external Run/Stop input 1-2
external shunt cal resistor 5-12
external waveform 2-15

F Gain 2-18
F Gain, default 2-31, 3-7
F Zero 2-33, 2-39
F Zero, default 2-31, 3-7
F.S. Val 2-32
F.S.Val, default 2-31, 3-7
F0–F3 keys 2-5
F1 key (shunt cal) 2-35
F2 key (shunt cal) 2-35
F3 key (shunt cal) 2-35
Fdback 2-17
Fdbk Pol 2-40
feedback 2-18
feedback conditioner 2-17
feedback limit detectors, defined B-5
feedback polarity 2-34, 2-40, 3-8, 3-9
feedforward gain 2-18
feedforward gain resistor 9-5
feedforward gain, defined B-12
FG specifications 11-2
filter characteristics, ac conditioner 6-7
filter characteristics, dc conditioner 5-11
filter, ac conditioner 6-7
filter, dc conditioner 5-11
fine zero 5-2, 6-2, 7-2
fine zero, 3-stage valve conditioner 2-39
fine zero, conditioner 2-33
fine zero, three-stage valve conditioner 2-39
fixed shelf mounting 4-20
floating source, ac conditioner resistors 6-9
force transducer calibration 5-20
Freq 2-15
frequency, function generator 2-15
front panel 1-2
full bridge 4-wire configuration 5-17
full bridge 8-wire configuration 5-18
full bridge 9-wire configuration 5-19
full scale output resistors, valve driver 7-7, 8-6
full scale, conditioner 2-32
full scale, three-stage valve driver 7-7
full scale, valve driver 8-6
function generator 1-2
  cycle count 3-2
  frequency 2-15
  parameters 2-15
  preset (maximum count 2-16, 2-42, 3-2
  setpoint 2-15
  span 2-16
  specifications 11-2
  waveform 2-15
Function Generator menu 2-15
function keys (F0–F3) 2-5

Gain 2-33, 2-39
gain, 3-stage valve conditioner 2-39
gain, 3-stage valve driver 2-40
gain, ac conditioner 6-2, 7-2
gain, conditioner 2-33
gain, dc conditioner 5-2
Gain, default 2-31, 3-7
gain, delta P 2-18
gain, derivative 2-18
gain, derivative, defined B-12
gain, feedforward 2-18
gain, integral 2-18
gain, integral, defined B-11
gain, proportional 2-17
gain, proportional, defined B-11
gains, saving PIDF 3-6
gains, servo loop B-11
gains, switching PIDF 3-6
grounding and voltage 4-2
guard connection 5-7, 5-10
guard reference 5-7, 6-5, 7-5

half bridge 3-wire configuration 5-16
handle kit, installing 4-18
header, shunt cal 5-13
High key, hydraulics 2-2
Hold key 2-3
Home key 2-5
Home key in menus 2-6
HPS configuration 2-12
HPS connections 4-6
HPS control 2-11
HPS control specifications 11-3
HPS interface 4-7
HPS interface, HPS connection 4-8, 4-9
HPS interface, modular I/O 4-7
HPS low fluid interlock 2-21
HPS over temperature interlock 2-22
HPS to pump interface 4-9
HPS to pump interface 4-8
HPS1 2-21
HPS2 2-22
HPSHSM configuration 2-12
HSM configuration 2-11
HSM connections 4-5
HSM connector, pinout 4-5
HSM control 2-11
HSM driver, adjusting 10-7
HSM switches 4-5
Hyd Config 2-11
Hyd connections, external 4-11
Hyd In connections 4-11
Hyd Out connections 4-11
hydraulic configuration 2-11
hydraulic configuration, HPSHSM 2-12
hydraulic interface, HPS connection 4-8, 4-9
hydraulic interface, modular I/O 4-7
hydraulic power supply connections 4-6
hydraulic power supply control specifications 11-3
hydraulic pressure control 1-2
hydraulic pressure keys 2-2
hydraulic pump interface 4-7
hydraulic service manifold connections 4-5

I Gain 2-18
I Gain, default 2-31, 3-7
I/O, modular in pump interface 4-7
Info key 2-5
information, on-screen 2-5
inhibit 1-3
inner loop, three-stage valve driver 7-9
input 1, digital 2-26, 2-27
input 2, digital 2-27
installing 407 Controller 4-20
installing 407 module 4-4
installing controller 4-20
integral gain 2-18
integral gain resistor 9-5
integral gain, defined B-11
interface, hydraulic 4-7
interlock
  digital input 2-22
  Din1 2-22
  Din2 2-22
  emergency stop 2-20
  end-of-count (EOC) 2-20

error 2-21
external 407 2-22
low hydraulic fluid 2-21
lower limit 2-21
overtemp hydraulic fluid 2-22
underpeak level (peak) 2-22
underpeak level (valley) 2-22
upper limit 2-21
user digital input 2-22
interlock configuration 2-13
interlock connections, external 4-12
interlock indicator 2-2
interlock master 2-13
interlock slave 2-13
interlock, defined 2-2
interlock, E-Stop 2-20
interlock, end-of-count (EOC) 2-20
interlocks 1-2
interlocks, checking 2-19
interlocks, resetting 2-5
internal guard 5-7, 5-10
internal/external excitation 5-7
Intlk Config 2-13
Intlk connections, external 4-12
Intlk In connections 4-12
Intlk Out connections 4-12
Intlk Status menu 2-19
inverting conditioner polarity 2-34
inverting valve polarity 2-38, 2-40, 2-41

jumper settings, dc conditioner 5-7
jumpers, ac conditioner 6-5
jumpers, analog controller 9-4
jumpers, dc conditioner 5-6, 5-7
jumpers, PIDF controller 9-4
jumpers, three-stage valve driver 7-5
jumpers, valve driver 8-5

key
+/– 2-7
0–9 2-7
Alt Fun 2-5
Back Space 2-5
Clear Entry 2-5
decimal point 2-7
down arrow 2-5
DVM 2-42, 3-2
DVM/Menu 2-5
Enter 2-5
F0–F3 2-5
High 2-2
Home 2-5
Info 2-5
Low 2-2
numeric 2-7
Off 2-2
Recall 2-5
Reset 2-5
Run 2-3
Save 2-5
Set Point 2-5
Span 2-5
up arrow 2-5
keypad, self-test 10-2
keys, arrow 2-5
keys, hydraulic pressure 2-2
keys, menu 2-5
knob, adjustment 2-7

LEDs, Power Supply OK 10-2
LEDs, self-test 10-2
level, access 2-14
level, P/V sensitivity 2-13
limit detection, defined B-4
limit detector specifications 11-2
Limit Settings menu 2-24
limit, error 2-24
limit, lower conditioner 2-24
limit, upper conditioner 2-24
limits, defining 2-24
limits, reset max/min 3-3
line voltage 4-2
list of choices 2-6
load cell calibration 5-20
loop, defined B-2
low hydraulic fluid interlock 2-21
Low key, hydraulics 2-2
low pass filter, ac conditioner 6-7
low pass filter, dc conditioner 5-11
lower limit 2-24
lower limit interlock 2-21
LVDT calibration 6-10
LVDT connector 7-3

maintenance, routine 10-1
master controller 2-13
Max Val 2-25
max/min limits, reset 3-3
maximum valley value 2-25
memory, self-test 10-2
menu
2-stage Valv Drv 2-37
3-stage Valv Drv 2-39
ACx Conditioner 2-29
Configuration 2-9
Controller 2-17
DCx Conditioner 2-29
Digital I/O 2-26
Function Generator 2-15
Intlk status 2-19
Limit Settings 2-24
Monitor Select 2-23
menu keys 2-5
menu summary 2-8
menus on display screen 2-4
menus, all 2-8
menus, moving through 2-6
Min Pk 2-25
minimum peak value 2-25
module, installing 407 4-4
module, removing 407 4-4
modules, plug-in 1-2
Mon1 2-23
Mon2 2-23
Monitor 2-34, 2-38, 2-41
ac conditioner 6-2
dc conditioner 5-2
three-stage valve driver 7-2
valve driver 8-2
Monitor 1&2 BNC connectors 2-3
monitor output specifications 11-2
Monitor Select menu 2-23
monitoring signals 2-3
mounting 407 Controller 4-20
mounting controller 4-20
mounting, fixed shelf 4-20
mounting, on slide top 4-22
MTS part numbers 10-4
multiple 407 configurations 4-11, 4-12
multiple 407 connections 4-11, 4-12

NONE (hyd configuration) 2-12
numeric keys 2-7

Off key, hydraulics 2-2
offset, ac conditioner 6-2, 7-2
offset, dc conditioner 5-2
operating sequence, typical 3-10
output 1, digital 2-27, 2-28
output 2, digital 2-28
output filter, ac conditioner 6-7
output filter, dc conditioner 5-11
overtemp hydraulic fluid interlock 2-22

P Gain 2-17, 2-40
P Gain, default 2-31, 3-7
P/V Sens 2-13
part numbers 10-4
password, security 2-14
peak value, minimum 2-25
peak/valley level 2-13
Phase 2-34, 2-40
phase, 3-stage valve conditioner 2-40
phase, ac conditioner 2-34, 2-40
Phase, default 2-31, 3-7
phase, three-stage valve conditioner 2-40
phasing, 3-stage valve 3-8
phasing, valve 3-8
PIDF controller
  board 9-3
  connectors 9-2
  jumpers 9-4
  rear panel 9-2
  resistors 9-5
PIDF controller, defined 9-1
PIDF controls 2-17
PIDF gains, saving 3-6
PIDF gains, switching 3-6
pinout, ac conditioner 6-3
pinout, analog controller 9-2
pinout, dc conditioner 5-4
pinout, HSM connector 4-5
pinout, PIDF controller 9-2
pinout, three-stage valve driver 7-3
pinout, two-stage valve driver 8-3
plug-in modules 1-2
Polarity 2-34, 2-38
polarity, 3-stage valve 3-8
polarity, conditioner feedback 2-34
Polarity, default 2-31, 3-7
polarity, Din1 2-27
polarity, Din2 2-27
polarity, Dout1 2-28
polarity, Dout2 2-28
polarity, feedback 3-9
polarity, valve 3-8
power check self-test 10-2
Power Supply OK LEDs 10-2
power supply specifications 11-1
power, 407 controller 4-2
power-up self-test 10-2
pre-shunt value 2-35
preamp zero reference 5-7, 6-5, 7-5
Preset 2-16, 2-42, 3-2
preset (maximum count), function generator 2-16, 2-42, 3-2
preset (on DVM) 3-5
preset, using 3-5
pressure control 1-2
pressure control keys 2-2
program control keys 2-3
program run key 2-3
program stop key 2-3
proportional gain 2-17
proportional gain resistor 9-5
proportional gain, 3-stage valve driver 2-40
proportional gain, defined B-11
pump interface, HPS connection 4-8, 4-9
pump interface, modular I/O 4-7

quarter bridge 3-wire configuration 5-15

ramp setpoint 2-10
ramp span 2-11
ramp wave 2-15
rate (derivative gain) 2-18
rate, defined B-12
rear panel connections 4-1
rear panel, ac conditioner 6-3
rear panel, analog controller 9-2
rear panel, dc conditioner 5-4
rear panel, PIDF controller 9-2
rear panel, three-stage valve driver 7-3
rear panel, valve driver 8-3
Recall key 2-5
releasing shunt cal 2-35
remote E-stop connections 4-13
remote emergency stop connections 4-13
removing 407 module 4-4
reset (gain), defined B-11
reset EOC 3-5
Reset key 2-5
reset max/min limits 3-3
reset time constant (integral gain) 2-18
resetting interlocks 2-5
resistor
  ac conditioner 6-5, 6-6
  ac conditioner floating source 6-9
  analog controller 9-5
  bridge balance 5-12
  bridge completion 5-12, 5-15
  completion 6-8, 7-8
  dc conditioner 5-9, 5-12
  delta P gain 9-5
  derivative gain 9-5
  external shunt cal 5-12
  feedforward gain 9-5
  integral gain 9-5
  PIDF controller 9-5
  proportional gain 9-5
  shunt cal 2-36, 5-14
ROM self-test 10-2
ROM, replacing 10-9
Run key 2-3
Run/Stop, external 1-2

Save key 2-5
saved parameters 2-31, 3-7
saving conditioner setup 2-30, 3-6
saving PIDF gains 3-6
screen, display 2-4
security access level 2-14
select resistors, ac conditioner 6-6
select resistors, dc conditioner 5-9
select valve clamping 8-5
selecting conditioner 2-17
selecting item 2-6
self-test, power-up 10-2
servo loop gains B-11
servovalve connections 4-17
servovalve control signal, defined B-3
Set Point key 2-5
Setpnt 2-15
setpoint key 2-5
setpoint ramp 2-10
setpoint, defined B-10
setpoint, function generator 2-15
SetPt R 2-10

setting limits 2-24
setup data, defined 2-31, 3-7
setup, saving conditioner 2-30, 3-6
setup, switching conditioner 2-30, 3-6
setups, saving example 2-31
shunt cal check, dc conditioner 2-35
shunt cal ranges 5-14
shunt cal resistor, external 5-12
shunt cal resistor, internal 5-7
shunt cal, deactivating 2-35
shunt calibration 2-35
  @ sign 2-35
  delta value 2-35
  pre-shunt value 2-35
  resistor 2-36
shunt calibration configuration 5-10
shunt calibration header 5-13
shunt calibration resistor 5-4
shunt calibration resistor, selecting 5-7
shunt calibration, dc conditioner 5-3, 5-13
shunt resistors 5-10
signal
  ACx COND 2-23
  CMD 2-23
  command 2-42, 3-2
  command max/min 2-42, 3-2
  command peak/valley 2-42, 3-2
  conditioner max/min 2-42, 3-2
  conditioner output 2-42, 3-2
  conditioner peak/valley 2-42, 3-2
  DCx COND 2-23
  ERROR 2-23, 2-42, 3-2
  error max/min 2-42, 3-2
  error peak/valley 2-42, 3-2
  valve command 2-42, 3-2
  valve command max/min 2-42, 3-2
  valve command peak/valley 2-42, 3-2
  valve monitor max/min 3-2
  valve monitor peak/valley 3-2
  VLV CMD 2-23
  VLV MON 2-23
signal common 4-2
signal monitoring 2-3
signal, Mon1 2-23
signal, Mon2 2-23
signal, Monitor 1 signal 2-23
signal, Monitor 2 signal 2-23
signal, underpeak 2-25
signals, 2-stage valve driver monitor 2-38
signals, 3-stage valve driver monitor 2-41
signals, conditioner monitor 2-34
signals, DVM 3-2
signals, valve driver monitor 2-38, 2-41
sine wave 2-15
slave controller 2-13
slide top, mounting on 4-22
slot information, self-test 10-2
slots, scanned in self-test 10-2
source, cycle counter 3-4
source, differentiator 2-18
Span 2-16
Span key 2-5
Span R 2-11
span ramp 2-11
span, defined B-9
span, function generator 2-16
specifications
  407.12 DC Conditioner 11-3, 11-4
  407.14 AC Conditioner 11-4
  407.15 Three-stage Valve Driver 11-5
  407.16 Valve Driver 11-6
  controller 11-1
  DVM 11-3
  function generator 11-2
  HPS control 11-3
  limit detector 11-2
  monitor output 11-2
  power supply 11-1
square wave 2-15
Stop key 2-3
stop, emergency 2-2
strain gage calibration 5-24
strain gage, reference data 5-27
switches, HSM 4-5
switching conditioner setup 2-30, 3-6
switching PIDF gains 3-6

three-stage valve conditioner coarse zero 2-39
three-stage valve conditioner excitation 2-40
three-stage valve conditioner fine zero 2-39
three-stage valve conditioner phase 2-40
three-stage valve driver
  balance 2-41
  board 7-4
  configuration (for 2-stage valve) 7-12
  demodulator filter 7-7
  dither 2-40
  dither frequency 7-6
  excitation frequency 7-6
  full scale 7-7
  gain 2-40
  inner loop 7-9
  jumpers 7-5
  output 7-2
  parameters 2-39
  polarity 2-41
  resistors 7-8
  specifications 11-5
  tuning 7-10
  valve clamping 7-6
three-stage valve driver, defined 7-1
three-stage valve feedback polarity 2-40
torque cell calibration 5-20
transducer excitation, ac conditioner 6-6
transducer excitation, dc conditioner 5-8
transducer connections 4-16
triangular wave 2-15
troubleshooting 10-3
  BRAM 10-3
  HPS 10-3
  interlock 10-3
  no display 10-3
  power supply failure 10-3
  self-test 10-3
  setpoint and span 10-3
tuning inner loop, three-stage valve driver 7-9
two-stage valve driver (See also VALVE DRIVER)
  balance 2-37
  dither 2-37
  parameters 2-37
  polarity 2-38
  valve clamping 8-5
two-stage valve driver, defined 8-1

underpeak detection, defined B-8
underpeak Peak interlock 2-22
underpeak Valley interlock 2-22
underpeak, selecting signal 2-25
Units 2-32
units, default 2-31, 3-7
units, engineering 2-9, 2-32
up arrow key 2-5, 2-6
Upk Sig 2-25
UpkPeak 2-22

UpkVly 2-22
upper limit 2-24
upper limit interlock 2-21
user digital I/O
  example 4-15
  input 1 action 2-26
  input 1 polarity 2-27
  input 2 action 2-27
  input 2 polarity 2-27
  input interlock 2-22
  inputs 2-26
  output 1 event 2-27
  output 1 polarity 2-28
  output 2 event 2-28
  output 2 polarity 2-28
  outputs 2-26
  wiring 4-15
user DIO connections 4-15
user I/O example 4-15
user I/O wiring 4-15
using DVM 2-42, 3-2
using menus 2-6

valley value, maximum 2-25
valve balance 2-37, 2-41
valve clamping command 8-5
valve clamping command jumper 8-5
valve clamping enable jumper 7-5, 8-5
valve clamping select 8-5
valve clamping, three-stage valve driver 7-6
valve clamping, two-stage valve driver 8-5
valve command 2-42, 3-2
valve command max/min 2-42, 3-2
valve commandpeak/valley 2-42, 3-2
valve command polarity 2-38, 2-41
valve driver
  board 8-4
  dither frequency 8-7
  full scale 8-6
  full scale selection 7-7, 8-6
  jumpers 8-5
  monitor output 8-2
  monitor signals 2-38, 2-41
  parameters, 2-stage 2-37
  parameters, 3-stage 2-39
valve driver, defined 8-1
Valve Driver, specifications 11-6
valve driver, three-stage, defined 7-1
valve monitor max/min 3-2
valve monitor peak/valley 3-2
valve phasing 3-8
valve polarity 3-8
VLV CMD signal 2-23
VLV MON signal 2-23
Vlv Pol 2-41
voltage and grounding 4-2
voltage, pre-shunt 2-35

waveform, function generator 2-15
wiring, digital I/O 4-15
wiring, user digital I/O 4-15
writing top, mounting on 4-22
Wvform 2-15

zero offset, ac conditioner 6-2, 7-2
zero offset, dc conditioner 5-2
zero reference, preamp 5-7, 6-5, 7-5