



## **L-Series Process Controller**

**Installation, Programming, and Troubleshooting Manual**



### General Precautions

Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment.

Practice all plant and safety instructions and precautions.

Failure to follow instructions can cause personal injury and/or property damage.



### Revisions

This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, check manual **26455**, *Customer Publication Cross Reference and Revision Status & Distribution Restrictions*, on the *publications* page of the Woodward website:

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### Proper Use

Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.



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The original source of this publication may have been updated since this translation was made. Be sure to check manual **26455**, *Customer Publication Cross Reference and Revision Status & Distribution Restrictions*, to verify whether this translation is up to date. Out-of-date translations are marked with . Always compare with the original for technical specifications and for proper and safe installation and operation procedures.

**Revisions**—Changes in this publication since the last revision are indicated by a black line alongside the text.

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## Warnings and Notices

### Important Definitions



This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

- **DANGER**—Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
- **WARNING**—Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- **CAUTION**—Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
- **NOTICE**—Indicates a hazard that could result in property damage only (including damage to the control).
- **IMPORTANT**—Designates an operating tip or maintenance suggestion.

#### **WARNING**

**Overspeed /  
Overtemperature /  
Overpressure**

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.

#### **WARNING**

**Personal Protective  
Equipment**

The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:

- Eye Protection
- Hearing Protection
- Hard Hat
- Gloves
- Safety Boots
- Respirator

Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.

#### **WARNING**

**Start-up**

Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.

#### **WARNING**

**Automotive  
Applications**

On- and off-highway Mobile Applications: Unless Woodward's control functions as the supervisory control, customer should install a system totally independent of the prime mover control system that monitors for supervisory control of engine (and takes appropriate action if supervisory control is lost) to protect against loss of engine control with possible personal injury, loss of life, or property damage.

**NOTICE****Battery Charging  
Device**

To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.

## Electrostatic Discharge Awareness

**NOTICE****Electrostatic  
Precautions**

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts:

- Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).
- Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.
- Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual **82715**, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

Follow these precautions when working with or near the control.

1. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
2. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
  - Do not touch any part of the PCB except the edges.
  - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
  - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

## Regulatory Compliance

### European Compliance for CE Marking:

These listings are limited only to those units bearing the CE Marking:

**EMC Directive:** Declared to 89/336/EEC COUNCIL DIRECTIVE of 03 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility.

These listings are limited only to those units bearing the ATEX markings as well as the CE Mark:

**ATEX – Potentially Explosive Atmospheres Directive:** Declared to 94/9/EC COUNCIL DIRECTIVE of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres. Zone 2, Category 3, Group II G, EEx nA II T3 X  
–40 °C ≤ Tamb ≤ +105 °C, IP56

**Special Condition for Safe Use:** *The installer of the L-series must take responsibility for meeting Sub-Clause 26.3.3.1 of EN60079-15:2003 regarding impact testing. The actuator by itself does not meet this requirement and therefore must be sufficiently protected when installed. See Chapter 2, Mechanical Installation, for more details.*

### Other European and International Compliance:

Compliance with the following European Directives or standards does not qualify this product for application of the CE Marking:

**Machinery Directive:** Compliant as a component with 98/37/EC COUNCIL DIRECTIVE of 23 July 1998 on the approximation of the laws of the Member States relating to machinery.

**Pressure Equipment Directive:** Exempt per Article 1-3.10

### North American Compliance:

These listings are limited only to those units bearing the CSA identification

**CSA:** CSA Certified for Class I, Division 2, Groups A, B, C, & D, T3C at 105 °C Ambient for use in Canada and the United States.  
Certificate 1380416

This product is certified as a component for use in other equipment. The final combination is subject to acceptance by the authority having jurisdiction.

Wiring must be in accordance with North American Class I, Division 2 or European Zone 2, Category 3 wiring methods as applicable, and in accordance with the authority having jurisdiction.

Field wiring must be suitable for at least 105 °C.

Connect ground terminal to earth ground.

The actuator should be protected from exposure to sunlight and rain.

 **WARNING**

**EXPLOSION HAZARD—Do not connect or disconnect while circuit is live unless area is known to be non-hazardous.**

**Substitution of components may impair suitability for Class I, Division 2 or Zone 2 applications.**

**Do not clean equipment unless power has been switched off or the area is known to be non-hazardous.**

 **AVERTISSEMENT**

**RISQUE D'EXPLOSION—Ne pas raccorder ni débrancher tant que l'installation est sous tension, sauf en cas l'ambiance est décidément non dangereuse.**

**La substitution de composants peut rendre ce matériel inacceptable pour les emplacements de Classe I, applications Division 2 ou Zone 2.**

# Chapter 1.

## General Information

### Purpose and Scope

The purpose of this manual is to provide the necessary background information for applying the L-Series Process Controller as an air/fuel (A/F) ratio control for gaseous-fueled reciprocating engines and as a limited process control. Topics covered include mechanical installation, electrical wiring, software configuration, tuning and troubleshooting. While this manual is primarily targeted at OEM customers, OEMs themselves may find it useful to copy some of the information from this manual into their application user manuals.

This manual revision (revision H) applies to all L-Series Process Controllers with software 5418-1681 rev NEW or 5418-2834 rev NEW. The software part number is provided on the Identification tab of the Service Tool. The following identifies the added/modified features available in 5418-2834 firmware:

- Dual dynamics option added to the Process PID.
- Dual Bias curve option added.
- Bias functionality was changed for AFR applications. In 5418-2834 firmware the bias is summed with the Process Setpoint whereas with 5418-1681 firmware it is summed with the Process PID output. Refer to Figures 4-8a and 4-8b in Chapter 4.
- Configurable delay added to Open Loop Active discrete output indication.

### How to Use This Manual

The following summarizes how to install an L-Series process controller into a new or existing system:

- Unbox, inspect and mount the hardware (Chapter 2).
- Wire the hardware (Chapters 3).
- Configure the control using the Service Tool (Chapter 6). Not required if pre-configured by OEM.
- Setup and tune the control (Chapter 7). Not required if set up by OEM.
- Troubleshooting the control (Chapter 8).
- Specifications are provided in Appendix B.

### Intended Applications

The L-Series process controller provides a flexible control solution for applications including air/fuel ratio control, pressure control and certain other process control functions. It provides a suitable replacement for mechanical systems that need more flexibility in control strategy. The L-Series process controller is designed for industrial applications ranging from generators and mechanical drives to pumps and compressors.

Key environmental characteristics of these applications include extended industrial operating temperatures (–40 to +105 °C/–40 to +221 °F), industrial EMC requirements, electrical transients, and lower operating voltages (12/24 V).

## Introduction

The Woodward L-Series process controller combines the L-Series electric actuator with integrated process control software to control the air/fuel ratio of a gaseous-fueled engine and various process functions, such as fuel gas pressure regulation. The L-Series is a microprocessor-based controller incorporated into the actuator, creating a single integrated package. This eliminates the need for an additional driver box and A/F ratio control box.

The L-Series provides a building block approach to a total engine management. The modular bi-directional actuator design easily attaches to trim valves or throttle bodies.

Woodward also offers L-Series actuator versions for Position Control and Speed Control applications. Refer to manuals 26289 (Position Control) or 26250 (Speed Control).

The L-Series process controller accepts a process input signal (e.g., O<sub>2</sub>, Diff Press, etc.), compares this to the process setpoint, and drives the 0–60 degree output shaft to the commanded position based on an internal shaft position sensor. The high-efficiency torque motor delivers 0.34 N·m (0.25 lb-ft) nominally over 60° travel range to operate fuel control devices (see specifications in Appendix B for torque performance over the full product temperature range).

The L-Series performs comprehensive diagnostics for easy troubleshooting. It is configured and tuned using the L-Series Service Tool. See Chapters 5, 6, and 7.

There are 5 AUX inputs for I/O functions, configurable as digital inputs, analog inputs, or used for RS-232 Service Tool communications. The functions available for AUX input configuration are listed below, however not all functions are available on all firmware versions.

- Process analog input
- Trim analog input
- Bias analog input
- Position Command analog input
- Target 2 Select digital input
- Trim Enable digital input
- Bias Curve 2 Select digital input
- Open Loop Select digital input
- Raise Process Setpoint digital input
- Lower Process Setpoint digital input
- Raise Trim Setpoint digital input
- Lower Trim Setpoint digital input
- Process Dynamics 2 Select digital input

For status purposes, a relay driver output is available that changes state whenever the L-Series controller experiences a fault or error condition. Some fault conditions are hard coded while others are configurable.

If the system requires, the L-Series provides a direct position output signal in the form of a dc voltage. The throttle position (TPS) output represents full counterclockwise (CCW) to clockwise (CW) rotation of the actuator shaft, and thus gives the operator an external position indication after installation and while the unit is operating.

### **WARNING**

**When included with an ITB, the actuator depends solely on the return spring inside the throttle body assembly to drive toward minimum fuel when not powered. Therefore other positive shutdown devices like fuel shut-off solenoids are recommended to ensure shutdown on loss of signal to the control system. Also, separate overspeed trip devices are always mandatory.**

## Basic Control Options

### L-Series Product

- 10–32 Vdc supply operation voltage
- CW / CCW (clockwise/counterclockwise) direction control
- 5 Configurable AUX Inputs
- TPS output for position indication
- Discrete output to indicate diagnostic states
- RS-232/Service Tool interface

### L-Series Service Tool

- Windows PC-based
- Download available at no cost to customers
- Used to Configure, Monitor, and Tune L-Series parameters
- Similar look & feel between all L-Series products
- Requires programming harness and serial cable
- Security options available

### L-Series A/F Ratio System

- Pre-catalyst, closed loop, exhaust oxygen feedback control
- Configurable for concurrent differential press regulation
- Configurable for concurrent mapped bias position
- Tunable valve dither
- Reversible control action
- Manual open loop enable switch
- On-the-fly switching between two sets of control parameters
- Diagnostics for min and max positions and O2 sensor failure

### L-Series Applications

- Air/Fuel Ratio control
- Full Authority System A/F control
- Process Control
- Position Control

#### **WARNING**

The actuator must be properly set up using the L-Series Service Tool prior to starting the prime mover.

#### **NOTICE**

OEMs and end users are strongly encouraged and expected to develop and thoroughly test specific L-Series Process Control schemes for their engines under both normal and extreme operating conditions before widely applying a control scheme. While extensive testing has been performed on a limited number of engines to prove the L-Series Process Control functions, no attempt has been made to test the many and varied possible control schemes on a broad number of engines in various process control applications.

#### **IMPORTANT**

The Service Tool is not included, but can be downloaded from the Woodward Internet website ([www.woodward.com/software/](http://www.woodward.com/software/)).

Use external monitoring of process to ensure proper action/reaction to desired system parameters, changes, and settings.

**LCS A/F Ratio Control Part Numbers**

Description	Woodward Part Number
AFR Trim Valve Assembly, 16 mm	8404-3001
AFR Trim Valve Assembly, 22 mm	8404-3002
Position Control Trim Valve Assembly, 16 mm	8404-3003
Gasket, Trim Valve—Mixer	3051-073
Screws, Metric Soc Hd, M5x0.8, 16 mm	1029-399
HEGO Sensor	1680-6005
UEGO Sensor Kit	DL08311000
HEGO/UEGO Weld-in Insert	1138-581
Electrical Connectors	See Chapter 3
Programming Harness	8923-1061

**IMPORTANT****The gasket must be ordered separately.****Programmable Features**

Control setup and tuning is accomplished through the use of a PC (personal computer), Woodward Service Tool software, and a programming harness. The features identified below are described in Chapter 4.

Briefly, the programmable features include:

- Application Setup
- General Setup Parameters
  - o Fail Direction (CCW or CW)
  - o Min Position Direction (CCW or CW)
- Valve Position Control Parameters
- Process Setpoint Setup Parameters
  - o Functionality Settings
  - o Control Action (Direct or Reverse)
  - o Settings and Rates
  - o Dynamics Settings
- Trim Control Setup Parameters
  - o Functionality Settings
  - o Control Action (Direct or Reverse)
  - o Settings and Rates
  - o Dynamics Settings
- Bias Setup
- Discrete Output Settings
- Discrete Input Settings
- Fault Settings
- Security Settings

**Service Tool Software**

The L-Series Service Tool software is a Microsoft Windows® based GUI (graphic user interface). The Service Tool Software is compatible with Windows 95/98/NT/2000/Me/XP and gives the OEM the ability to:

- Configure product settings based on application requirements
- Tune the control with the engine running during application development
- Create configuration files for downloading into multiple controls
- Upload and Download configuration files
- Extract and view fault codes for field diagnosis
- Update control dynamics during field service
- Calibrate the control for user stops

In addition, the Service Tool can be configured to incorporate security to limit access to and protect application settings where needed.

Detailed descriptions of software features and installation are available in Chapters 4–7.

## Determining Proper Valve Size

The proper valve size can be determined using the equation below. The required Cv (Flow Coefficient) should be calculated for both the minimum and maximum flows expected on the application. This design allows for 80 degrees of throttle plate rotation.

Using the graph and table below, select the closest valve that has a Cv equal to or greater than the maximum flow value at approximately 80% opening (64 degrees) to ensure reasonable flow margin. Also, check that the particular valve's minimum Cv listed below is less than the minimum calculated Cv for good low idle performance.

$$Cv = \frac{Q * 0.00976}{P1} \sqrt{\frac{(T + 460) * P1 * Sg}{P1 - P2}}$$

Where:

Cv = Flow Coefficient

Q = Mass Flow (PPH [pounds/hour] (1 pound = 0.45 kg)

Sg = Specific Gravity of Gas (use 1.0 for air)

T1 = Upstream Gas Temperature (°F) (°F = 1.8 \* °C + 32)

P1 = Inlet Pressure (psia) (1 psi = 6.895 kPa = .06895 bar)

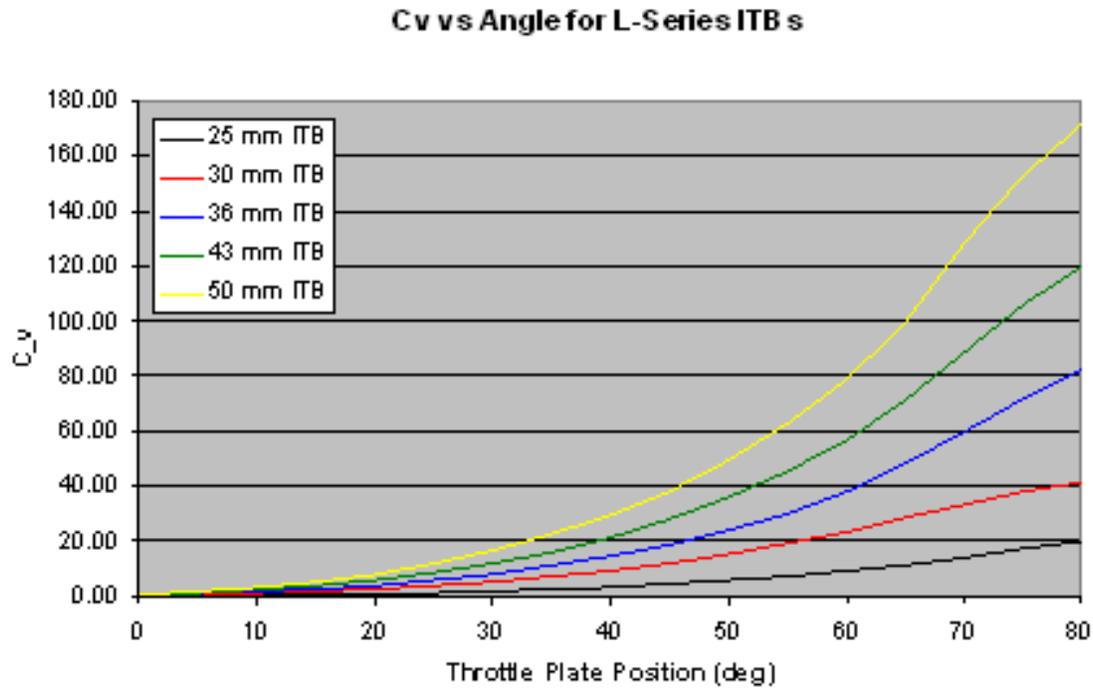
P2 = Downstream Pressure (psia)

### Note!

P2 must be greater than 0.528\*P1 or flow becomes choked. If P2 less than 0.528\*P1, then use P2= .528\*P1

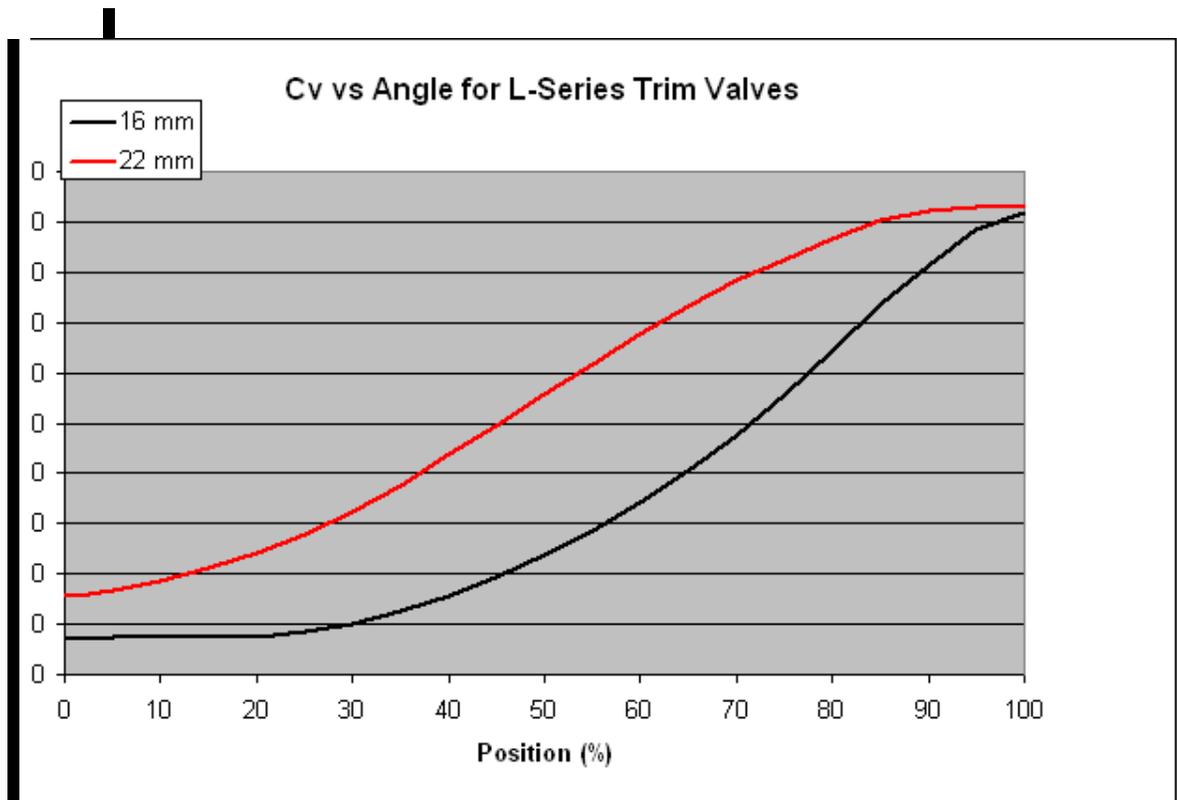
Plate Angle	25 mm	30 mm	36 mm	43 mm	50 mm
0	0.56	0.71	0.74	0.97	1.06
5	0.59	0.93	1.13	1.48	1.85
10	0.63	1.33	1.71	2.66	3.18
20	0.98	2.84	4.10	6.23	8.31
30	1.89	5.53	8.24	12.15	16.99
40	3.54	9.57	14.53	21.24	29.48
50	6.02	15.41	23.96	35.83	49.51
60	9.48	23.55	38.27	56.93	78.80
70	14.37	33.39	59.26	88.25	127.75
80	20.03	41.18	82.45	119.95	171.32

Table 1-1. Cv (Flow Coefficient)



The proper valve size can be determined using the equation below. The required Cv (Flow Coefficient) should be calculated for both the minimum and maximum flows expected on the application. This design allows for 60 degrees of throttle plate rotation.

16	
Pos (%)	C_v
100	9.19
95	8.85
90	8.15
85	7.35
80	6.43
75	5.56
70	4.75
65	4.04
60	3.42
55	2.86
50	2.37
45	1.92
40	1.56
35	1.26
30	1.02
25	0.86
20	0.76
15	0.73
10	0.73
5	0.73
2.5	0.72
0	0.72



## Chapter 2. Mechanical Installation

### General Installation, Operation Notes, and Requirements

**WARNING**

**EXPLOSION HAZARD**—Do not connect or disconnect while circuit is live unless area is known to be non-hazardous.

Substitution of components may impair suitability for Class I, Division or Zone applications.

**WARNING**

Use an independent device for positive shutdown, such as a fuel shut off valve is highly recommended. Failure to comply with this recommendation can cause personal injury and/or property damage.

Use of an external spring to return to minimum fuel is highly recommended. Failure to comply with this recommendation can cause personal injury and/or property damage.

Use of a predicted min fuel shutdown procedure is highly recommended. Failure to comply with this recommendation can cause personal injury and/or property damage.

**WARNING**

External fire protection is not provided in the scope of this product. It is the responsibility of the user to satisfy any applicable requirements for their system.

**WARNING**

Due to the hazardous location listings associated with this product, proper wire type and wiring practices are critical to operation.

**CAUTION**

Due to typical noise levels in turbine or engine environments, hearing protection should be worn when working on or around the L-Series.

**CAUTION**

The surface of this product can become hot enough or cold enough to be a hazard. Use protective gear for product handling in these circumstances. Temperature ratings are included in the specification section of this manual.

**NOTICE**

Do not connect any cable grounds to “instrument ground”, “control ground”, or any non-earth ground system. Make all required electrical connections based on the wiring diagrams (Figure 3-1a–d).

### Unpacking

Be careful when unpacking the actuator. Check the unit for signs of damage, such as bent or dented panels, scratches, and loose or broken parts. Notify the shipper and Woodward if damage is found.

## Mechanical Installation

### Mounting Location

**IMPORTANT**

To meet ATEX Hazardous Location requirements, the installer of the L-series must take responsibility for meeting Sub-Clause 26.3.3.1 of EN60079-15:2003 regarding impact testing. The actuator by itself does not meet this requirement and therefore must be sufficiently protected when installed. According to EN60079-15, the protection must be such that a 1 kg mass, fitted with an impact head in the form of a hemisphere of 25 mm diameter, can be dropped vertically from a height of 0.7 meter, and not cause significant damage to the actuator.

Locate the L-Series controller a distance from sources of extreme radiant heat, such as exhaust manifolds or turbochargers. The operating temperature range of the control is  $-40$  to  $+105$  °C ( $-40$  to  $+221$  °F). In spark-ignited applications, make sure the L-Series is located away from the ignition coil, and that harness wires are not routed next to the spark plug wires.

As shown in the specifications, the L-Series controller has been designed for and verified to a given accelerated life vibration test level at the mounting surface of the actuator. The user should be aware that in any application, bracket design could significantly change the vibration levels at the actuator. Therefore, every effort should be made to make the bracket as stiff as possible so that engine vibrations are not amplified, creating an even more severe environment at the actuator. Additionally, when possible, orienting the actuator shaft parallel to the crankshaft of the engine will often reduce the vibration load on the actuator's rotor system in reciprocating engine applications.

### Mounting the L-Series Actuator with an ITB or Trim Valve

Complete installation instructions are provided in manual 26249. Typical mounting of a L-Series actuator with an ITB or Trim valve is accomplished by fastening the throttle to the inlet and outlet pipes. Ensure that the pipes can support the weight of the L-Series actuator and the throttle body.

### Output Shaft

The L-Series actuator has  $58$ – $62$ ° of available travel. The max fuel direction of this travel is software configurable in the clockwise or counterclockwise direction through the Service Tool.

### Mounting Orientation

While it is not a requirement, it is good practice to orient the connector feature on the control in a horizontal or downward orientation to minimize fluid accumulation between the enclosure and the mating connector's gasket.

## Actuator Configuration

The L-Series actuator utilizes a 2.0" (50.8 mm) square mounting bolt pattern and is intended to fit within an envelope of 2.618 x 2.618 x 2.540" (66.50 x 66.50 x 64.52 mm) with the short dimension along the shaft axis. Two shaft seal configurations are available, an internal lip seal and an external lip seal with spring backup (Figure 2-4). In addition, six independent output shaft configurations are available (Figure 2-5). Consult Woodward applications engineering for the application appropriate seal and shaft configuration.

## Mounting Hardware

Use M5 or #10 fasteners torqued to 4 N·m (35 lb-in) to attach the L-Series controller to the mounting bracket. The bracket and attaching hardware must be designed to hold the weight and to withstand the vibration associated with prime mover mounting. Use the appropriate fasteners for securing the mounting bracket to the engine.

## Mechanical Stops

**Gas Engine Stops**—Butterfly valves in the fuel supply will often bind if rotated too far toward minimum or maximum. For this reason, hard stops in the throttle body or associated linkage should be used at both minimum and maximum positions. The engine must always shut down when the actuator is at the minimum stop.

**External Stops**—Process installations may include external minimum and maximum position stops. The internal actuator stops must not prevent the actuator from driving the process linkage to the minimum and maximum positions. The linkage should be designed to use as much actuator travel as possible, without preventing minimum and maximum positions.

## Linkage

Proper design and installation of the linkage from the actuator to the fuel valve or other end device is necessary for the unit to provide the best control possible. Woodward recommends that linkages use at least 40 degrees of actuator shaft rotation, centered in the full 60-degree range. This maximizes the resolution of the actuator control loop. Refer to Figure 2-1 for examples of typical linkage designs.

To increase the amount of actuator rotation, move the rod end closer to the actuator shaft or farther away from the fuel valve or end device shaft. To decrease the amount of actuator rotation, move the rod end farther from the actuator shaft or closer to the fuel valve or end device shaft.

Once installed, manually stroke the control linkage from stop to stop as if the actuator were moving it. The linkage must move freely, without friction and backlash. Lubricate or replace worn linkage or other parts as required.

Always make sure the fuel valve or end device has a return spring that pulls towards minimum fuel, or to a safe process position, when no power is applied to the control. Size the return spring so that the actuator output shaft sees no more than 0.07 N·m (0.05 lb-ft) of torque at maximum loading conditions.

In addition to a return spring, always make sure the gas engine application includes an overspeed protection device.

NOTICE	<p>The actuator's maximum slew rate can place stress on the fuel system stops and on the linkage between the actuator and the fuel system. The maximum actuator speed is 1100 degrees per second in both increase and decrease fuel directions under normal operating conditions. Exceeding the control input voltage requirements may cause a unit shutdown in which the actuator speed may exceed 3500 degrees per second.</p>
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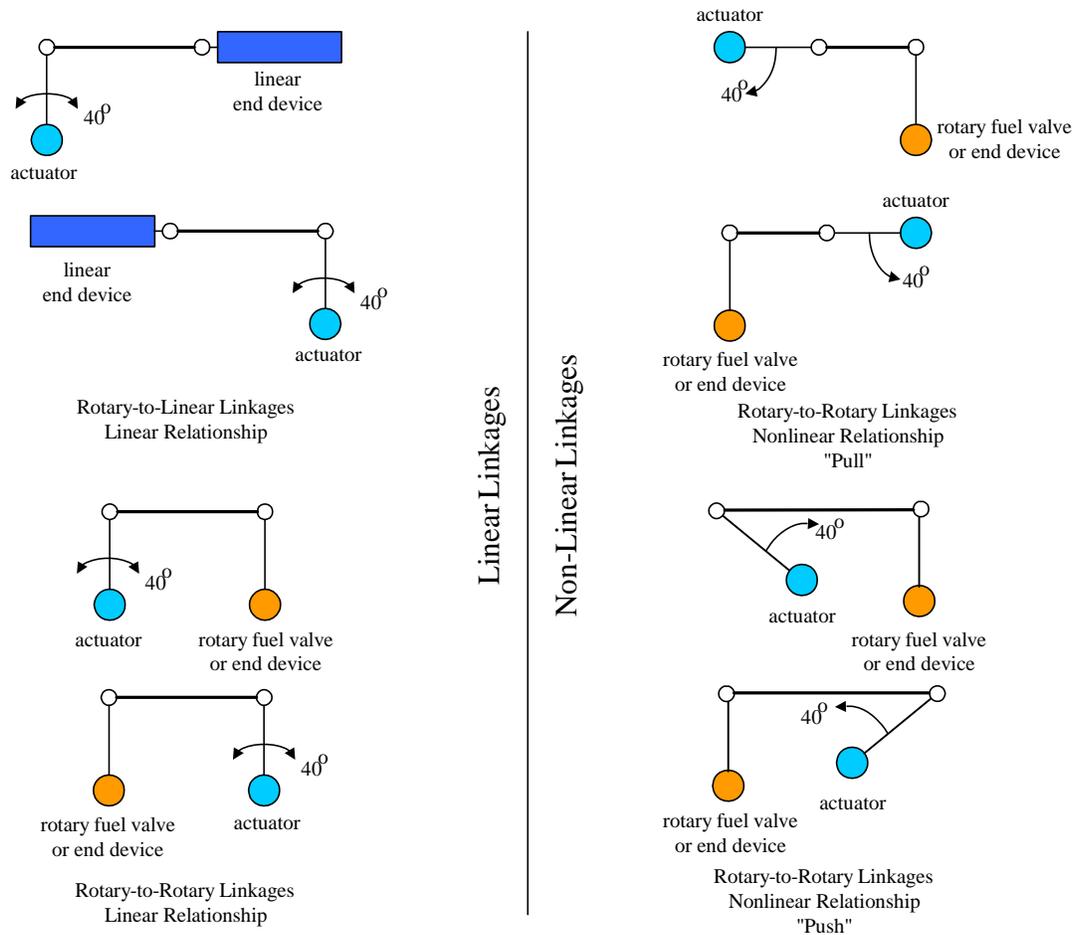


Figure 2-1. Linkage Design Examples

The Mass Moment of Inertia (MMOI) for the L-Series actuators is 1.48 E-5 kg-m<sup>2</sup> (1.57E-3 lb-in-s<sup>2</sup>). External fuel or process system stops should be used and must be adequate to absorb the actuator MMOI in addition to the linkage inertia without damage.

Use of good rod-end connectors with as little free play as possible is essential. Select rod ends that will remain tight and wear well during the nearly constant movement associated with precise fuel or process control. The link connecting the actuator lever to the fuel-control or process-control lever must be short and stiff enough to prevent flexing while the engine is running.

Occasionally, in a linkage system, there may be links and levers that are supported by customer-supplied bearings. There may also be a section of the linkage where the mass is supported fully by the actuator output shaft. Minimizing the mass the actuator is required to support is essential in that excessive mass or vibration levels may damage the actuator's rotor system and shorten the life of the actuator.

## Mounting the HEGO or UEGO Sensor

The typical life expectancy of the O<sub>2</sub> sensor is 2000 to 4000 hours, or approximately three to six months of continuous service.

The HEGO or UEGO sensor should be located upstream of the catalyst if applicable:

- In the combined exhaust stream from all the cylinders or after the turbocharger if applicable.
- Within 60 cm (24 inches) of the exhaust manifold outlet or turbo outlet.
- Shielded from the exhaust pulses of another bank or turbo (where two exhaust streams join) to avoid "cross-talk" feedback from the wrong bank.
- On the top 180° of the exhaust pipe (to avoid corrosion and thermal shock from condensation).
- Drill and spot face a 15.5 mm hole in a suitable location.
- Tap or weld internally threaded (M18 x 1.5) port around the hole (Woodward p/n 1138-581).
- Install sensor with anti-seize thread lubricant and torque to 40 N·m (30 lb-ft).

## Oxygen Sensor Poisoning

***Lubricants and sealants of any kind must be checked for oxygen sensor compatibility***—even for use on the intake or crankcase ventilation system. Contaminants drawn into the engine can propagate through the combustion process, and even small amounts can poison the activity of oxygen sensors. Common sensor poisons include silicon, lead, and excessive oil contamination. Gasket sealers (RTV silicone), pipe thread sealers (pipe dope), and solder or brazing materials will typically contain these materials. Most products intended for modern automotive use are sensor-safe, but many products common in industrial environments are not. Double check products during repair or maintenance, and when in doubt, use automotive products and procedures. Excessive oil consumption by the engine will also affect oxygen sensor life—regular maintenance of piston rings (and valve seals, where applicable) is very important. Although the sensors are inexpensive, they are damaged by the same contaminants that will eventually poison the exhaust catalyst. In other words, a sensor failure may give warning that maintenance is needed before the catalyst is also damaged.



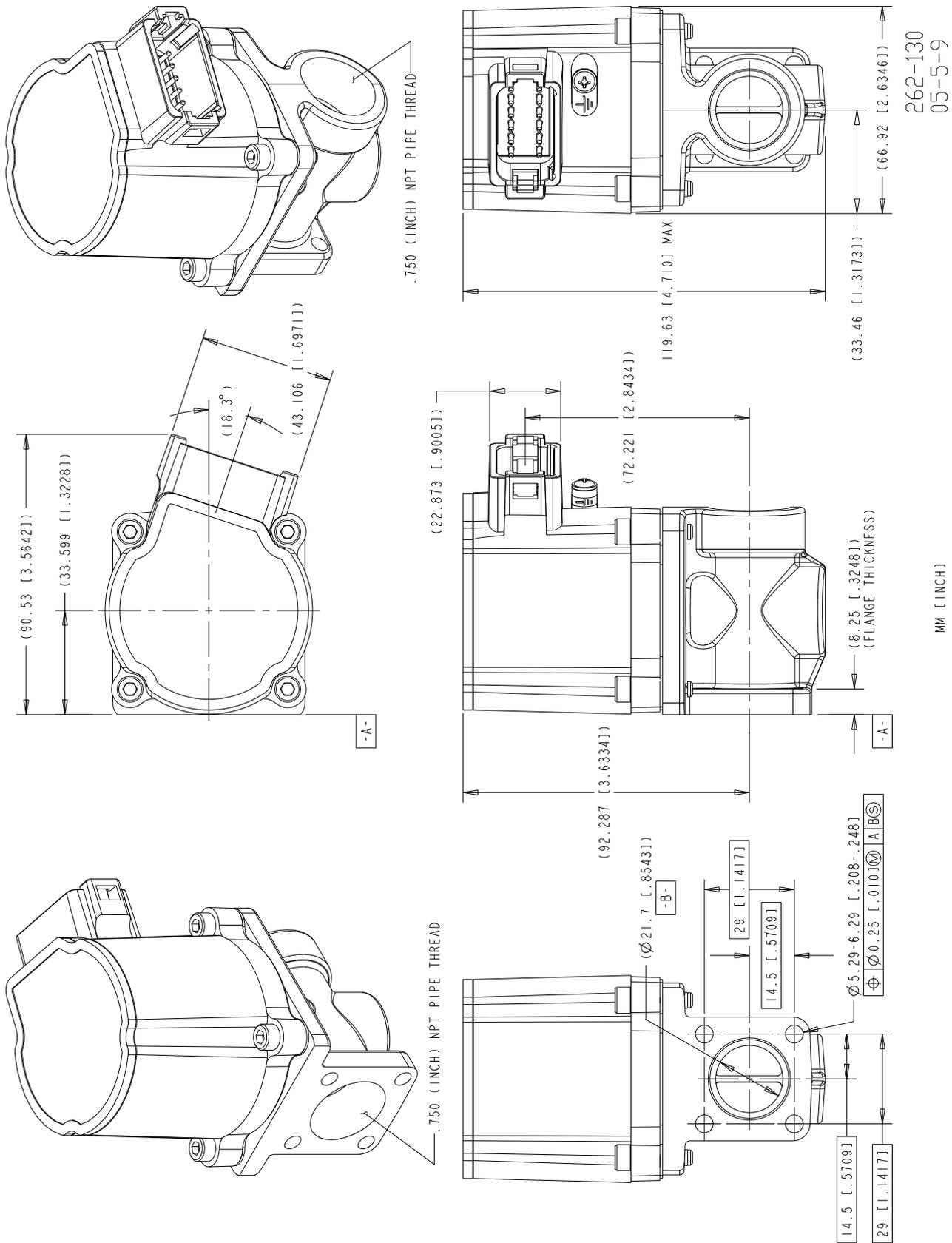
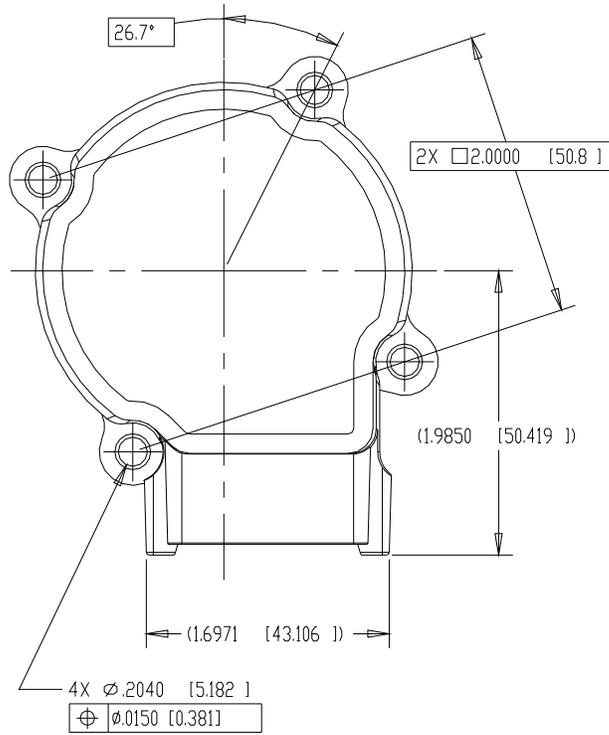


Figure 2-2b. L-Series A/F Ratio Trim Valve, 22 mm



NOTES:

1. MOUNTING HARDWARE TO BE SOCKET HEAD CAP SCREWS -- #10(.190)-24, M5, OR EQUIVALENT. NO WASHERS TO BE USED. RECOMMENDED SCREW TORQUE = 35 IN-LB [4 N-M].
2. FOR BRACKET-MOUNT APPLICATION, A BRACKET OUT-OF-FLATNESS OF .010 [0.25] MAXIMUM IS RECOMMENDED.
3. FOR CONNECTOR INFORMATION, REFER TO CONNECTOR TABLE AND APPROPRIATE WIRING DIAGRAM.
4. USE OF INTERNAL ACTUATOR STOPS IN APPLICATION NOT RECOMMENDED. TORQUE AGAINST STOPS NOT TO EXCEED 200 IN-OZ.
5. DIMENSIONS ARE SHOWN IN INCHES [MM].
6. DETAILS SHOWN HERE ARE COMMON TO ALL ACTUATOR ASSEMBLIES. HENCE, NEITHER COVERS NOR SHAFTS ARE SHOWN IN THESE VIEWS. SEE COVER AND SHAFT DETAILS ELSEWHERE IN THIS MANUAL.

INTEGRATED DEUTSCH CONNECTOR (REF: DT04-12PA)		
ITEM	RECOMMENDED	OPTIONAL
MATING CONNECTOR	DT06-12SA-P012	DT06-12SA
SECONDARY LOCK	W12S-P012	W12S
SOCKETS	0462-201-16141	0462-201-16141
WIRING HARNESS STRESS RELIEF SUPPORT	WITHIN 16 INCHES FROM CONNECTOR	
NOTE: IN THE EVENT A WIRE IS NOT USED FOR EACH OF THE 12 PINS ON THE CONTROL, A DEUTSCH 114017 PLUG MUST BE USED IN PLACE OF EACH MISSING WIRE TO ENVIRONMENTALLY SEAL THE CONTROL.		

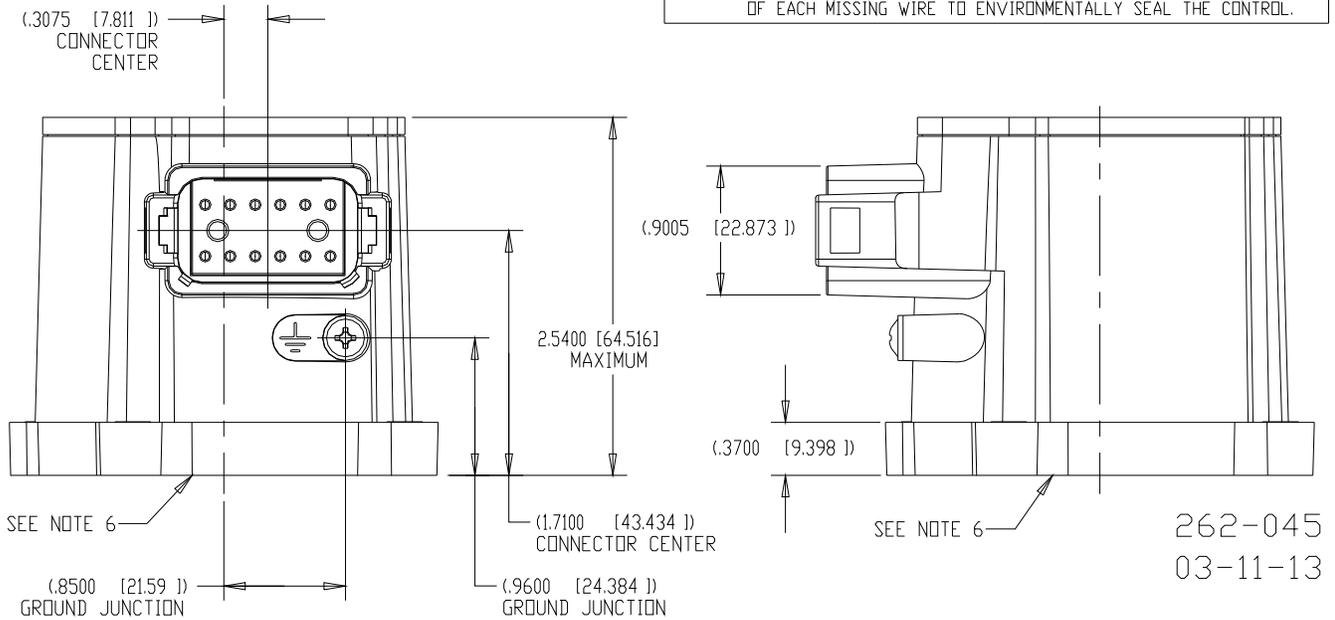
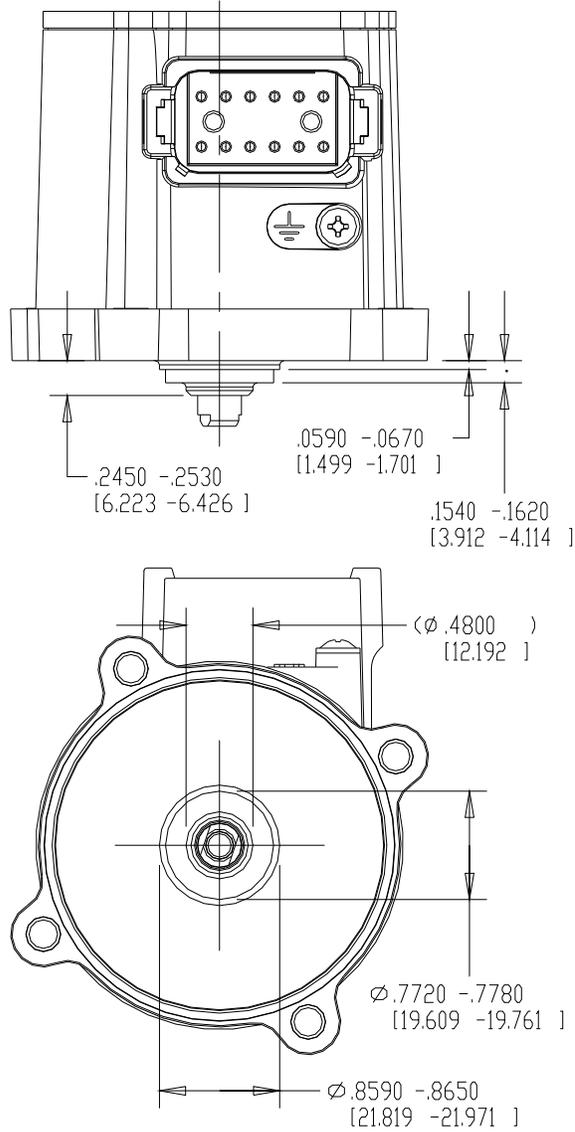


Figure 2-3. L-Series Outline Drawing

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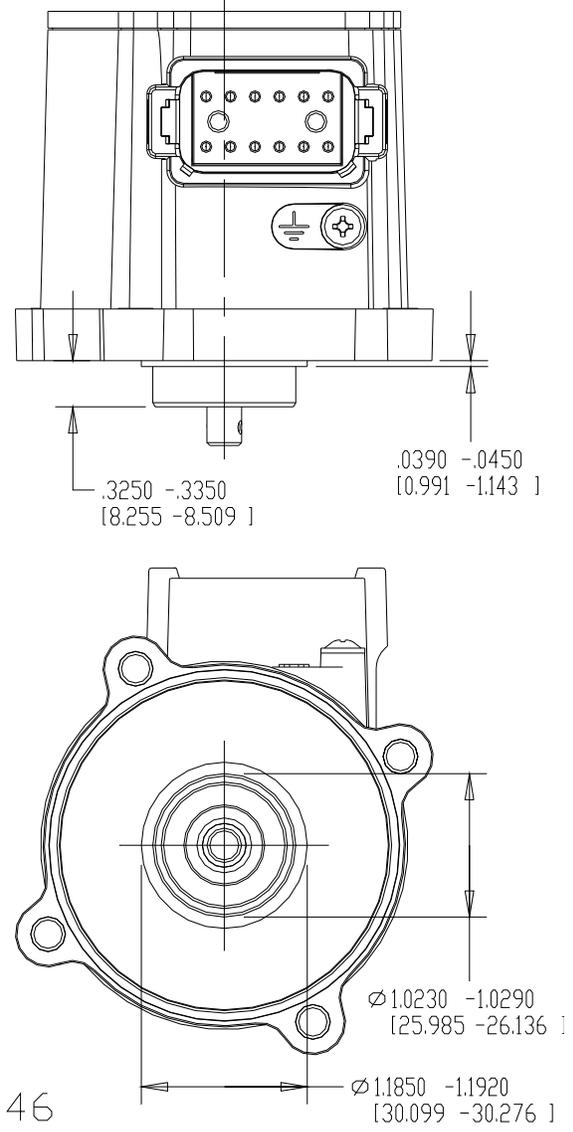
COVER TYPE 1

INTERNAL LIP SEAL  
SHAFT TYPE 1 PHANTOM / INCHES [MM]



COVER TYPE 2

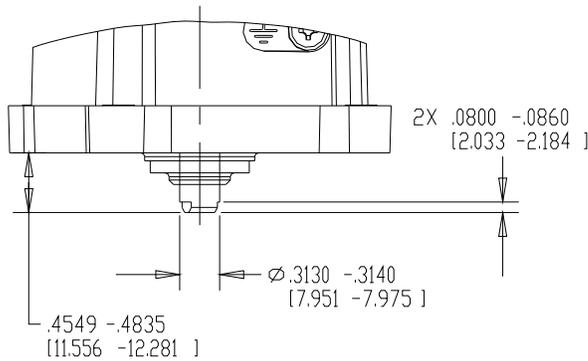
EXTERNAL SPRING-LOADED LIP SEAL  
SHAFT TYPE 1 PHANTOM / INCHES [MM]



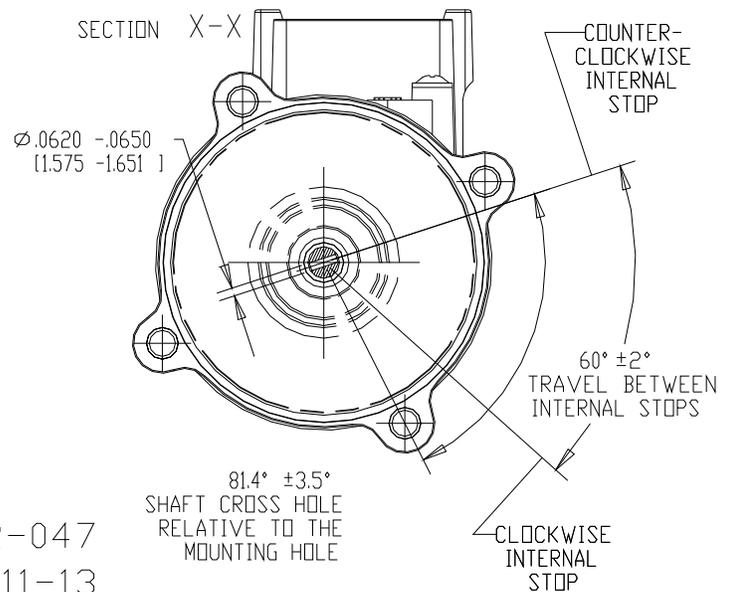
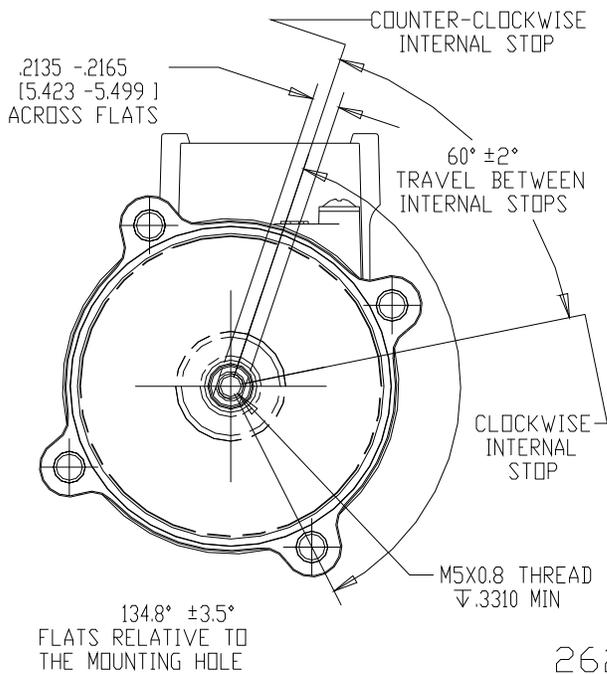
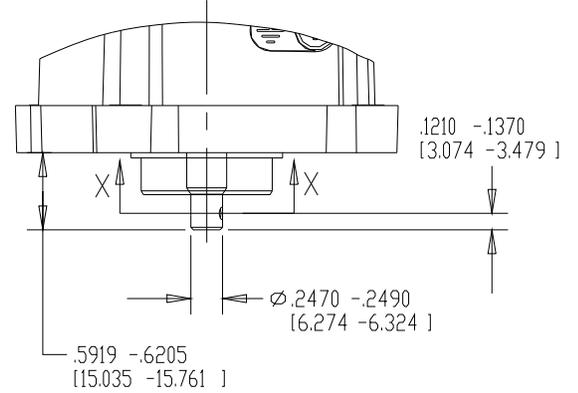
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Figure 2-4. L-Series Cover Types

SHAFT TYPE 1  
 2X FLATS, THREADED AXIAL HOLE  
 COVER TYPE 1 PHANTOM / INCHES [MM]



SHAFT TYPE 2  
 Ø.2480, 1X CROSS HOLE  
 COVER TYPE 2 PHANTOM / INCHES [MM]

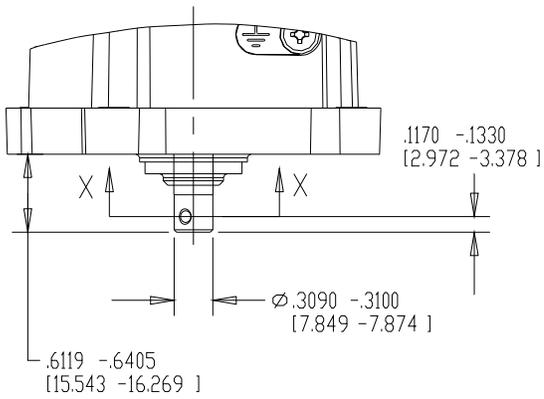


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Figure 2-5a. L-Series Shaft Types

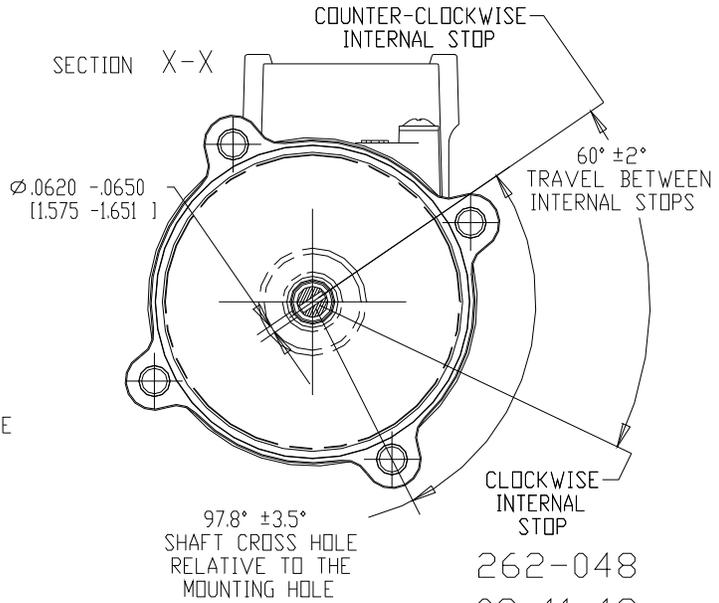
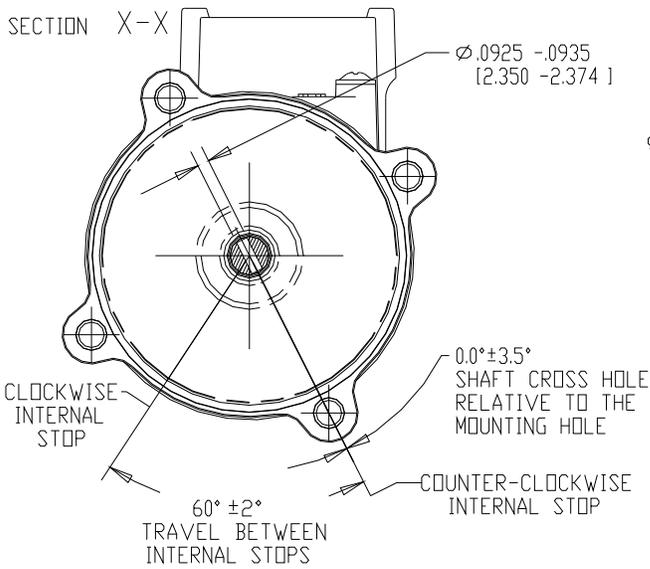
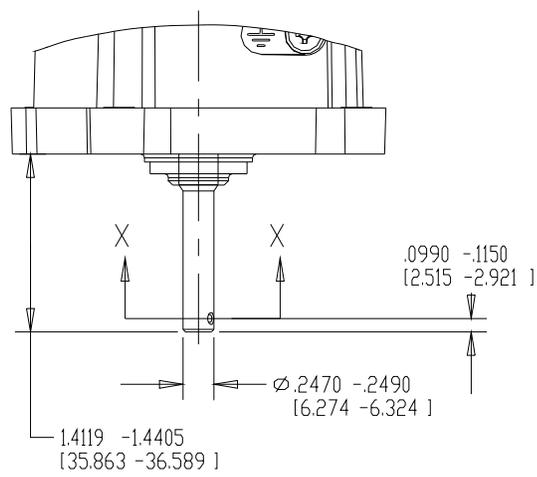
SHAFT TYPE 3

Ø.3095, 1X CROSS HOLE  
COVER TYPE 1 PHANTOM / INCHES [MM]



SHAFT TYPE 4

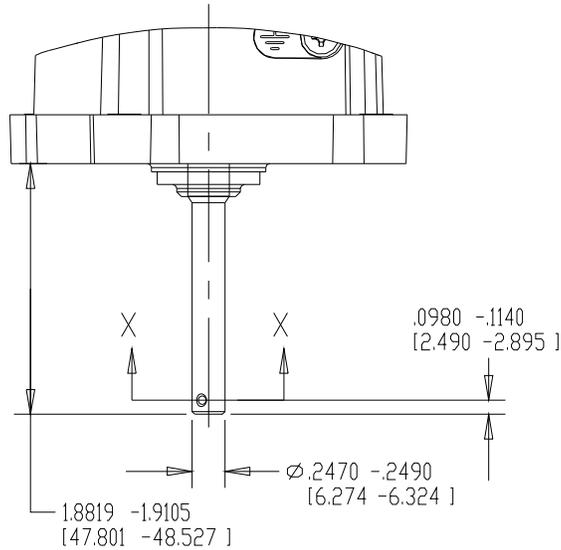
Ø.2480, 1X CROSS HOLE  
COVER TYPE 1 PHANTOM / INCHES [MM]



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Figure 2-5b. L-Series Shaft Types

SHAFT TYPE 5  
 Ø.2480, 1X CROSS HOLE  
 COVER TYPE 1 PHANTOM / INCHES [MM]



SHAFT TYPE 6  
 Ø.2480, 2X CROSS HOLE  
 COVER TYPE 1 PHANTOM / INCHES [MM]

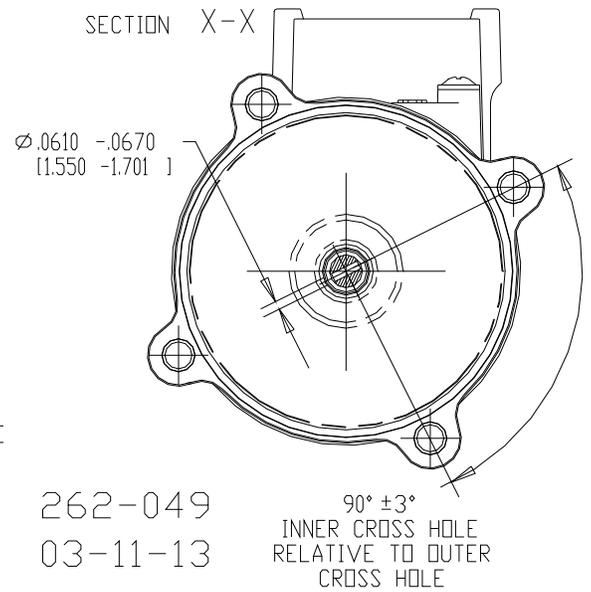
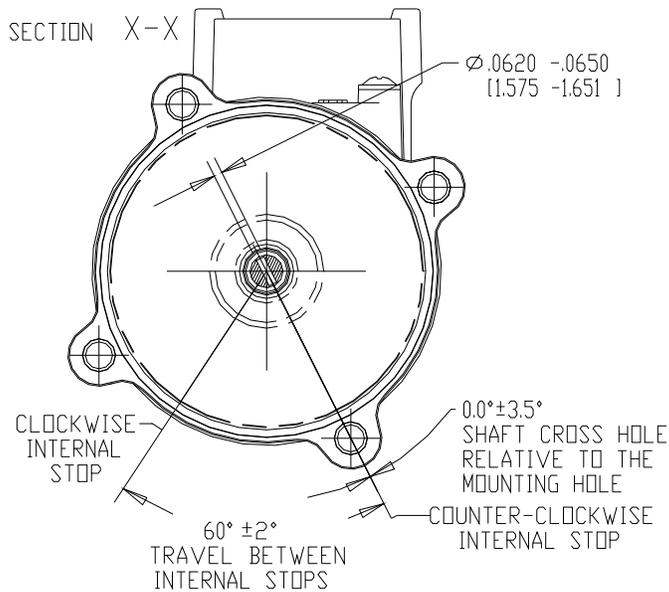
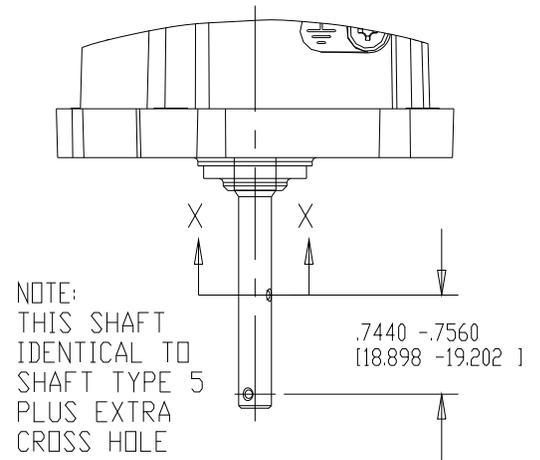


Figure 2-5c. L-Series Shaft Types

## Chapter 3. Electrical Installation

### Introduction

This chapter provides instructions on connecting the L-Series controller into a system. A wiring pinout of the L-Series control is shown in Figure 3-2, as viewed looking into the control's connector feature. Figure 3-1a–d show typical external I/O device connection examples for various control configurations. Description of Operation for each configuration type is found in Chapter 4.

The L-Series has an operating voltage range of 10 to 32 Vdc with nominal voltages of 12 or 24 Vdc. The power supply is reverse polarity protected, and consumes 32 W maximum power at a peak current of 1 A (32 V) assuming 4  $\Omega$  stator resistance at 25 °C. These assumptions are based on the fact that the software limits the power to the rotary actuator to 25 W at any given time and input voltage (in the valid range).

The control system should be protected with a 6 A fuse in the voltage supply lines. Typical max average current is 2.1 A, or max 25 W at 12 V. The application should be configured to turn on power to the actuator when the engine is first cranked or the process is ready to start or starting.

#### **NOTICE**

**Centralized load suppression is required when using an L-Series. The L-Series itself is not designed to withstand transient events typical of industrial or automotive environments (alternator load dump or power line surge).**

### Shielded Wiring

The use of cable with individually shielded-twisted pairs is required where indicated by the control wiring diagram (Figure 3-1a–d). Cable shields must be terminated as indicated in the control wiring diagram using the installation notes described below. DO NOT attempt to directly ground the shield at both ends or an undesired ground loop condition may occur. If it becomes necessary to terminate the shield at the end opposite of the L-Series, it must be done through a high-frequency capacitor.

#### Installation Notes

- Wires exposed beyond the shield should be as short as possible, not exceeding 50 mm (2 inches).
- The shield termination wire (or drain wire) should be kept as short as possible, not exceeding 50 mm (2 inches), and where possible the diameter should be maximized.
- Installations with severe electromagnetic interference (EMI) may require additional shielding precautions. Contact Woodward for more information.

Failure to provide shielding can produce future conditions which are difficult to diagnose. Proper shielding at the time of installation is required to assure satisfactory operation of the product.

## Electrical Connections



### WARNING

**EXPLOSION HAZARD—Do not connect or disconnect while circuit is live unless area is known to be non-hazardous.**

**Substitution of components may impair suitability for Class I, Division or Zone applications.**

Prior to installation, refer to the wiring diagrams and the representative I/O interfaces schematic in this chapter. Also, review the hardware I/O specifications in Appendix B.



### WARNING

**The control will only meet ingress protection specifications while the Deutsch connector is installed in the unit. As such, the unit should not be exposed to operating environments unless the mating connector is installed. In addition, if a wire is not used for each of the 12 pins on the control, a Deutsch 114017 plug must be used in place of each missing wire. Failure to adhere to these guidelines may result in product failure or decreased life.**

Use 1 to 1.5 mm<sup>2</sup> (16 to 18 AWG) stranded copper wire with insulation that meets temperature requirements in the harness design. A wiring harness stress relief within 400 mm (16") of the control's connector is recommended. Limit all I/O and signal lines to less than 30 m (98 ft). Also limit input power (B+/B-) connections to an earth grounded battery or conditioned power interface to less than 10 m (33 ft) from the L-Series product.



### IMPORTANT

**A conditioned power interface is an interface that offers equivalent common mode and differential mode conditioning to that of a grounded 24 V lead acid battery.**

Dress the harness with wire loom to contain it in a single bundle. Use grommets when passing the harness through metal panels.

### Control Electrical Connector

The following Deutsch connector components are recommended for control harness designs:

	Recommended	Optional
Mating Connector	DT06-12SA-P012	
Secondary Lock	W12S-P012	
Sockets	0462-201-16141	1062-16-0122
Crimp Tool	HDT-48-00	DTT-16-00
Sealing Plug	114017	

For convenience, Woodward part number 8928-396 is a kit that provides all the necessary Deutsch components (crimp tool *not* included).



### IMPORTANT

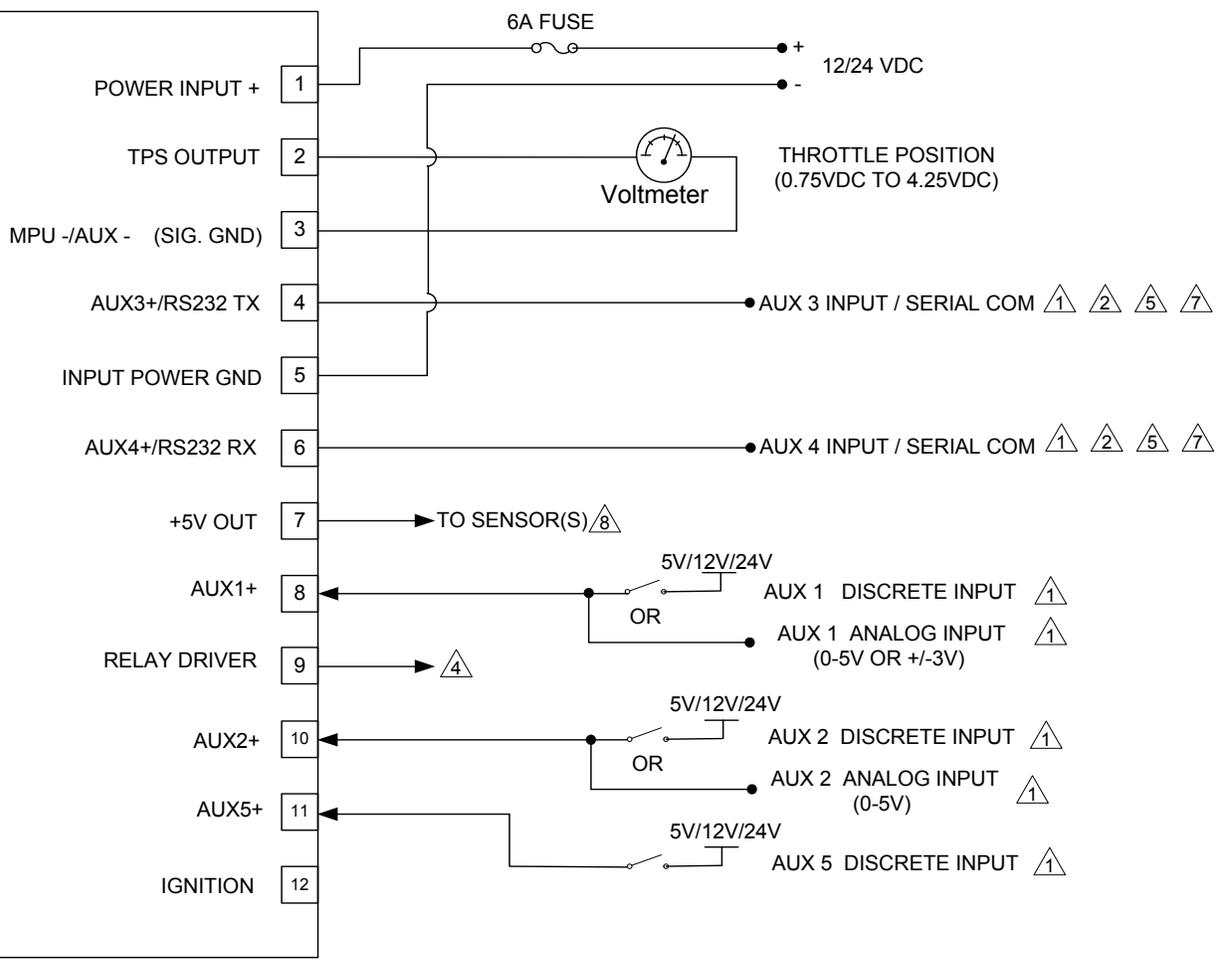
**Crimping methods for the Deutsch connector pins must be followed as prescribed by the manufacturer. Woodward is not responsible for damage or loss of performance resulting if any other method of crimping is used. Use of the listed part numbers of Deutsch connector components is strongly recommended.**



### WARNING

**Due to the hazardous location listings associated with this product, proper wire type and wiring practices are critical to operation.**

**NOTICE** Do not connect any cable grounds to “instrument ground”, “control ground”, or any non-earth ground system. Make all required electrical connections based on the wiring diagram (Figure 3-1a-d).



**NOTES:**

- ① REFERENCE ALL DISCRETE AND ANALOG INPUTS TO PIN 3 (SIG GND). TO PREVENT ELECTRICAL NOISE EMISSIONS FROM INTERFERING WITH THE AUX INPUT SIGNALS, IT IS RECOMMENDED THAT WIRING TO AUXILIARY (AUX) INPUTS **NOT** BE ROUTED WITHIN 150 MM (6 INCHES) OF ANY HIGH VOLTAGE IGNITION LEADS.
- ② AUX 3 AND AUX 4 CAN ALSO BE CONFIGURED AS DISCRETE OR ANALOG INPUTS IN A SIMILAR MANNER AS AUX 1 AND AUX 2, BUT ARE NOT FUNCTIONAL WHILE SERIAL COMMUNICATIONS ARE CONNECTED.
- ③ ALL SHIELD TIES ARE TO BE *NO LONGER THAN 2"* BETWEEN THE CABLE AND GROUND.
- ④ LOW-SIDE DRIVE OUTPUT DESIGNED TO DRIVE A RELAY, LAMP, OR OTHER STATUS INDICATOR. MAXIMUM CURRENT ALLOWED THROUGH THE COIL OR LAMP IS 500 mA. MAXIMUM VOLTAGE ALLOWED AT THIS TERMINAL IS 32 VDC.
- ⑤ USE WOODWARD KIT 8923-1061 TO CONNECT TO A COMPUTER FOR USE WITH THE SERVICE TOOL.
- ⑥ THE 5V OUTPUT IS PROVIDED FOR POWERING EXTERNAL SENSORS. RATED AT 10mA MAX.
- ⑦ WHEN CONFIGURED AS AN ANALOG INPUT, THE RANGE IS 0-5 V.

Figure 3-1a. L-Series Process Control Application Wiring

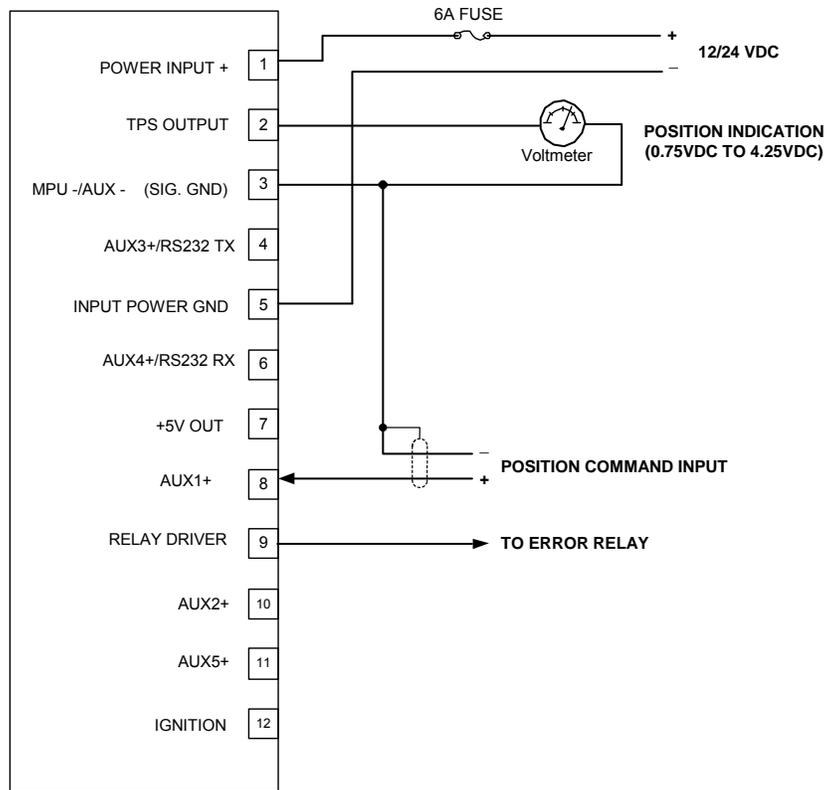


Figure 3-1b. Typical Position Control Application Wiring

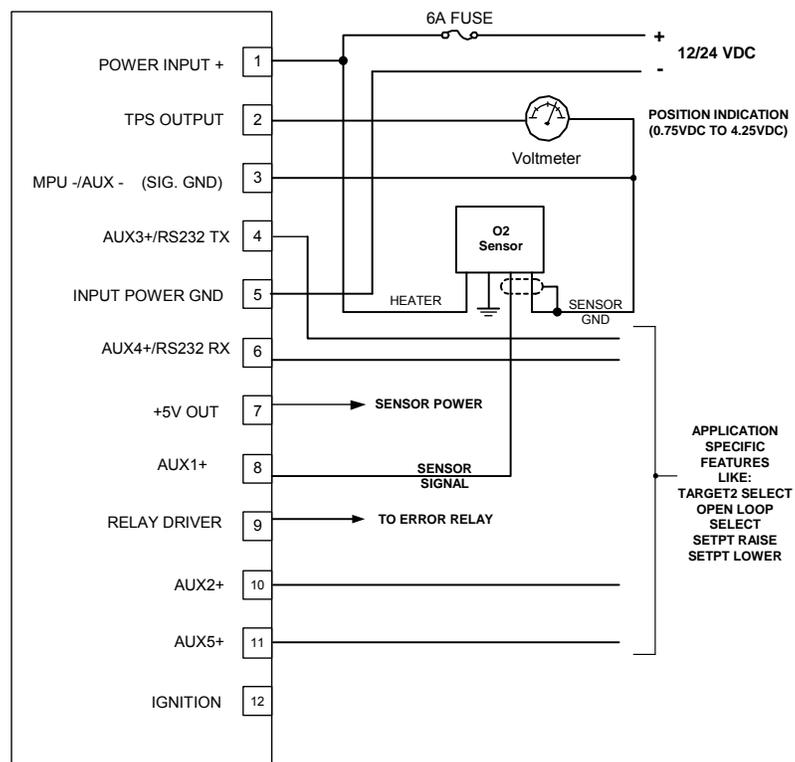


Figure 3-1c. Typical Main or Trim A/F Ratio Control Application Wiring

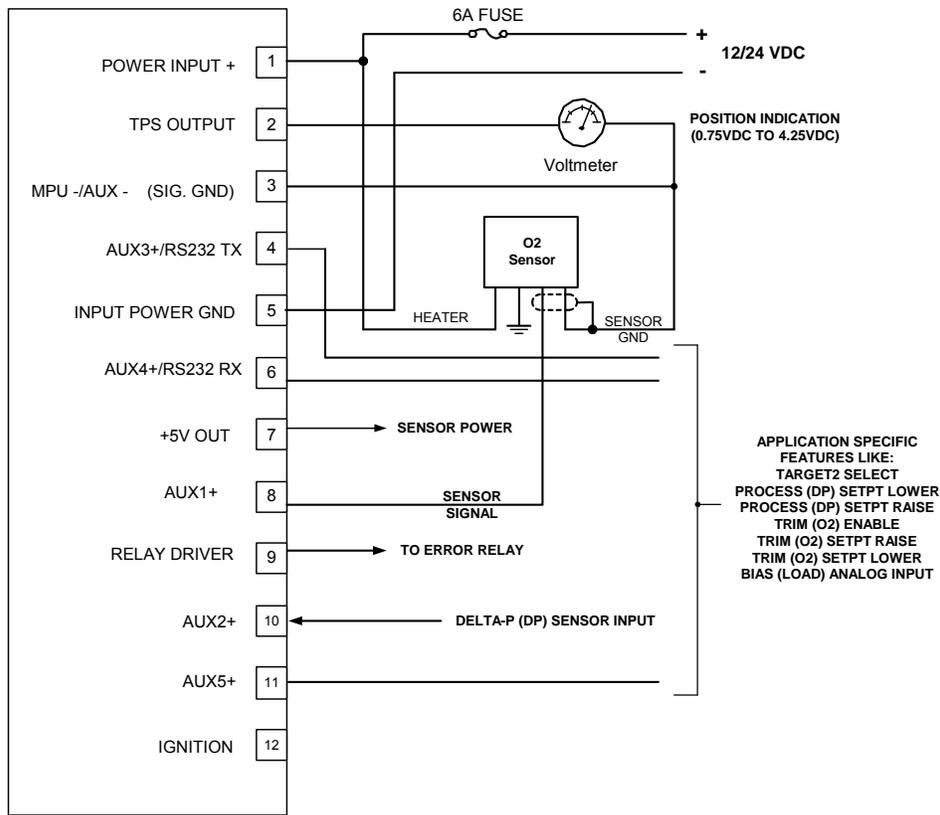


Figure 3-1d. Typical Full Authority Process Control Application Wiring

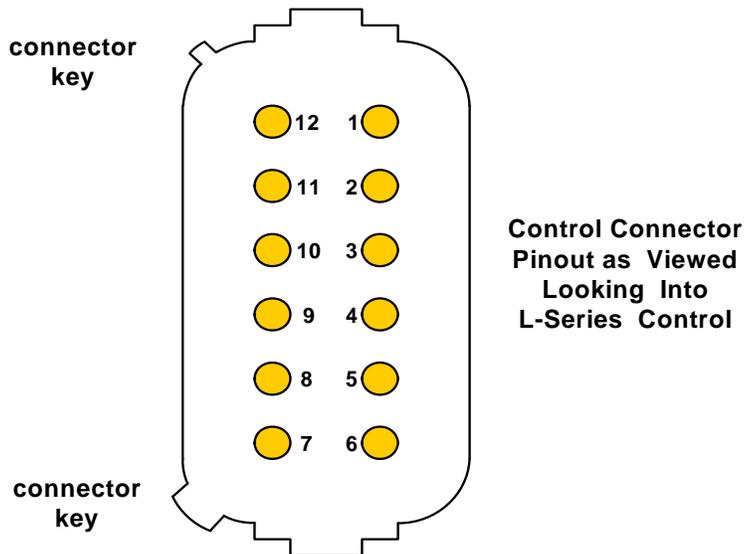


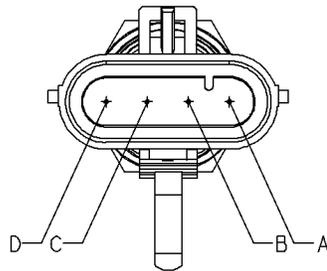
Figure 3-2. L-Series Process Control Connector Pin Arrangement

## HEGO Sensor Connector

The following Packard Connector components are recommended for HEGO harness designs:

	Recommended
Mating Connector	12162144
Secondary Lock	12047948
Crimp Terminals	12048074
Cable Seals	12048086

For convenience, Woodward part number 8928-427 is a kit that provides all the necessary Packard components.



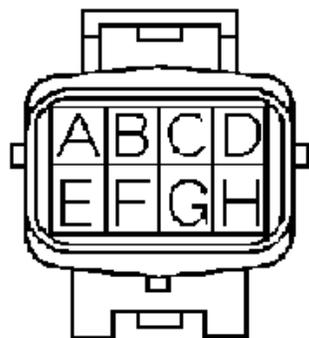
PIN A: SENSOR GROUND (GREY WIRE)  
 PIN B: SENSOR SIGNAL (BLACK WIRE)  
 PIN C: SENSOR HEATER (WHITE WIRE)  
 PIN D: SENSOR HEATER (WHITE WIRE)

View shown is looking into HEGO connector

Figure 3-3. HEGO Sensor Connector Pin Arrangement

## UEGO Sensor Connector

The UEGO kit part number DL08311000 includes the sensor, control box and a cable with mating connectors attached. The following connector pin arrangement is for information only. The mating connector is not sold separately.



COLOR	TERMINAL	CONNECT
Orange	A	Heater +
Yellow	B	Heater -
-----	C	Compensating Resistance
-----	D	Compensating Resistance
-----	E	Dummy Plug
Red	F	Vs Cell +
White	G	Ip Cell +
Black	H	Vs Cell -
		Ip Cell -

## UEGO Color of Lead Wire and Terminal Arrangement

Figure 3-4. UEGO Sensor Connector Pin Arrangement

## Description of Electrical I/O

Representative circuitry for the L-Series inputs/outputs is shown in Figures 3-5 to 3-8.

### NOTICE

Centralized load suppression is required when using an L-Series. The L-Series itself is not designed to withstand transient events typical of industrial or automotive environments (alternator load dump or power line surge).

#### Power Supply Input (+12 Vdc/24 Vdc at pin 1, ground at pin 5)

The L-Series will handle a voltage range of 10 to 28 Vdc at full-specified torque. The actuator is functional in the range of 8 to 32 Vdc, but accuracy and/or torque can be diminished at the extreme ends of this range.

The power supply terminals are reverse polarity protected, and in case a reverse polarity condition exists, the L-Series actuator will not power-up and will remain at the minimum stop if an internal return spring is attached to a throttle body.

Woodward recommends using a 6 A fuse on the power supply line feeding pin 1 of the L-Series actuator.

The supply voltage failure levels are below 6.25 V and above 33 V. The unit can be configured to either alarm or shut down upon detection of a supply voltage fault.

### WARNING

The input power must be fused. Failure to fuse the L-Series could, under exceptional circumstances, lead to personal injury, damage to the control valve, and/or explosion.

Take special care when wiring the L-Series controller.

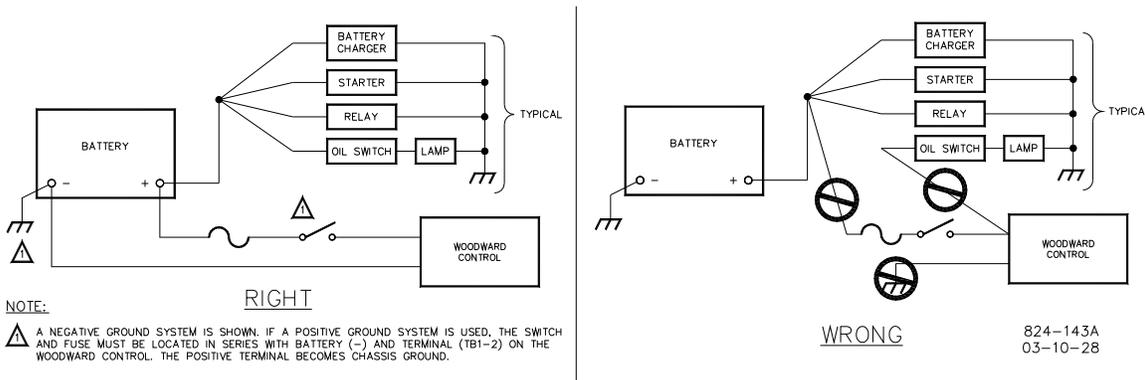


Figure 3-5. Correct and Incorrect Wiring to Power Supply

The control will continue to function down to a supply voltage of 8 V, to withstand a prime mover start from the same battery system, however the control will not function completely within specifications. During the low voltage, the L-Series will **not** meet the transient response times or the max torque output.

## Ground Symbol Conventions

	=	<b>Internal Circuit Board Common</b> Used to show equipotentials in electronic circuits, normally internal to a control system.
	=	<b>Earth Ground</b> Represents a connection to "Earth" Ground.
	=	<b>Chassis Ground</b> Sometimes used as symbol for system ground. Normally associated with connection to engine skid or vehicle frame. In the case of the L-Series, it also represents system ground.
	=	<b>Protective Earth Ground.</b> Normally used as a safety ground in high-voltage (> 42V) systems. (Not applicable to L-Series Controls)

### TPS Output (pin 2, referenced to either pin 3 or pin 5)

The L-Series provides a 0–5 V signal representing actual shaft rotational position, where 0.75 V and 4.25 V correspond to full counterclockwise to clockwise rotation, respectively. This signal is fed directly off the position sensor to ensure the processor does not introduce delays. However, this signal is uncorrected, so the difference between this signal and actual position can vary up to  $\pm 10\%$  over the operating temperature range. This provides the end user an indication of throttle position.

### **WARNING**

Do not try to inject signals *into* the TPS output, as it will negatively impact the performance of the L-Series actuator. This output is meant to be used with a high impedance device, such as a voltmeter. Do not tie pin 2 directly to battery or ground. If the application does not use this output, leave it open.

### **IMPORTANT**

The TPS Output is meant for an approximate indication of shaft position only. The unconditioned output accuracy must be considered when using this signal externally. Refer to the specifications section for TPS accuracy.

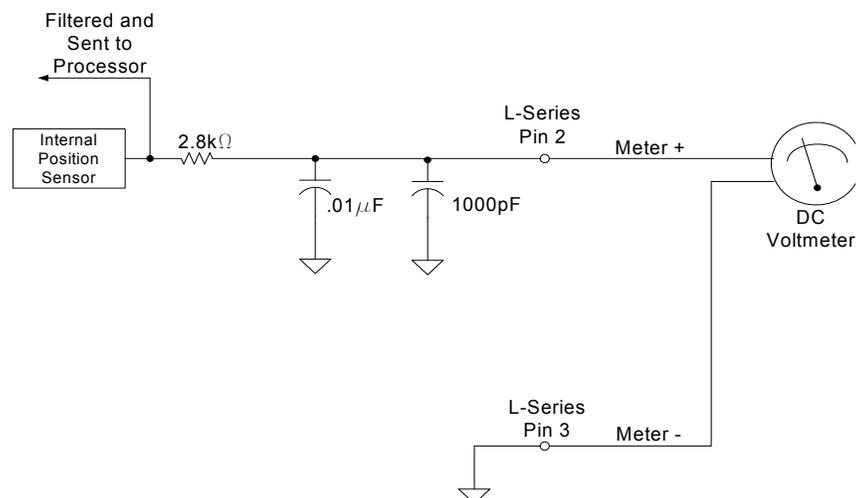


Figure 3-6. TPS Output

**Relay Driver Output (pin 9)**

A discrete output is provided to serve as a status indicator. This switchable discrete output is a closure to ground capable of sinking 250 mA with an output voltage rise of less than 1.5 V, and is available to power external relays for devices such as alarms or fuel shutoff solenoids. The circuit is protected internally against over-current and inductive spikes; so external clamping is not necessary.

This output can be configured to be either normally on/closed (preferred failsafe setting) or normally off/open. In addition, the faults that drive the relay status can be configured individually. For details, refer to Chapter 6 (Configuration). By default, this circuit will be configured in a failsafe manner, meaning it will be active (conducting) when no fault exists, but if power is lost or the L-Series actuator detects a fault, the circuit will open. See Figure 3-7 for typical usage of this feature.

There are two conditions that will prevent the discrete output from operating correctly. The first is if battery positive is accidentally connected to it, and the second is if it is shorted to ground. The circuit will protect itself in the event of a mis-wire, but it will hold the output open (floating) until the fault is removed.



**It is recommended that the Relay Output be configured for the failsafe 'Normally On' mode, to ensure maximum fault protection and annunciation. Failure to follow these guidelines could, under exceptional circumstances, lead to personal injury and/or property damage.**

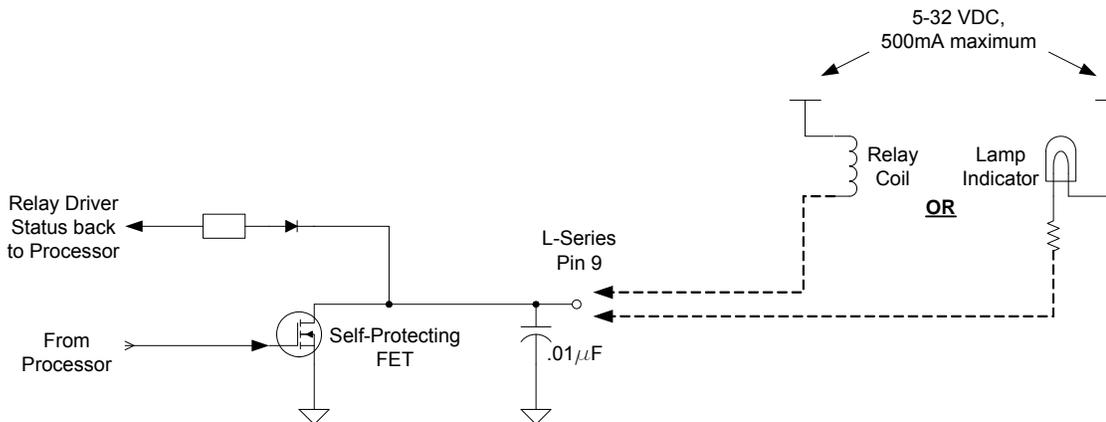


Figure 3-7. Relay Driver Output

**5 V Output (pin 7, referenced to pin 3)**

A 5 Vdc output has been provided on the L-Series actuator to power external sensors, if necessary. The 5 V output is limited to 10 mA, but this is sufficient for most light-duty ratiometric sensors



**All connector pins are short-circuit protected to ground and power except pins 3 and 5, which are not protected against shorts to battery positive. Installation of a fuse on the power ground wire to pin 5 would provide protection to these pins but this does not mean a fuse is not also needed in the power connection. Pin 1 (B+) still needs fuse protection against a short to ground.**

**AUX Inputs** (+ at pins 4, 6, 8, 10 and 11; ground at pin 3)

There are five auxiliary inputs on the L-Series controller. Aux 1—4 are capable of both analog and discrete functions. Aux 5 is limited to a discrete input function only. The Aux functions (listed below) are mapped to an Aux input using the Service Tool. If desired, multiple functions can be mapped to a single Aux input. For added flexibility, discrete functions can be programmed to be always on or always off as well as open or closed for the selected function. Analog inputs can also be inverted (direction reversed).

**IMPORTANT**

**Aux 5 discrete input will retain its last voltage level when the input is opened (as opposed to being pulled high or low). A 2-position switch that is either connecting this input to ground or to a positive voltage is recommended.**

Although they are very flexible, two Aux inputs are shared with the serial communications so these will be unavailable if the L-Series is connected to the Service Tool. However, a means of simulating these inputs through the Service Tool interface is provided for test purposes.

The functions available for AUX input configuration are:

- Process analog input
- Trim analog input
- Bias analog input
- Target 2 Select discrete input
- Open Loop Select discrete input
- Raise Process Setpoint discrete input
- Lower Process Setpoint discrete input
- Raise Trim Setpoint discrete input
- Lower Trim Setpoint discrete input
- Process PID Dynamics 2 Select discrete input (5418-2834 firmware only)
- Bias Curve 2 Select discrete input (5418-2834 firmware only)

The Service Tool communicates over RS-232 using Aux inputs 3 and 4. Whenever connected, the configured Aux input is not connected and ignored.

Aux X Input Options

Aux1 (0–5 V analog, 0–1.25 V analog, discrete input)

Aux2 (0–5 V analog, discrete input)

Aux3 (0–5 V analog, discrete input, service tool RS-232)

Aux4 (0–5 V analog, discrete input, service tool RS-232)

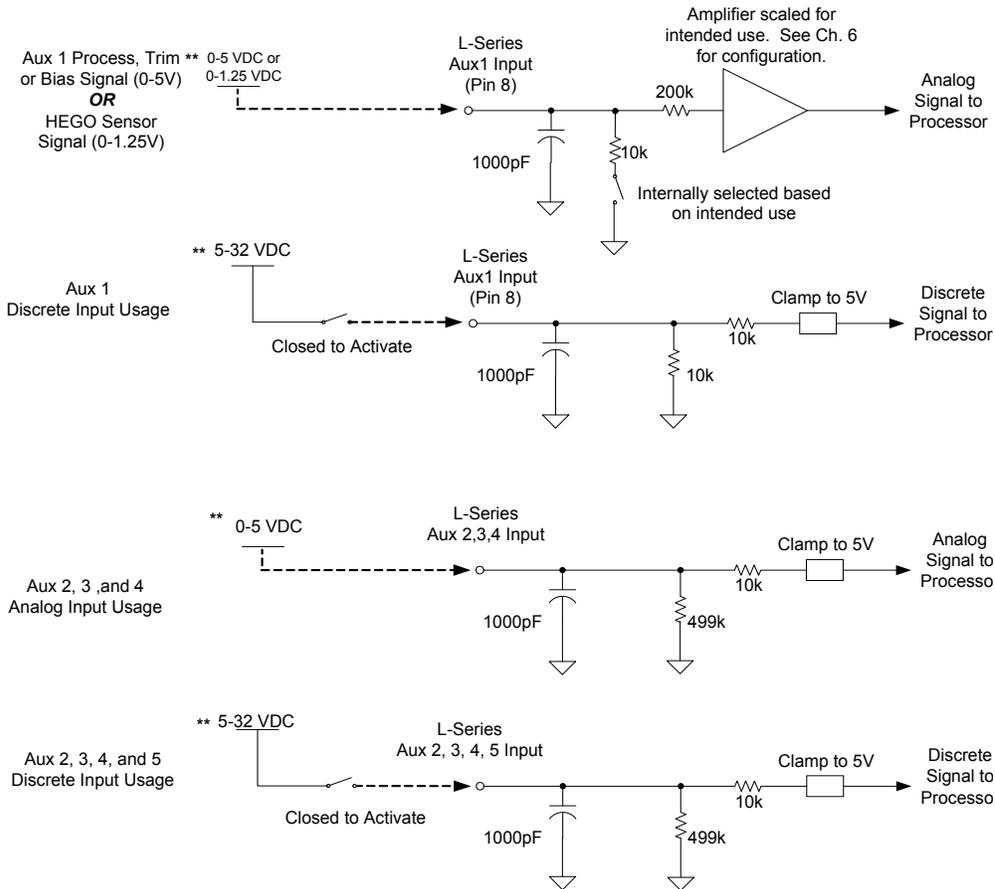
Aux5 (discrete input)

Connecting an auxiliary input pin to battery positive voltage activates it, assuming the input is configured for Active Closed. Removing battery voltage from an input pin or shorting the pin to ground deactivates the input. If not using battery voltage with the auxiliary digital inputs, it is recommended that at least 3 V be present on an input pin in order to change its state from inactive to active. For AUX2, AUX3, and AUX4, greater than 2.5 Vdc is considered high, and less than 0.8 Vdc is considered low. For the AUX1 discrete input only, the input must exceed 3 V to activate the discrete state. AUX3 and AUX4 are also used for digital communications such as RS-232 (service tool).

Figure 3-8 shows the most typical usage of the various auxiliary inputs.

**IMPORTANT** Aux inputs 3 and 4 are used as service port connections, but can also be used as either discrete or analog inputs, much the same as Aux 2. When used as a service port, the analog and discrete functions will not work. Woodward recommends that the service port not be connected during normal use. It is intended for system setup and troubleshooting only.

**IMPORTANT** To prevent electrical noise emissions from interfering with the AUX input signals, it is recommended that wiring to auxiliary (AUX) inputs *not* be routed within 150 mm (6 inches) of any high voltage ignition leads.



\*\* Reference all analog or discrete inputs to L-Series signal ground (Pin 3)  
 Figure 3-8. Typical AUX Input Usage

## Communications

RS-232 communications are available on the L-Series when used with an external transceiver connected to pins 4 and 6. Serial communications allow for the use of a service and configuration tool with the L-Series actuator. The simplest way to establish this interface is to use Woodward kit part number 8923-1061.

**RS-232/Service Tool Connections** (pin 4 and pin 6)

These pins are for serial communication with the L-Series actuator. An external RS-232 transceiver is necessary to make communications possible with the Woodward L-Series Service Tool. A connectivity kit can be purchased from Woodward to accomplish this. Further instructions for using this connectivity kit are provided in Chapter 5.

It is recommended that the OEM or packager provide a breakout cable that is connected to the L-Series service port and run to an easily accessible area on the engine. The service port is absolutely necessary to set up and troubleshoot the L-Series.

Any RS-232 wiring must meet the requirements in the EIA RS-232 Standard document. The RS-232 standard states that the length of the RS-232 cable between the driver and the PC must be less than 50 ft (15 m) with a total capacitance less than 2500 pF. The RS-232 data rate is fixed at 19.2 kbps. The communication port is non-isolated and susceptible to both EMI noise and ground loops related to PC connections and typical industrial environments.

Functions available through the Service Tool include tuning, monitoring, and configuration of the A/F Ratio or Process controller. Comprehensive driver status information is also available. For details, refer to the Service Tool chapters of this manual.

**IMPORTANT**

**The service port is not isolated and is not intended to function while the prime mover is in normal operation. The service port is provided for configuration, setup and for dynamic tuning operation only.**

**Ground Junction** (see Figure 3-11)

This grounding junction is provided for joining external ground wires. **THERE IS NOT AN INTERNAL CONNECTION TO CIRCUIT GROUND.** Terminal pins 3 and 5 must be used for access to the circuit ground. This junction point is completely electrically isolated from the L-Series actuator's electronics and is solely for convenience during installation.

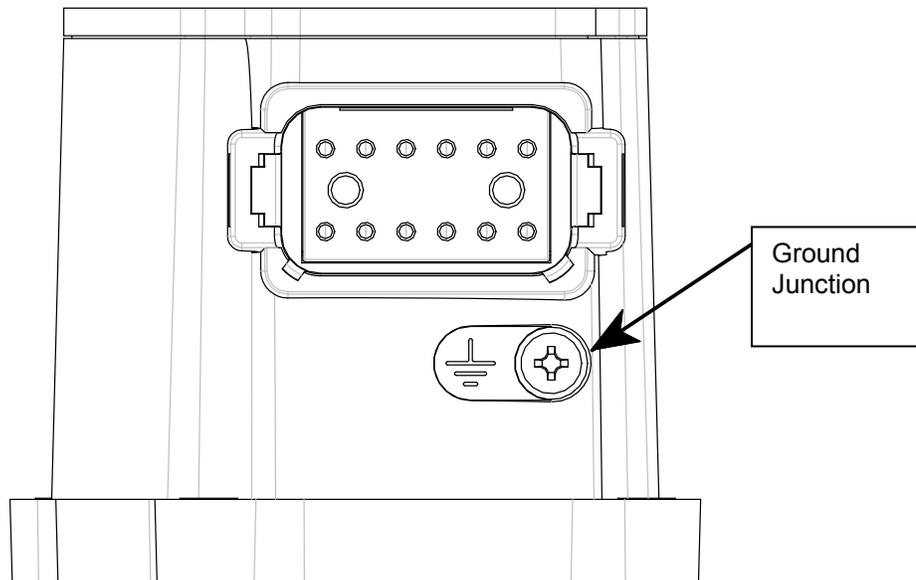


Figure 3-11. Ground Junction Point

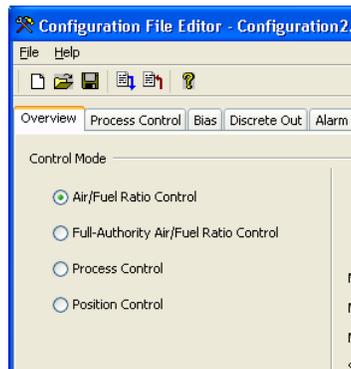
# Chapter 4.

## Description of Operation

### General

The L-Series Process Controller is an electric actuator with position feedback and an integrated digital process control. The actuator output shaft connects to the fuel gas valve of a reciprocating engine or to another process control end device. The output shaft maximum rotation is 60 degrees and is configurable for CW or CCW rotation. A manual position mode is provided to facilitate setting up the actuator system.

Applications for this product range from a Positioner, to an Air/Fuel (A/F) Ratio controller, to a Full-Authority pressure controller (FAPC) with A/F trim and load feed forward control, to a general-purpose process controller. The application is determined by the Control Mode selection on the Service Tool. All applications are implemented in a common software with a user-configurable setup.



When used as an A/F Ratio Control, the L-Series provides air/fuel ratio control for engines using three-way catalytic converters to reduce exhaust emissions. The L-Series A/F with an LC-50 mixer with standard production (stoichiometric) fuel hole sizes will allow closed-loop stoichiometric operation with gaseous fuels from low-quality pipeline natural gas to HD-5 LPG (propane).

When used as a full-authority pressure controller, the L-Series' primary function is to control the air/fuel differential pressure ( $\Delta P$ ). In addition, the L-Series can reduce emissions by providing air/fuel ratio control and a feed forward load input can be programmed to improve overall performance.

When used as a general-purpose process controller, the L-Series can provide closed-loop control on any process including: pressure, flow, temperature, load, or level. Most end devices and linkage are not offered and must be provided by others. Woodward can provide carburetors, mixers and a limited offering of trim valves and integrated throttle bodies (ITB).

When used as a positioner, the L-Series positions the output to a commanded position setting. The position command input type is limited to a 0–5 Vdc analog signal.

Control adjustments are made using the L-Series Service Tool. The Service Tool is a Windows based software tool used to configure, monitor, adjust, and troubleshoot an L-Series process control system. It runs on a personal computer and communicates with the L-Series process control through a serial connection. The L-Series Service Tool includes optional password protection to provide security against tampering.

The control has a switching power supply with excellent spike, ripple, and EMI (electromagnetic interference) rejection. Discrete inputs are capable of rejecting EMI and variable resistance in switch or relay contacts. Analog inputs are differential type with extra filtering for common-mode noise rejection.

The control provides one discrete output that changes states based on pre-defined alarm or status conditions. The control also provides one 0–5 V analog output which provides a position feedback indication. This analog output may be used with an analog meter, recorder, or as input to another control or computer.

The control provides a communications port which can be used as an RS-232 serial interface. The RS-232 port is the service port used by the L-Series Service Tool to configure and tune the L-Series system.

## Controller Features Description

As you review the following features, keep in mind that most applications will only require a few of the functions to be activated. The choices are available to provide maximum flexibility in a single package. The user must set up the actuator direction, process input, setpoint logic, and desired I/O.

The controller I/O consists of input power, 5 configurable aux inputs, a status output, and an actual position indication (see Figure 4-1).

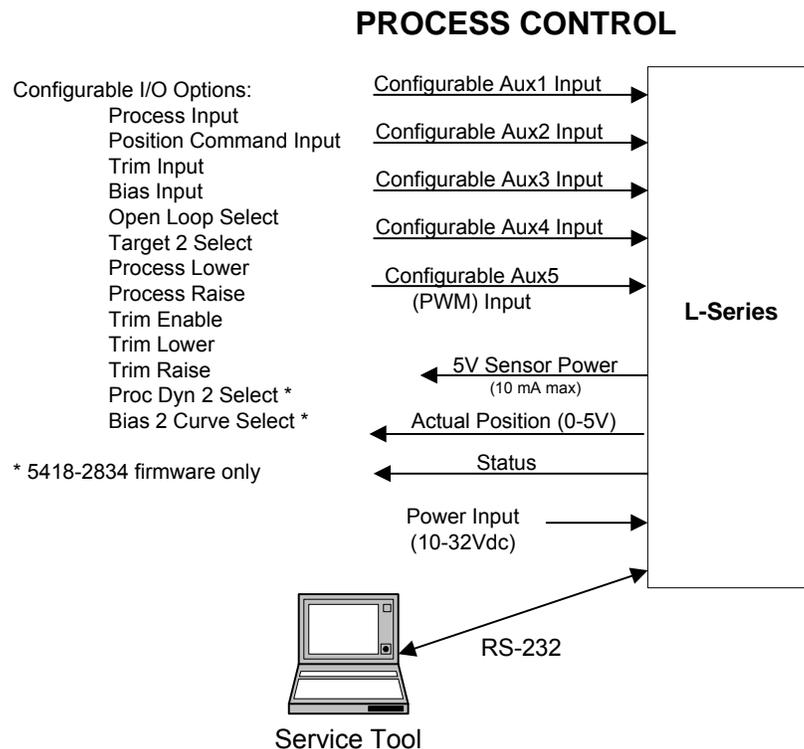


Figure 4-1. Overview of L-Series Inputs/Outputs

## System Overview

The functionality available is application-dependent and is based around 3 PIDs; Position, Process and Trim (see Figure 4-2). The position PID receives the position setting and controls the output shaft to the desired position setting based on feedback from an internal position sensor. The Process PID sets a position command based on the process setpoint and the process input. The overall Process setpoint is the sum of the Trim PID, the Process setpoint and a Bias input. The Bias input is provided to either function as a remote adjustment of the process setpoint or as a feed forward process modifier. Lastly, the Trim PID is cascaded into the Process loop.

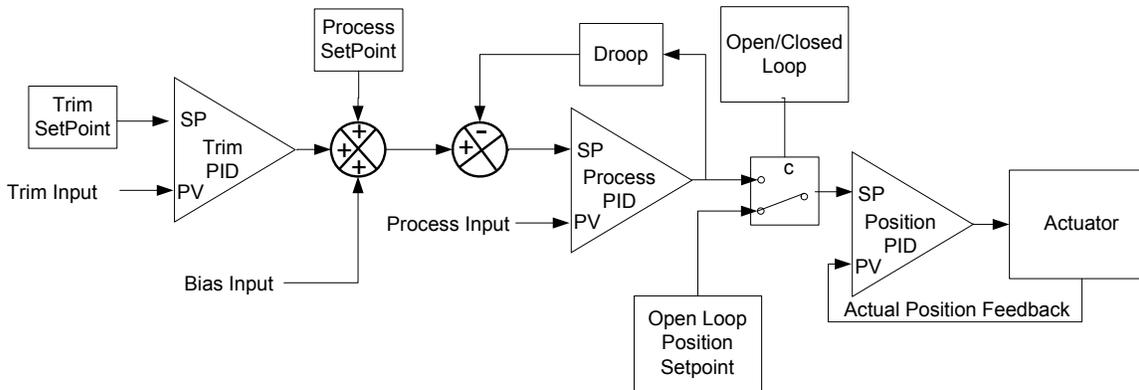


Figure 4-2. Basic Functional Overview

The unit can be configured as a position control or process control. When configured as a process controller, it can be set up as follows:

The full authority (FAPC) controller uses fuel/air differential pressure (delta-P) as the primary control process and also can use a HEGO or UEGO (O<sub>2</sub>) sensor to adjust the position and a kW load signal for feed forward control. This application uses the delta-P as the Process input, the kW load as the Bias input and the HEGO sensor as the Trim input.

The A/F controller simply uses the HEGO or UEGO (O<sub>2</sub>) sensor as the Process input. The Bias input can also be configured. An O<sub>2</sub> sensor input fault can be configured to fail to open loop control to the Bias input curve. Open and Closed loop operation is provided.

When configured as a general Process controller, all of the functions (i.e. Trim and bias) are available for use, if desired.

When configured as a Position controller, none of the process or trim functions are available.

Each of the described application configurations is described in detail in the following sections.

### NOTICE

OEMs and end users are strongly encouraged and expected to develop and thoroughly test specific L-Series Process Control schemes for their engines under both normal and extreme operating conditions before widely applying a control scheme. While extensive testing has been performed on a limited number of engines to prove the L-Series Process Control functions, no attempt has been made to test the many and varied possible control schemes on a broad number of engines in various process control applications.

## Position Control Basics

When configured as a Position controller, the L-Series accepts a 0–5 Vdc analog input position command signal, determines the desired position and actively controls the shaft to the desired set position (Figure 4-3). A 5-point curve is applied to the command signal input to scale the position signal setting and to allow setting a non-linear relationship between the position command signal and the desired position setpoint.

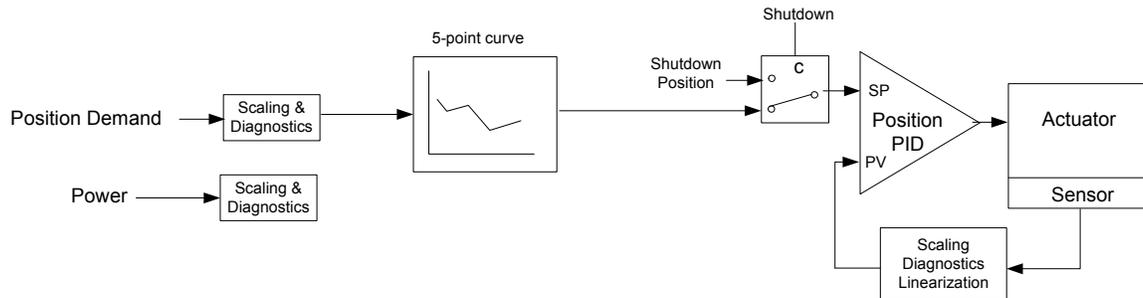


Figure 4-3. Positioner Functional Overview

User-configurable min and max input failure levels are provided. The unit can be configured to either alarm or shutdown upon detection of a position command failure. If a shutdown fault occurs, the L-Series will force the actuator to the user-configured shutdown position.

## Air/ Fuel Ratio Control Basics

The L-Series A/F Ratio Control is a microprocessor-based air/fuel ratio control for four-stroke, gaseous-fueled engines operating with a near-stoichiometric air/fuel ratio. It is designed to work in conjunction with a three-way catalytic converter to efficiently reduce exhaust emissions. By automatically maintaining an optimum air/fuel mixture, emissions compliance is achieved and catalyst life is maximized without operator intervention.

A catalyst that simultaneously eliminates hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) is referred to as a “three-way” catalyst. The use of a three-way catalyst will reduce the emissions of a stoichiometric engine. However, for these reductions to be reliable and maximized, and to protect the catalyst element from premature aging or damage, a very precisely controlled air/fuel ratio is required.

If a three-way catalyst receives exhaust gas containing emissions in the proportions shown in the “Stoich” window of Figure 4-4a, the resulting emissions exiting the catalyst will be reduced to the levels shown in Figure 4-4b.

The heated exhaust gas oxygen sensor (HEGO) generates a voltage signal that indicates where the engine is operating relative to this ideal stoichiometric window. The HEGO sensor operates as a reference-gas sensor, and compares the residual oxygen in the exhaust gas with the oxygen in the reference atmosphere. The active sensor ceramic is heated by an internal heating element. Sensor heating reduces the influence of the exhaust gas temperature on the sensor-ceramic temperature and therefore the temperature-dependent sensor functions. The L-Series A/F monitors the system O<sub>2</sub> sensor output and adjusts fuel flow to maintain emissions at a target O<sub>2</sub> voltage.

A wide-range or universal exhaust gas oxygen sensor (UEGO) mounted in the engine exhaust flow provides a measurement of the amount of excess oxygen during combustion that precisely indicates the air/fuel ratio. The amount of excess air during combustion indicates the leanness of the air/fuel mixture. Since excess air in combustion reduces NO<sub>x</sub> formation, controlling the amount of excess air controls the NO<sub>x</sub> emissions. Unlike the stoichiometric exhaust oxygen sensors, the UEGO sensor signal is proportional to exhaust oxygen over a wide range from a Lambda value of 0.9 to 2.0. A value of 1.00 means the actual air/fuel ratio and the stoichiometric air/fuel ratio are equal, or there is no excess air. Values greater than 1.00 indicate a lean mixture, while values less than 1.00 indicate a rich mixture.

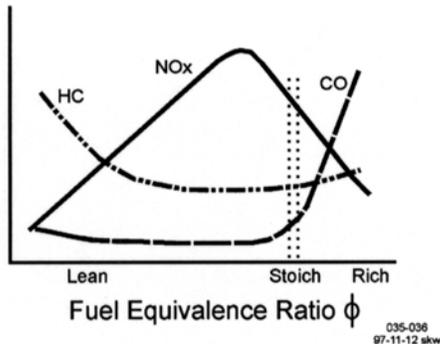


Figure 4-4a. Pre-Catalyst Emissions

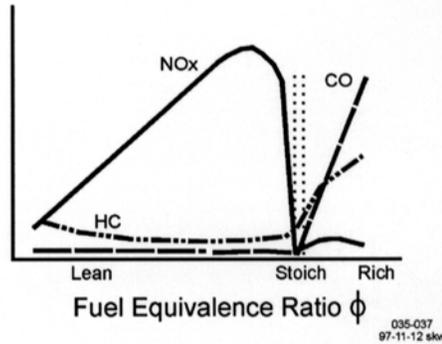


Figure 4-4b. Post-Catalyst Emissions

## A/F Overview of Operation

When power is first applied to the L-Series A/F Ratio Control, the control operates open-loop until the configured closed-loop delay time expires and the HEGO voltage falls below the configured closed-loop threshold. **Pull-up resistors maintain the HEGO signal input at about 1.5 V** until the sensor warms up. When the sensor is up to temperature and operating normally, the impedance is low enough to draw the L-Series input down into its typical 0–1 V operating range. As the sensor ages or is damaged (or if the sensor becomes disconnected), its impedance rises and the input will be pulled up over the closed-loop threshold, which again causes open-loop operation. The open-loop setting can be adjusted during operation by raise or lower discrete inputs.

Dual open-loop position settings can also be configured along with direct or reverse action for each setting.

A failed HEGO sensor can also be configured to follow the Bias input instead of the open-loop setting. **With this configuration, the control will be set to open-loop control only during starting or when selected by digital input and will follow the configured Bias input when a HEGO sensor fault is detected.**

The HEGO sensor signal response to air/fuel ratio is highly non-linear, and this is accounted for in the control response. The L-Series A/F has a control curve that compensates for the response of a specific HEGO sensor (Woodward part number 1680-6005). The response of this sensor is depicted in the Figure 4-5. The L-Series A/F is specifically designed to operate with a HEGO sensor that has the output shown. The accuracy of the HEGO voltage reading is critical for consistent emissions. If a HEGO sensor other than that specified is used, the emissions output may be erratic.

Stoichiometric operation is indicated by a F/A ratio ( $\phi$ ) of 1. For the L-Series A/F system, this corresponds to a voltage output of approximately 0.2 to 0.6 V. In this voltage range, the response of the A/F valve is relatively slow. As the voltage exceeds 0.65 V or drops below 0.15 V, the valve response speed increases.

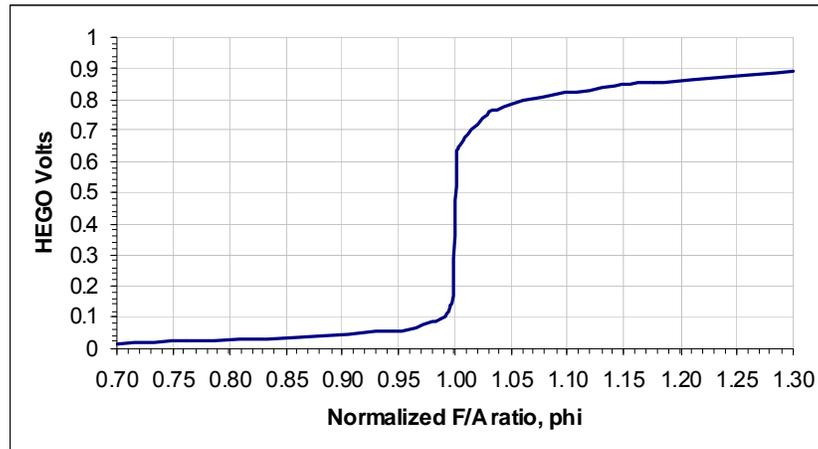


Figure 4-5. L-Series A/F Expected O<sub>2</sub> Sensor Response

## Air/Fuel Ratio Applications

### Trim Valve and Main Valve Air/Fuel Ratio

The A/F Ratio controller will start in open-loop control and transfer to closed loop control once the O<sub>2</sub> sensor has warmed up and the closed-loop delay timer expires. If at any time during operation the O<sub>2</sub> voltage exceeds the programmable threshold, the control is put back into open-loop mode. Open-loop operation can be manually selected by configuring and using the Open Loop Select discrete input. Whenever the control is in open-loop control, the valve will go to a programmable default position.

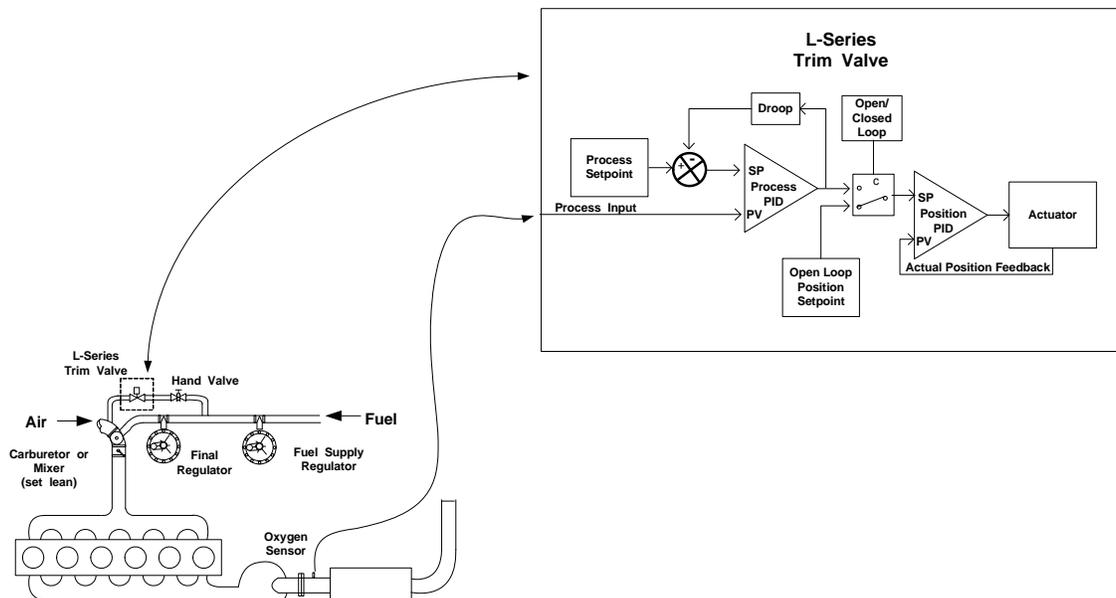


Figure 4-6. Air/Fuel Ratio Trim Valve Application

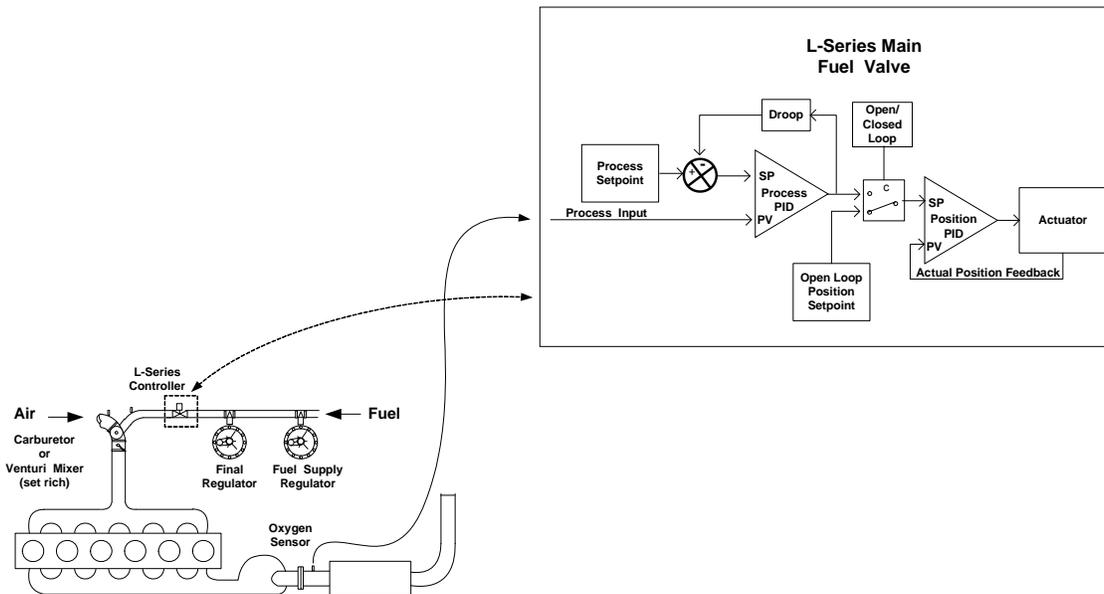


Figure 4-7. Air/Fuel Ratio Main Fuel Valve Application

The setpoint can be adjusted using raise/lower discrete input commands. When in closed-loop control, the  $O_2$  setpoint is adjusted and when in open-loop mode the open-loop position is adjusted.

Two sets of control targets, reverse control actions, and position limits can be configured. The target position setting and control action can be changed during operation by configuring and switching the Target 2 Select digital input. Typically, this feature allows switching between dual fuel gases and positive or negative fuel pressure sources. For example, when switching from pipeline natural gas to stored LPG for an emergency electrical generator set. When switching between the fuel parameter sets, the control will ramp to the configured position of the selected fuel, then continue normal operation from that position.

A functional overview is provided in Figure 4-8. With the 5418-2834 firmware, the functionality of the bias input changed, when configured as Air/Fuel Ratio control. The location of the summing point was moved from biasing the position command to biasing the process setpoint. Also dual bias and dual process PID dynamics options were added.

When configured as an Air/Fuel Ratio controller and operating in closed-loop control, the L-Series accepts an analog (typically 0–1.25 V) signal input, compares this to the desired setpoint and actively controls the shaft to the desired setting using the Process PID (Figure 4-7). The input and setpoint are normalized for controllability due to the non-linear HEGO sensor signal.

## Air / Fuel Ratio Control

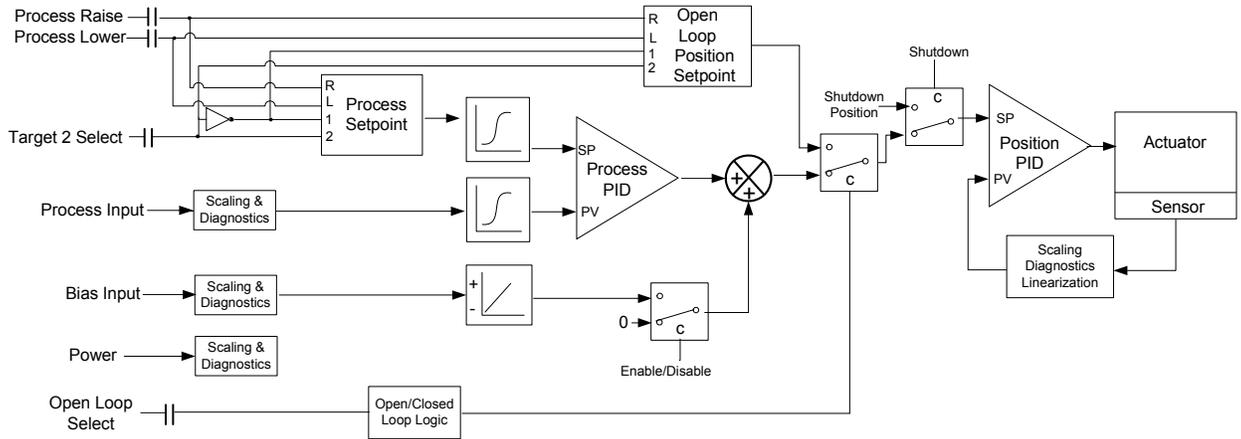


Figure 4-8a. Air/Fuel Ratio Functional Overview (5418-1681 firmware)

## Air / Fuel Ratio Control

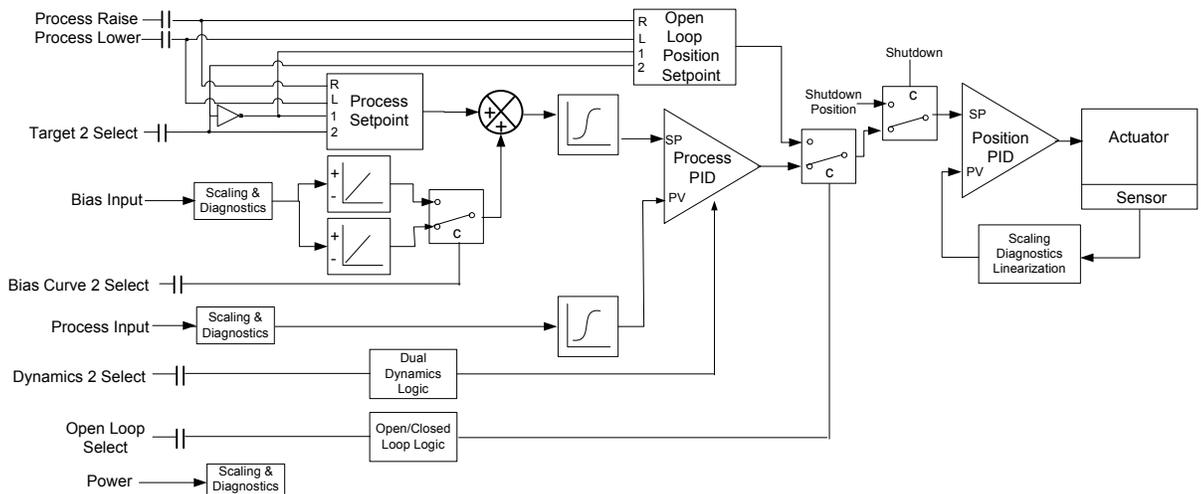


Figure 4-8b. Air/Fuel Ratio Functional Overview (5418-2834 firmware)

User-configurable min and max input failure levels are provided for the Process input, however, they should be set to min and max values since the HEGO sensor operates normally throughout the entire input voltage range.

The unit has several fault conditions that can be configured for either alarm or shutdown upon detection. If a shutdown fault occurs, the L-Series will force the actuator to the user-configured shutdown position. Refer to the Faults section for more details.

For Trim Valve applications the final regulator must be a Zero-Pressure Regulator (ZPR) set slightly lean to give the trim valve sufficient authority to richen the mixture and obtain a controlled stoichiometric mixture at all load conditions. **Typically a 20 to 30 % trim valve position at No-Load is a good initial target for adjusting the final regulator setting.**

For Main Fuel Valve applications the final ZPR regulator must be set slightly rich to give the main fuel valve sufficient authority to lean the mixture and obtain a controlled stoichiometric mixture at all load conditions. **Typically a 60 to 70 % main fuel valve position at Rated Load is a good initial target for adjusting the final regulator setting.**

## Full Authority Air/Fuel Ratio

A full-authority application will be in closed-loop differential fuel gas pressure control at all times, unless a fault occurs. A fault condition will force the actuator to the shutdown position. The open/closed loop function is not used with this application.

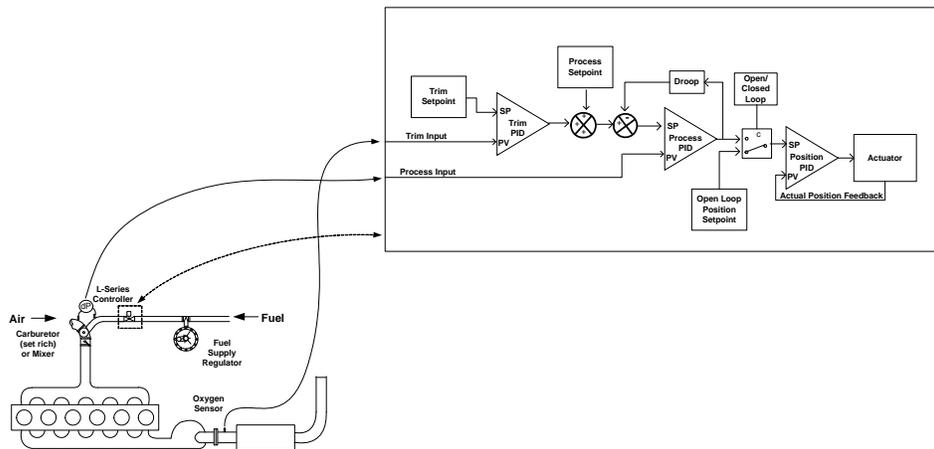


Figure 4-9. Full Authority Air/Fuel Ratio application

When configured as a Full Authority controller, the L-Series accepts an analog (typically 0–5 V) signal input, compares this to the desired setpoint and actively controls the shaft to the desired differential fuel gas pressure setting using the Process PID (Figure 4-9).

The Trim controller can be combined with Process control for full authority A/F Ratio control. If used, the controller will be enabled once the O<sub>2</sub> sensor has warmed up and the closed-loop delay timer expires. During operation, the trim control is disabled if the O<sub>2</sub> voltage exceeds the configured fault levels. For manual enable/disable of trim control, a Trim Enable discrete input can be configured. Whenever the control is disabled, the trim controller output is set to zero. The input and setpoint are normalized for controllability due to the non-linear HEGO sensor signal. The setpoint can be adjusted using Trim Raise/Lower discrete input commands.

A load indication, provided by a load sensor or a throttle position signal into the Bias logic, can be used as a feed forward controller signal to anticipate changing operating conditions. Signal must be stable and properly scaled to maintain full authority at all load levels.

Two sets of control targets, reverse control action, and position limits can be configured. The target position setting and control action can be switched during operation by configuring and using the Target 2 Select digital input. Typically, this feature allows switching between dual fuel gases and positive or negative fuel pressure sources. For example, when switching from pipeline natural gas to stored LPG for an emergency electrical generator set. When switching between the fuel parameter sets, the control will ramp to the configured position of the selected fuel, then continue normal operation from that position.

A functional overview is provided in Figure 4-10. With the 5418-2834 firmware, dual bias and dual process PID dynamics options were added.

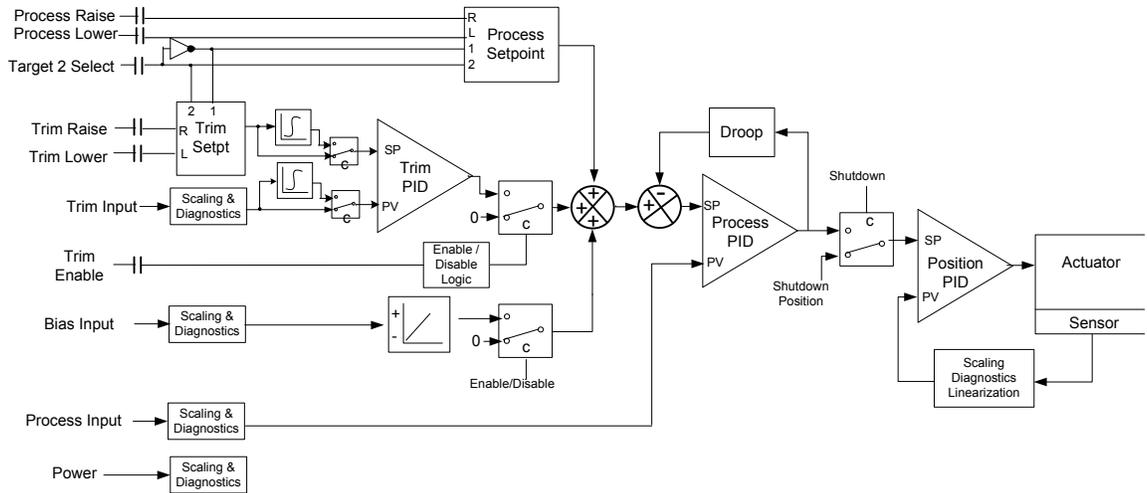


Figure 4-10a. Full Authority Functional Overview (5418-1681 firmware)

**Full Authority Control**

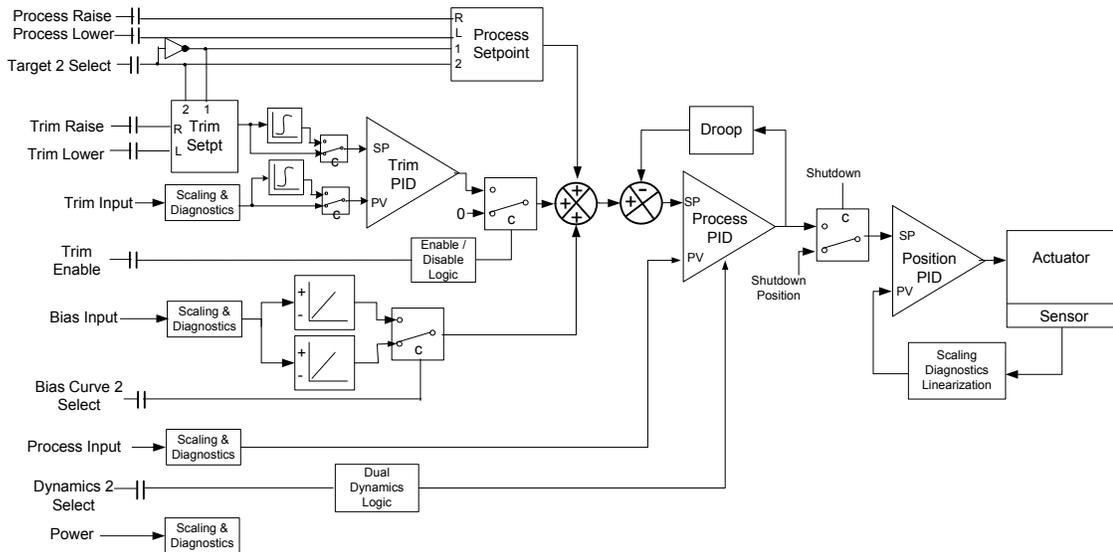


Figure 4-10b. Full Authority Functional Overview (5418-2834 firmware)

User-configurable min and max input fault levels are provided for the Process, Trim, and Bias inputs. However, the trim input fault levels should be set to min and max values since the HEGO sensor operates normally throughout the entire input voltage range.

The unit has several fault conditions that can be configured for either alarm or shutdown upon detection. If a shutdown fault occurs, the L-Series will force the actuator to the user-configured shutdown position. Refer to the Faults section later in this chapter for further details.

### Full Authority Air/Fuel Ratio plus Process Controller

A combination of a Full Authority Air/Fuel Ratio plus Process control provides further opportunity for total fuel system control. The only function not covered is the fuel shutoff.

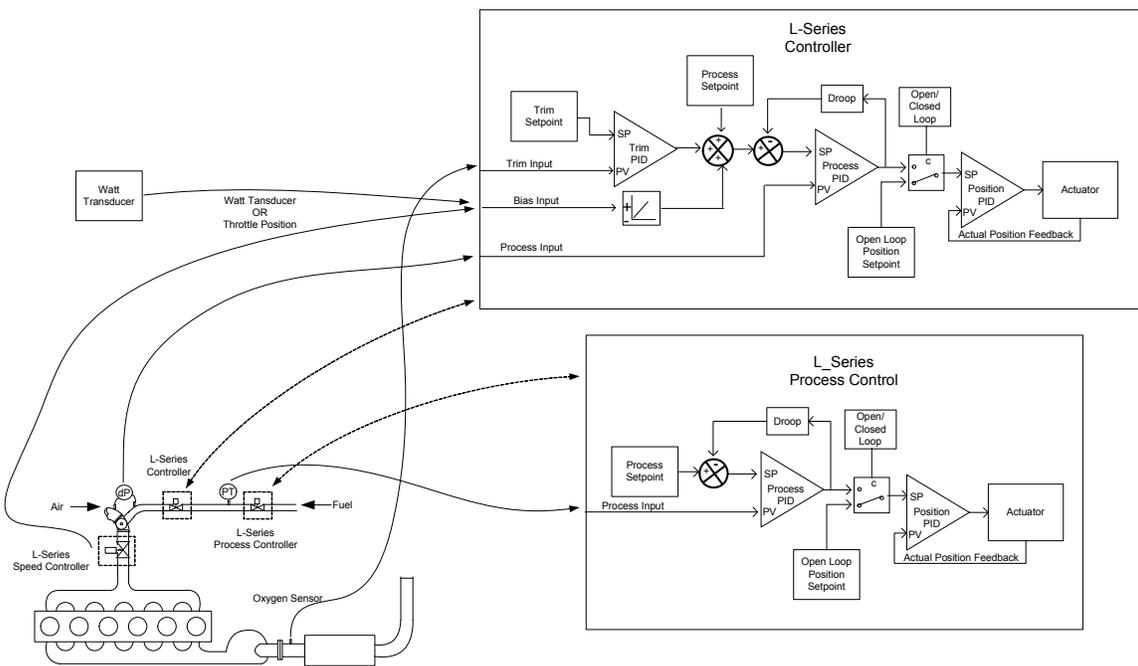


Figure 4-11. Full Authority Air/Fuel Ratio Control combined with a Process Control

## Process Control Application

The functions available for the general Process Controller application are identical to the Full-Authority pressure controller. The only difference is the Trim input cannot be used to control A/F Ratio. In this configuration, the L-Series is in closed-loop process control at all times, unless a fault occurs. A fault condition will force the actuator to the user-configured shutdown position.

A functional overview is provided in Figure 4-12. With the 5418-2834 firmware, dual bias and dual process PID dynamics options were added.

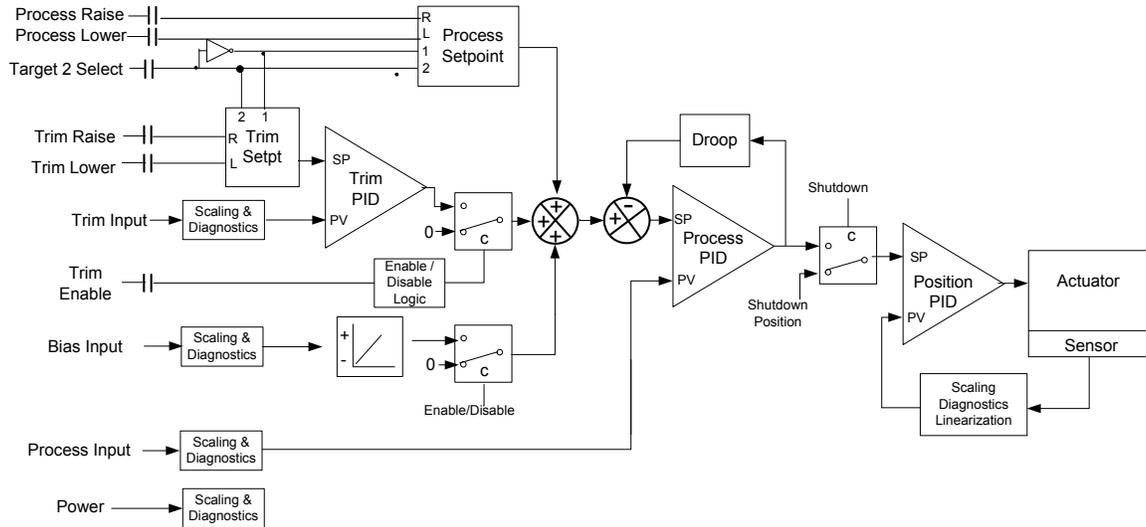


Figure 4-12a. Process Control Functional Overview (5418-1681 firmware)

## General Process Control

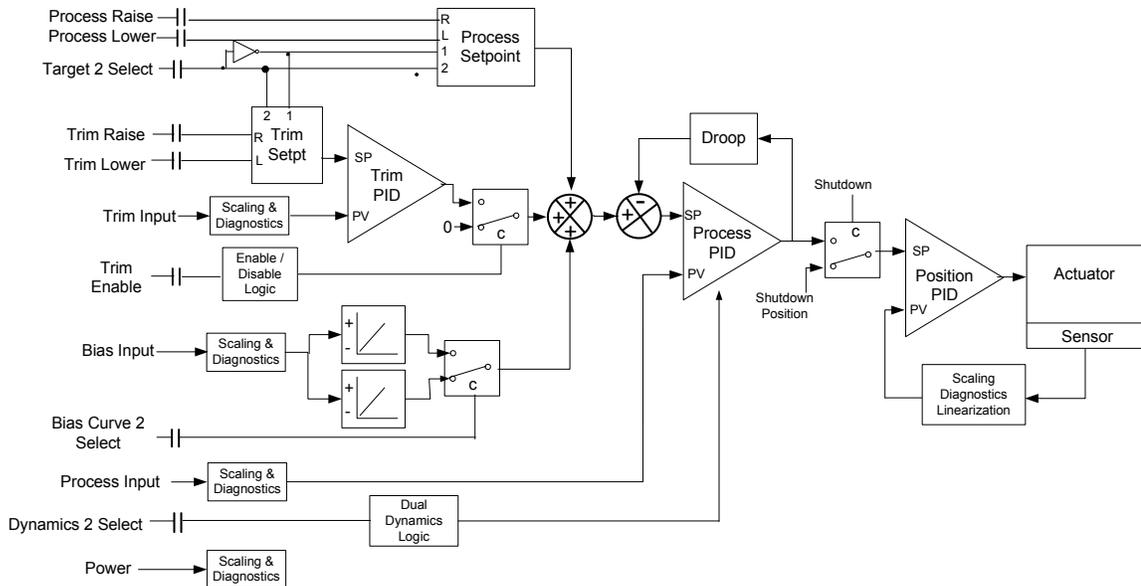


Figure 4-12b. Process Control Functional Overview (5418-2834 firmware)

## System Operation

The L-Series actuator is ready for operation once the power supply is connected. Power may be connected to the control at the same time the engine starter motor is engaged.

On an engine shutdown command, the independent engine shutdown solenoid or solenoid valve in the fuel supply should be de-activated and the power supply disconnected from the process control. This shutdown signal should be sent directly from the engine control panel and should be independent and separate from the L-Series controller.

!
**WARNING**

The L-Series control should not be used as the primary means of shutting down the engine.

**IMPORTANT**

Use external monitoring of process to ensure proper action/reaction to desired system parameters, changes, and settings.

### Functional Overview

The diagram illustrates the functional overview of the L-Series process controller. It shows the flow of signals from external inputs through various processing blocks to the final actuator and sensor. Key components include:

- Inputs:** Position Demand, Process Raise/Lower, Target 2 Select, Trim Raise/Lower, Trim Input, Trim Enable, Bias Input, Process Input, Open Loop Select, and Power.
- Setpoints:** Process Setpoint (R, L, 1, 2) and Position Setpoint (R, L, 1, 2).
- Control Logic:** Scaling & Diagnostics blocks, Trim PID, Process PID, Position PID, Droop, and Open/Closed Loop Logic.
- Actuator and Sensor:** The final output to the Actuator and feedback from the Sensor.
- Feedback and Diagnostics:** Scaling & Diagnostics Linearization, Disabled Value, and Failed Value blocks.

Figure 4-13a. Functional Overview (5418-1681 firmware)

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Woodward

## Software Overview

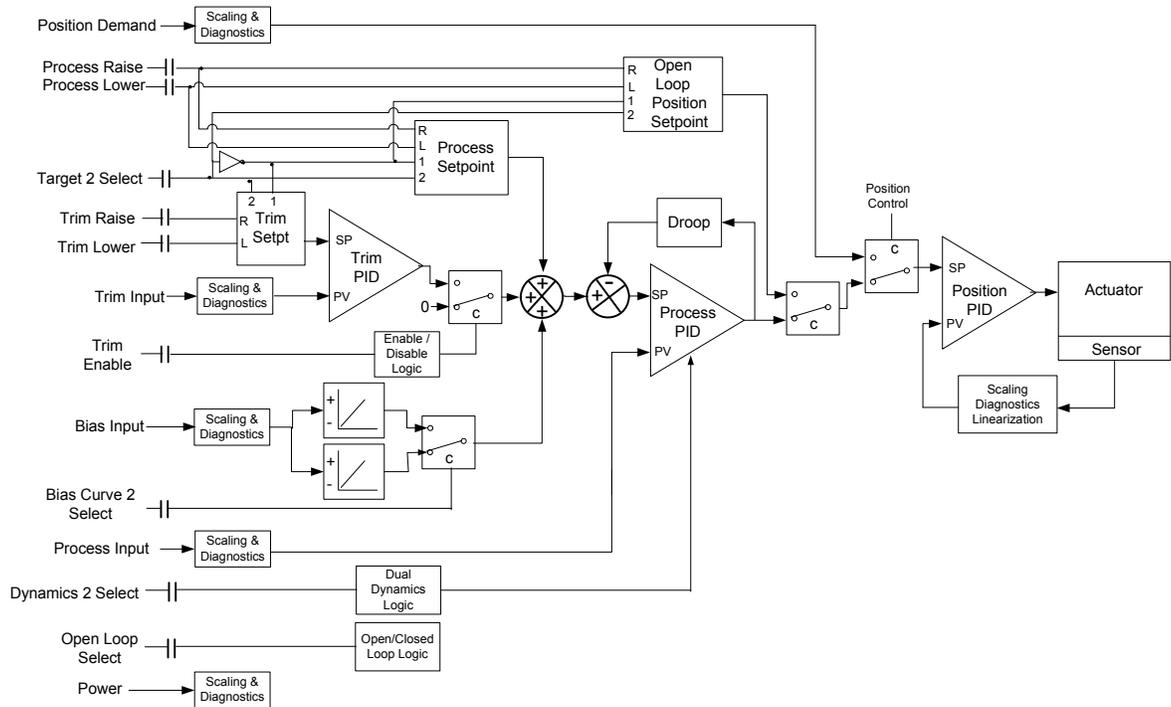


Figure 4-13b. Functional Overview (5418-2834 firmware)

Applications for this product range from a Positioner, to an Air/Fuel (A/F) Ratio controller, to a Full-Authority pressure controller (FAPC) with A/F trim and load feed forward control, to a general-purpose process controller. The application is determined by the Control Mode selection on the Service Tool. All applications are implemented in a common software as shown in Figures 4-13a and 4-13b, depicting the differences between the two firmware versions (5418-1681 and 5418-2834). The two versions are functionally nearly identical except dual bias and dual process PID dynamics options were added in the 5418-2834 firmware and, when configured as an Air/Fuel Ratio control, the bias summing point changed (see Figure 4-8). The following paragraphs detail the functionality of the individual logic functions.

## Process Control

The process control consists of a Process input, a Process Setpoint, and a Process PID. The output of the Process PID determines the commanded position when in closed-loop control.

The function of the Process control loop varies with the configuration of the L-Series. When configured as an Air/Fuel Controller, this loop controls the  $O_2$ . When configured as a Full Authority controller, this loop controls the fuel delta-P. When configured as a General Process controller, this loop controls the primary process under control (e.g., pressure, level, temperature, etc.). This loop is not used when configured as a Position controller.

**NOTICE**

OEMs and end users are strongly encouraged and expected to develop and thoroughly test specific L-Series Process Control schemes for their engines under both normal and extreme operating conditions before widely applying a control scheme. While extensive testing has been performed on a limited number of engines to prove the L-Series Process Control functions, no attempt has been made to test the many and varied possible control schemes on a broad number of engines in various process control applications.

## Process Input

The process input is scaled and compared to the process setpoint. The overall process setpoint is the sum of the process setpoint, the bias input, and the trim input error. Process droop can be configured which will bias the setpoint downward.

The Process setpoint will have 4 positions; raise, lower, target 1, and target 2. The Process setpoint will have 2 rates; raise/lower rate and target rate. When in closed loop control, the raise and lower discrete inputs will adjust the process setpoint within the setpoint min/max limits. The process controller PID will NOT have the same steady-state/duty-cycle modes as the old LCS. Instead a normal PID controller will be used with a catalyst perturbation option (see below).

The Service Tool can be used to tune the Process PID, to change the Process setpoint, and to set the default Process setpoint(s). The Process control values will be displayed in programmable engineering units.

## Setpoint Functions

The setpoint can be configured as a single value, a 2-setpt select, or a 3-setpt select. Raise and lower commands can be used to adjust the setpoint and the setpoint can be biased with an analog input. Droop is also available.

### Single setpoint select

Sets the setpoint to a single value when power is first applied. This is the default setting for the controller. If no other features are enabled, the process will run at one setpoint.

### Two setpoint select

This feature allows the user to toggle the process control voltage between two different setpoints. The toggle is accomplished through a Target 2 Select discrete input. The user can toggle between the two setpoints at any time during operation. Transition between the two setpoints is ramped at the user-defined target ramp rate.

### Raise/Lower adjust

Ramps to and holds at any value between two process setpoint limits based on discrete signal inputs while the process is running. While adjusting the setpoint, the setpoint moves at the user-defined setpoint adjust ramp rate.

- **Lower**—This discrete input acts directly on the internal setpoint within the L-Series and will progressively decrease the setpoint down to a programmable lower limit, at a programmable rate, for as long as the Lower command is active. When the lower command is released, the setpoint reference will remain fixed at the last setting reached.

- **Raise**—The Raise discrete input acts directly upon the internal setpoint within the L-Series and will progressively increase the setpoint reference up to a programmable upper limit, at a programmable rate, for as long as the Raise command is active. When the raise command is removed, the setpoint reference will remain fixed at the last setting reached.

Two additional features are available when using the raise/lower setpoint adjustment, a pulsed raise/lower option and an automatic default value save function. When enabled, the pulsed raise/lower option moves the process setpoint a fixed amount each time a raise or lower command is selected. To move the setpoint further, the command must be released and re-applied. The auto save feature, when enabled, will save the current setpoint as the default setpoint after 30 seconds.

### Three or Four setpoint select

The setpoint can be configured to act as a three or four setpoint select by using a combination of Target 2 Select, Raise, and Lower discrete inputs. The user can toggle between the setpoints at any time during operation. Transition between the two setpoints moves at either the adjust ramp rate if a raise or lower command is selected or the target ramp rate if the target 2 select is used.

### Droop

Biases the current process setpoint by a negative percentage based on actuator position.

This feature allows for a change in setpoint with a change in L-Series position. For an example, if the L-Series is controlling a valve to regulate pressure in a process with variable flow rates, the controlled pressure would droop as the flow rate increases and the valve opens. This behavior mimics the behavior of mechanical pressure regulators, and can sometimes be a benefit to system stability.

A position feedback device is provided within the L-Series to monitor actuator position. Setting Droop to 0% means the control will have no setpoint bias. With droop, the desired process voltage reduces with the following formula:  $\text{Setpoint} * \text{Droop Percentage} * \text{Actual Position}$ . This droop calculation assumes full travel (0–100%) corresponds to the droop range.

### Process PID Dynamics

The Process PID has 2 dynamics options; either a single set of dynamics or a 5-point gain vs position curve. In addition, a dual gain window is provided to improve overall dynamic response.

Firmware 5418-2834 has an option for dual dynamics, with a configurable input selection. This allows for either two proportional gain settings or two 5-point curves. When the input selection is active, the second set of dynamics is used and when not active the first set is used.

During online dynamics tuning, the service tool displays and trends the process setpoint, process input, position setpoint, and actual position parameters on the scope screen.

## Dual Gain Settings

Gain Window and Gain Ratio settings further modify the applied proportional gain. These Dual Gain Dynamic settings can improve both steady state and transient load performance by automatically switching between two gain settings. A low gain setting is applied during steady-state operation. A high gain setting is applied during transients. Dual Gain Dynamics are available for all gain configurations.

During steady-state loaded operation, the control uses the primary gain setting. In this region, gain is set to prevent the control from responding to minor process fluctuations inherent with reciprocating engines. This essentially eliminates harmful jiggle of the actuator output and the fuel system or other process linkage during steady-state loaded operation.

During load transients, should the PID error exceed the adjustable Gain Window width, the primary gain setting is multiplied by the gain ratio setting to temporarily increase the applied gain. This higher gain produces a faster actuator output response to quickly restore the process to the process setting. The primary gain setting is restored once the control senses a return to steady-state operation (see Figure 4-14). Setting the gain ratio to 1 disables the function.

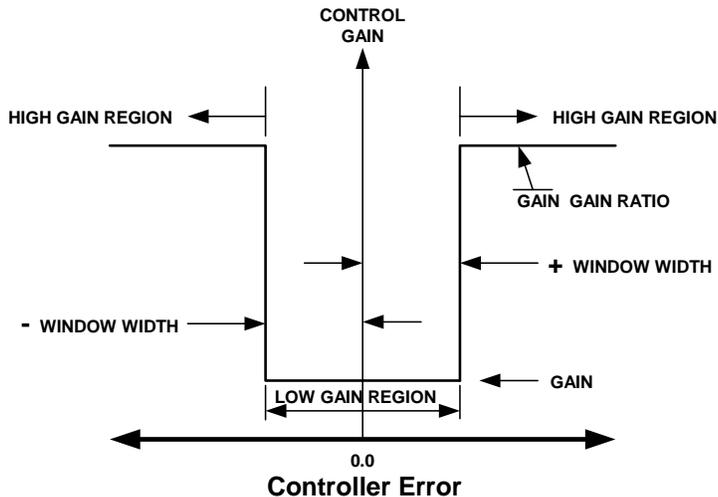


Figure 4-14. Control Gain as a Function of Controller Error

## Oxygen Sensor Functions

The oxygen sensor functions are only available when the unit is configured as an Air/Fuel Ratio controller or as a Full Authority controller with Air fuel Ratio Trim.

### Closed-loop/HEGO Voltage Threshold

The closed-loop/HEGO voltage threshold prevents closed-loop control activity until the HEGO sensor is operational.

A cold HEGO sensor has very high impedance ( $\gg 1\text{M ohm}$ ), which decreases as the sensor element comes up to operating temperature. The HEGO signal during warm-up can be slow and difficult to accurately measure, so the air/fuel ratio control remains open-loop at the appropriate default position (for the selected fuel) until the feedback signal is reliable. A pull-up resistor keeps the feedback voltage higher than the typical HEGO response voltage range ( $\sim 0\text{--}1\text{V}$ ) until the sensor impedance falls below about  $100\text{K ohms}$ . Once the signal (plus pull-up) falls below a programmable threshold voltage (typically about  $1\text{ volt}$ ), the signal is believable and reliable enough to enable closed-loop control. A HEGO sensor quickly warms up, and the time from the  $\sim 100\text{K ohm}$  impedance level to the typical operating impedance of  $2\text{--}3\text{K ohm}$  is only a few seconds, by which time any offset voltage due to the pull-up is negligible.

The feedback voltage is also pulled up when the HEGO input circuit is open, so this feature detects an open-circuit failure and maintains safe engine operation at the default position.

### Closed-loop Delay Timer

The L-Series A/F control offers a delay timer function that disables closed-loop operation during engine start-up and HEGO sensor warm-up. Both the closed-loop/HEGO voltage threshold and delay timer criteria must be met for closed-loop to be active. The closed-loop delay timer keeps the control in open-loop for a programmable amount of time after the HEGO sensor drops below the sensor closed-loop threshold.

### Catalyst Perturbation

When configured as an air/fuel controller, a catalyst perturbation option is available. This function induces an oscillation between rich and lean that causes the engine exhaust to cycle between oxidizing and reducing.

The implementation includes three configurable settings, a setpoint Delta Min, setpoint Delta Max and a setpoint Hysteresis. Delta Min is used at 0% position and Delta Max is used at 100% position. Intermediate values are applied at intermediate positions. This allows the Delta to vary with load. Typical values are  $0.01\text{V}$  ( $10\text{ mV}$ ) for Delta min and max and  $0.005\text{ V}$  ( $5\text{ mV}$ ) for Hysteresis (example shown below). Set these values to zero to disable the function.

The Delta is added to the controller setpoint. Once the HEGO ( $\text{O}_2$ ) feedback volts ( $\text{mV}$ ) goes above the controller setpoint plus the Hysteresis, the Delta is subtracted from the setpoint until the feedback drops below the setpoint minus the Hysteresis. This add/subtract is repeated as long as the air/fuel controller is active. This function affects the Process control setpoint, when configured as a basic air/fuel controller, or the Trim setpoint when configured as a Full Authority controller.

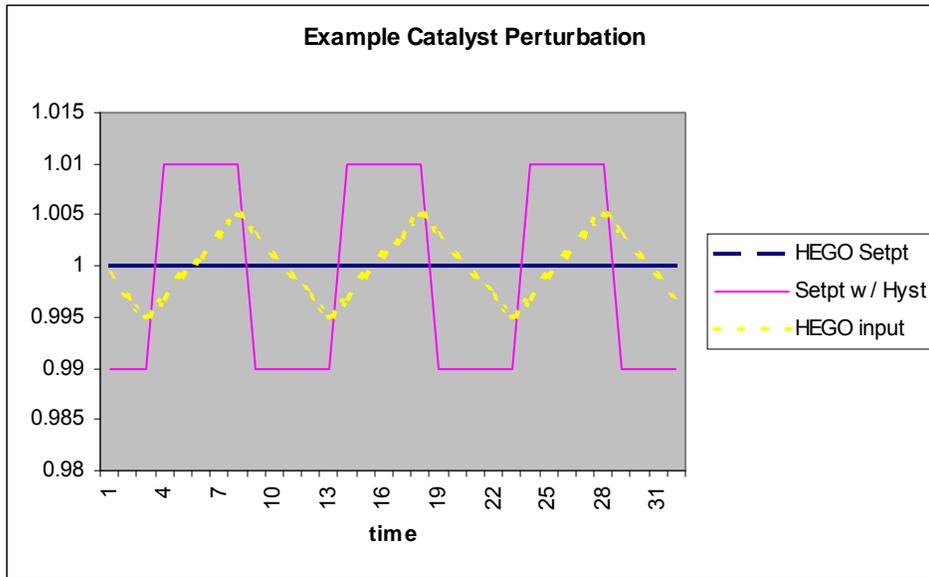


Figure 4-15. Catalyst Perturbation

## HEGO Input Linearization

When configured as a HEGO input, the actual HEGO voltage and Target HEGO voltages are fed through a normalizing interpolation table in order to convert HEGO voltage to an air/fuel ratio. This is necessary to linearize the data. Since the curve varies between HEGO sensors, it is important to use the recommended sensor (see Chapter 1).

## Trim Control

The Trim Control consists of a Trim input, a Trim Setpoint, and a Trim PID. The output of the Trim PID moves the Process setpoint and the Process PID determines the commanded position. Trim is only available when the unit is configured as a Full Authority controller or as a General Process controller.

### Trim Input

Diagnostics will be performed on the trim input. If the input fails, Trim control is disabled and the output is set to zero. If configured as an O<sub>2</sub> sensor input, the trim will remain disabled until the O<sub>2</sub> sensor warms up.

The Service Tool can be used to tune the Trim PID, to change the Trim setpoint, and to set the default Trim setpoint.

## Trim Setpoint

The trim setpoint can be configured as a single value, a 2-setpt select, or a 3-setpt select. Raise and lower commands can be used to adjust the setpoint.

### Single setpoint select

Sets the setpoint to a single value when power is first applied. This is the default setting for the controller. If no other features are enabled, the process will run at one setpoint.

### Two setpoint select

This feature allows the user to toggle the process control voltage between two different setpoints. The toggle is accomplished through a Target 2 Select discrete input. The user can toggle between the two setpoints at any time during operation. Transition between the two setpoints is ramped at the user-defined target ramp rate.

### Raise/Lower adjust

Ramps to and holds at any value between two process setpoint limits based on discrete signal inputs while the process is running. While adjusting the setpoint, the setpoint moves at the user-defined setpoint adjust ramp rate.

- **Lower**—This discrete input acts directly on the internal setpoint within the L-Series and will progressively decrease the setpoint down to a programmable lower limit, at a programmable rate, for as long as the Lower command is active. When the lower command is released, the setpoint reference will remain fixed at the last setting reached.
- **Raise**—The Raise discrete input acts directly upon the internal setpoint within the L-Series and will progressively increase the setpoint reference up to a programmable upper limit, at a programmable rate, for as long as the Raise command is active. When the raise command is removed, the setpoint reference will remain fixed at the last setting reached.

Two additional features are available when using the raise/lower setpoint adjustment, a pulsed raise/lower option and an automatic default value save function. When enabled, the pulsed raise/lower option moves the process setpoint a fixed amount each time a raise or lower command is selected. To move the setpoint further, the command must be released and re-applied. The auto save feature, when enabled, will save the current setpoint as the default setpoint after 30 seconds. If target 2 is selected, then the target 2 default will be set to the current setpoint value.

### Three or Four setpoint select

The setpoint can be configured to act as a three or four setpoint select by using a combination of Target 2 Select, Raise, and Lower discrete inputs. The user can toggle between the setpoints at any time during operation. Transition between the two setpoints moves at either the adjust ramp rate if a raise or lower command is selected or the target ramp rate if the target 2 select is used.

## Trim Controller

The Trim control logic uses a PID to control the Trim input level at setpoint by modifying the process setpoint. The PID has a single set of dynamics plus the same type of dual gain window as the Process PID. Reverse Trim control action can be configured. Trim Control can be enabled/disabled using the O<sub>2</sub> warm logic or by using the Trim Enable discrete input.

## Bias Function

This feature allows the user to alter the process setpoint with an external signal. The Bias input will be run through a 5-point curve and is added to the process setpoint. Diagnostics will be performed on the bias input. If the input fails, bias will be disabled. When disabled, the bias value is zero. A sliding deadband is available on the bias input to reduce the effects of small signal movement from affecting control action.

Firmware 5418-2834 has an option for dual bias curves, with a configurable input selection. This allows for two independent input-selected 5-point curves. When the input selection is active, the second curve is used and when not active the first curve is used.

The Bias function is *not* available when the unit is configured as a Position Control.

## Actuator Position Limiter Functions

The actuator position limiter functions include an Open Loop Setpoint Max Actuator Position Limit, a Min Actuator Position Limit, Aux Limiter and Raise/Lower commands.

### Open/Closed Loop Mode

An Open Loop mode can be forced using the Open Loop Select discrete input. If configured as an Air/Fuel Ratio controller, the unit will remain in open loop mode until the O<sub>2</sub> sensor warms up and the closed loop delay time expires. The Open Loop setpoint has 4 positions (raise, lower, target 1, target 2) and 2 rates (raise/lower rate and a target rate). When using 2 targets, each target has configurable position limits, default position, and direction settings. When in open loop control, the raise and lower discrete inputs can be used to adjust the open loop position within the position limits allowed.

#### Open Loop Setpoint

The open loop setpoint can be adjusted using the Target 2 Select, or the Raise and lower commands.

The Target 2 Select discrete input feature allows the user to toggle the open loop position between two different setpoints. The user can toggle between the two setpoints at any time during operation. Transition between the two setpoints moves at a user-defined ramp rate.

- **Lower**—This discrete input acts directly on the open loop position setpoint when the control is in the open loop mode. The setpoint will progressively decrease the setpoint down to a programmable lower limit, at a programmable rate.
- **Raise**—The Raise discrete input acts directly on the open loop position setpoint when the control is in the open loop mode. The setpoint will progressively increase the setpoint down to a programmable upper, at a programmable rate.

Two additional features are available when using the raise/lower setpoint adjustment, a pulsed raise/lower option and an automatic default value save function. When enabled, the pulsed raise/lower option moves the process setpoint a fixed amount each time a raise or lower command is selected. To move the setpoint further, the command must be released and re-applied. The auto save feature, when enabled, will save the current setpoint as the default setpoint after 30 seconds.

#### **Manual open-loop/closed-loop switch input**

The Manual open-loop/closed-loop switch input allows the user or external control system to force open-loop operation or enable closed-loop operation. This function is only available when configured as an Air/Fuel Ratio controller.

When closed-loop control is selected, the L-Series will operate closed-loop if the O<sub>2</sub> sensor voltage threshold criterion is met. When open-loop control is selected with the discrete input, the L-Series control is forced open-loop regardless of other closed-loop criteria, and the relay contact output will respond accordingly.

The feedback voltage is also pulled up when the HEGO input circuit is open. This feature detects an open-circuit failure and maintains engine operation at the default position.

#### **Max Actuator Position**

The Max actuator position limits the actuator position while the process is running. Separate max actuator position limits are provided for dual fuels (targets), selectable with the Target 2 select switch function.

#### **Min Actuator Position**

The Min actuator position limits the actuator position while the control is running closed-loop. Separate min actuator position limits are provided for dual fuels (targets), selectable with the Target 2 select switch function.

### **Position Stops User Calibration**

User Stops defines a limited range of travel within the total overall 60 degree nominal travel of the shaft. For example a certain valve may only use 50 degrees of travel. The Users Stops maps the position demand to the actual customer-used travel such that 0–100% demand corresponds to 0–100% of actual travel. This also prevents the unit from driving hard against a stop and heating up the unit because the demanded travel cannot be attained.

Refer to the Setup and Tuning in Chapter 7 for details on position calibration and verification using the Service Tool.

### **Current Limiting**

The controller provides actuator current limiting based on the electronics temperature. Dependent on board and actuator thermal models, the software reduces current as necessary to avoid conditions that would damage the device due to extreme temperatures.

Current limiting based on temperature begins when the combined current and temperature environment causes board temperatures greater than 117 °C. The limit curve is a linear derate from full current at 117 °C down to zero current at 125 °C. At 125 °C, an OverTemp fault is annunciated. Depending on the current (actuator torque) and ambient operating temperatures, the unit may never reach a reduced level.

## Temperature Sensing

The L-Series has an on-board temperature sensor to monitor board temperatures and protect the unit from overtemperature. This temperature is monitored and a fault is annunciated if the set point is exceeded.

## Faults

Faults can be configured to either alarm or shutdown on occurrence. An alarm basically does nothing but annunciate the fault. A shutdown forces the actuator to a predetermined position regardless of the demanded position. When the shutdown condition no longer exists, the L-Series is returned to a non-shutdown state.

Faults are separated into two categories: Logged Faults and Current Faults. The Current Faults are volatile and reset every time power is applied. The Current Faults annunciate faults that are presently active/detected. All Logged Faults are latched and written to the EEPROM. They must be cleared through the Service Tool.

Faults can be globally configured as either latching or non-latching. This is a general setting that applies to all faults, unless otherwise noted. When configured as non-latching, a Reset is not needed. If latching mode is configured, a Reset or power-cycle is required to clear the fault and resume positioning. A Reset command can be accomplished by opening and closing a Run Enable discrete input (if configured) or by using the Service Tool.

A parameter is available to configure each fault to either an alarm or a shutdown. Each fault can also independently be set to change the state of the discrete output. The shutdown action performed is fault-dependent. Some faults are dedicated as alarms or shutdowns and cannot be configured—they are identified as such below.

Faults displayed and detected are application specific. The following lists are provided to clarify what faults are utilized in each type of configuration.

### Position Control Faults

- Watchdog Reset (internal fault)
- Brownout Reset (internal fault)
- EEPROM Fault (internal fault)
- Position Sensor Fault (internal fault)
- Temp Sensor Fault (internal fault)
- OverTemp
- Relay Output Shorted
- Supply Voltage Fault
- Position Error
- Position input failed

**Air/Fuel Ratio Control Faults**

- Watchdog Reset (internal fault)
- Brownout Reset (internal fault)
- EEPROM Fault (internal fault)
- Position Sensor Fault (internal fault)
- Temp Sensor Fault (internal fault)
- OverTemp
- Relay Output Shorted
- Supply Voltage Fault
- Open Loop
- Position Error
- At Min Position
- At Max Position
- Process Input Fault
- Process Control Error (if configured, 5418-2834 firmware only)

**Full Authority Control Faults**

- Watchdog Reset (internal fault)
- Brownout Reset (internal fault)
- EEPROM Fault (internal fault)
- Position Sensor Fault (internal fault)
- Temp Sensor Fault (internal fault)
- OverTemp
- Relay Output Shorted
- Supply Voltage Fault
- Position Error
- At Min Position
- At Max Position
- Process Input Fault
- Process Control Error (if configured, 5418-2834 firmware only)
- Bias Input Fault (if Bias is configured)
- Trim Input Fault (if Trim is configured)
- Trim Input Disabled (if Trim is configured)

**Individual Fault Details**

Each possible fault is described below.

**Watchdog Reset**

Watchdog Reset is true if a watchdog timer timeout occurred which resulted in a reset of the microprocessor. This is a hard-coded alarm. If detected, the control will attempt to continue normal operation. This fault is always latching, and a reset is required to clear it.

**Brownout Reset**

Brownout Reset is true if CPU Voltage drops below 4.2 V but not below 1 V. The brownout detect circuit will reset the CPU. This is a hard-coded alarm. If detected, the control will attempt to continue normal operation. This fault is always latching, and a reset is required to clear it.

**EEPROM Fail**

EEPROM Fail indicates failure or corruption of the internal non-volatile memory. If the CRC is not correct for the EEPROM data, this fault will be set true. This is a hard-coded internal shutdown. If detected, the control output will go limp. This fault is always latching and a reset is required to clear it.

**Position Sensor Fault**

This indicates a failure of the internal Position Sensor. This is a hard-coded internal shutdown. If detected, the control output will drive full CW or CCW direction using current control. If the configured shutdown position is closer to the CW stop it will go CW. If the configured shutdown position is closer to the CCW stop it will go CCW.

Failure levels: >4.75 V and < 0.25 V

Persistence: 650 ms

**Supply Voltage Fault**

Indicates an out-of-range signal on the input power. Could indicate input power out of range or a fault in the supply voltage sense circuitry.

Failure levels: >33 V and <6.25 V

Persistence: 650 ms

Can be configured as an alarm or shutdown. If detected, the control output will drive to the configured shutdown position. If configured as an alarm, the control will internally default to an assumed 32 V power supply voltage (decreased torque at lower actual voltages) and attempt to continue normal operation if this fault is detected. The value displayed on the Service Tool will show sensed value, not default.

**Temp Sensor Fault**

Indicates a failure of the internal on-board Temperature Sensor.

Failure levels: >150 °C and <-45 °C

Persistence: 650 ms

Hysteresis: 5 °C (<145 °C or >-40 °C to clear)

Can be configured as an alarm or shutdown. If detected, the control output will drive to the configured shutdown position. If configured as an alarm, the control will attempt to continue normal operation if this fault is detected—however, if the sensor fails to a high/max signal the control will go limp due to the temperature limiting algorithm.

**OverTemp**

If the on-board temperature sensor reads above 125 °C, this error will be set. Above 125 °C, the processor can fail in an unpredictable manner, so this fault is recommended as a shutdown. The Current Limiting based on temperature will effectively make the output "limp" by reducing the drive current to zero.

Failure levels: >125 °C

Persistence: 650 ms

Hysteresis: 5 °C (<120 °C to clear)

Can be configured as an alarm or shutdown. If configured as a shutdown, the control will go limp if this fault is detected. If configured as an alarm, the control will attempt to continue normal operation if this fault is detected.

**Position Error**

Position Error detection logic will indicate a difference between commanded position and actual position exceeded for longer than the set delay. The error magnitude and duration are customer-configurable parameters.

Failure levels: Set by customer variable, Error > |Pos Error Max|

Persistence: Set by customer variable, Position Error Delay.

Hysteresis: none

Override: Whenever the current is being limited to a factor of 1/2 normal maximum or less. This would be because of high temperature (see section on Temp Sensing and Current Limiting) or a shutdown that causes the output to go "limp".

Can be configured as an alarm or shutdown. If detected, the control output will drive to the configured shutdown position. If configured as an alarm, the control will attempt to continue normal operation if this fault is detected.

#### **Relay Output Shorted**

The relay driver is thermally protected against wiring errors. If incorrectly wired, the output will turn off and then set the Error Bit.

Can be configured as an alarm or shutdown. If detected, the control output will drive to the configured shutdown position. If configured as an alarm, the control will attempt to continue normal operation if this fault is detected.

#### **Open Loop**

Indication that the control is in open loop.

Can be configured as an alarm or shutdown—based on Shutdown Faults bit. If configured as a shutdown, the control will drive to Fail Direction (using position control) if this fault is detected. If configured as an alarm, the control will attempt to continue normal operation if this fault is detected.

Persistence: Set by customer variable ( > Open Loop Active Delay). This delay setting is available in 5418-2834 firmware only and is zero in 5418-1681 firmware versions.

#### **At Min Position**

Detects when the actuator position reaches the min actuator position limit. This function limits the control response to in-range system faults, such as an aging HEGO sensor or unacceptable fuel quality variation. When the control reaches the minimum actuator position limit, it will set the relay contact output to a flashing fault state (if enabled), and the software will store a fault bit in EEPROM. However, the control is still in closed-loop and will move off the "peg" if the HEGO voltage drops below the set point.

Hysteresis: 1%

Can be configured as an alarm or shutdown—based on Shutdown Faults bit. If detected and configured as a shutdown, the control output will drive to the configured shutdown position. If configured as an alarm, the control will attempt to continue normal operation if this fault is detected.

#### **At Max Position**

Detects when the actuator position reaches the max actuator position limit. This function limits the control response to in-range system faults, such as an aging HEGO sensor or unacceptable fuel quality variation. When the control reaches the minimum actuator position limit, it will set the relay contact output to a flashing fault state (if enabled), and the software will store a fault bit in EEPROM. However, the control is still in closed-loop and will move off the "peg" if the HEGO voltage rises above the set point.

Hysteresis: 1%

Can be configured as an alarm or shutdown—based on Shutdown Faults bit. If configured as a shutdown, the control will drive to the configured shutdown position on fault detection. If configured as an alarm, the control will attempt to continue normal operation.

### Process Input Fault

An indication that the Process signal is failed.

Can be configured as an alarm or shutdown—based on Shutdown Faults bit. If configured as a shutdown, the control will drive to the configured shutdown position on fault detection. If configured as an alarm, the control will attempt to continue normal operation.

Failure levels: Set by customer variable ( <Proc Flt Min or >Proc Flt Max)

Persistence: 650 ms

Hysteresis: 0.05 V

Override: When configured as a Positioner.

### Process Input Fault (5418-2834 firmware only)

This fault is set as an indication that the Process control system is not functioning properly. This is a latching fault that, when set, indicates the process error (input-setpt) has not changed sign (+/-) for longer than the configurable error delay. Only enabled when in closed loop control, disabled when in open loop.

Can be configured as an alarm or shutdown—based on Shutdown Faults bit. If configured as a shutdown, the control will drive to the configured shutdown position on fault detection. If configured as an alarm, the control will attempt to continue normal operation.

Failure levels: based on sign change of the process error (input-setpoint)

Persistence: Set by customer variable ( > Process Control Error Delay)

Override: When configured as a Positioner, or if Use Process Control Error is not selected (Input tab of Process Control), or while in Open Loop control.

### Bias Input Fault

Indication of the Bias input out of range, used only when the Bias function is configured for use.

Can be configured as an alarm or shutdown—based on Shutdown Faults bit. If configured as a shutdown, the control will drive to the configured shutdown position on fault detection. If configured as an alarm, the control will attempt to continue normal operation.

Failure levels: Set by customer variable ( <Bias Flt Min or >Bias Flt Max)

Persistence: 650 ms

Hysteresis: 0.05 V

Override: When configured as a Positioner, or if Bias is not configured for use.

### Trim Input Fault

Indication of the Trim input out of range, used only when the Trim is configured for use.

Can be configured as an alarm or shutdown—based on Shutdown Faults bit. If configured as a shutdown, the control will drive to the configured shutdown position on fault detection. If configured as an alarm, the control will attempt to continue normal operation.

Failure levels: Set by customer variable ( <Trim Flt Min or >Trim Flt Max)  
Persistence: 650 ms  
Hysteresis: 0.05 V  
Override: When configured as a Positioner, or if Trim is not configured for use.

**Trim Disabled**

Indication that the Trim function is disabled.

Can be configured as an alarm or shutdown—based on Shutdown Faults bit. If configured as a shutdown, the control will drive to the configured shutdown position on fault detection. If configured as an alarm, the control will attempt to continue normal operation.

# Chapter 5. Service Tool

## Introduction

This chapter covers the installation and use of the L-Series Service Tool. It is assumed that the control has already been installed on the engine.

**IMPORTANT**

Many applications are delivered pre-configured, calibrated, and tuned. These units do not require the use of the Service Tool.

## Description

The Service Tool software is used to configure, tune, and troubleshoot the L-Series controller. This chapter describes installation and use of the Service Tool. It identifies the control parameters available for viewing.

Refer to Chapter 6 for comprehensive configuration instructions to set up the L-Series control for customer specific applications.

The Service Tool software resides on a PC (personal computer) and communicates to the L-Series through connector pins 4 and 6. An external RS-232 transceiver is necessary to make communications possible with the Woodward L-Series service tool. A connectivity kit for this purpose, Woodward part number 8923-1061, can be purchased from Woodward.

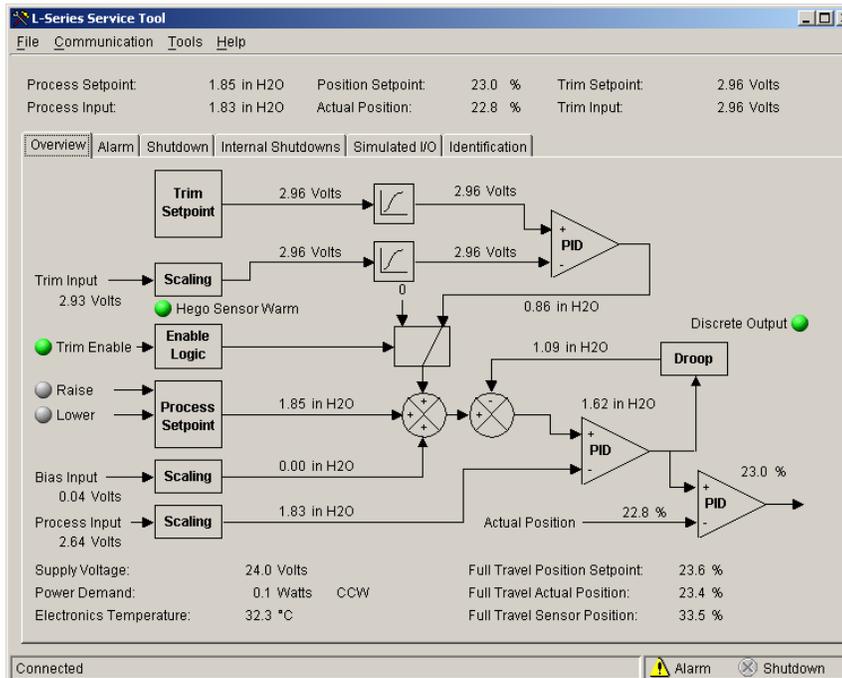


Figure 5-1. Example Service Tool Screen

The following hardware is required to work with the L-Series control:

- PC-compatible laptop or desktop computer\* with at least one available serial communications port, and Windows 95/98/2000/NT/Me/XP as the operating system.
- Programming/datalink harness as shown in Figure 5-2.

In addition to the hardware, the following are the distributions of tool software needed to communicate with the control:

- Woodward part number 9927-1222, L-Series Service Tool

## NOTICE

\*—There is a potential for serial port damage when communicating with the L-Series control. This is caused by a difference in ac voltage between neutral and earth ground. If the PC RS-232 port ground is referenced to ac neutral, and the L-Series control is referenced to battery ground (ac earth ground), a large amount of current can be experienced. To avoid this situation, we strongly recommend placing an isolation transformer between the ac outlet and the PC.

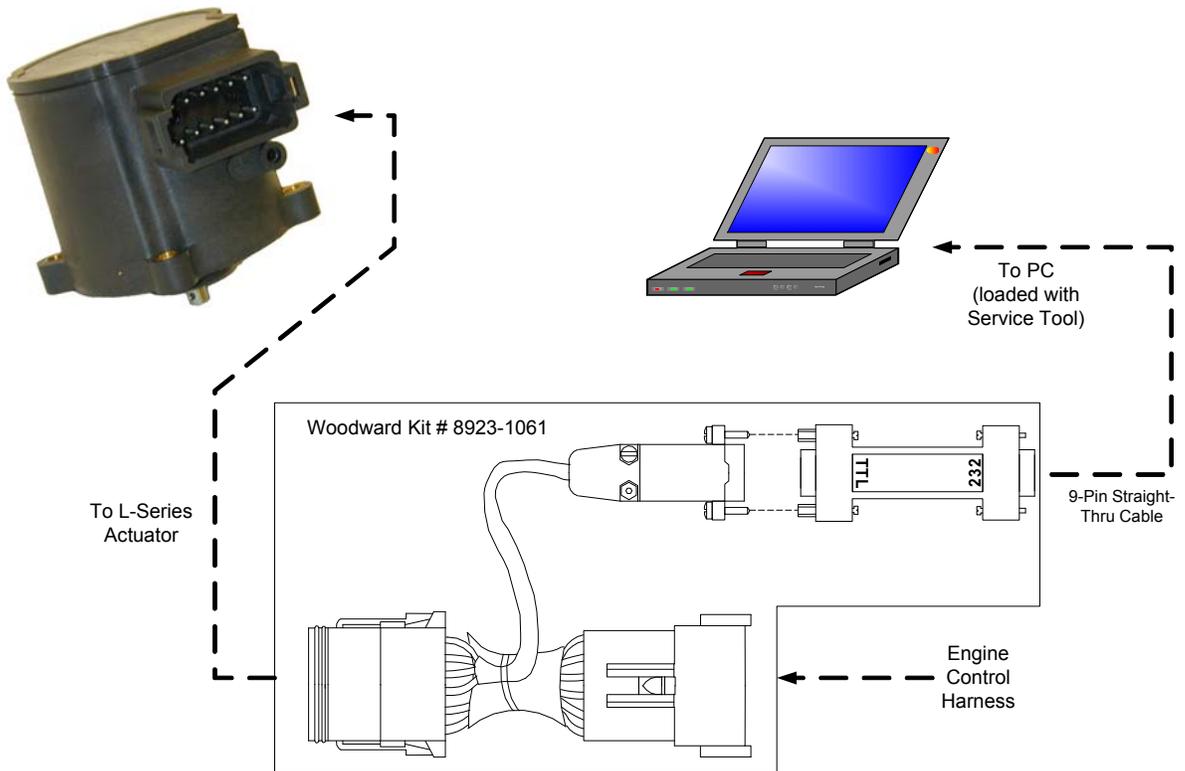


Figure 5-2a. Programming Harness Connections

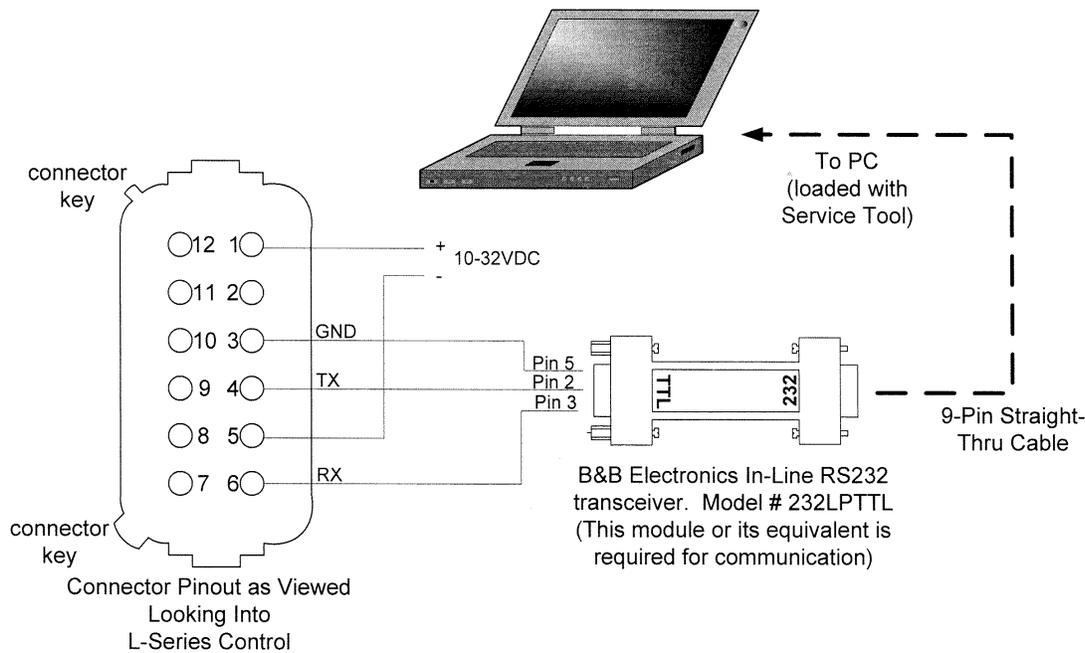


Figure 5-2b. Programming Harness Wiring

## Getting Started

### Installation Procedure

The Service Tool software can be downloaded and installed from the Woodward Internet site ([www.woodward.com/software/](http://www.woodward.com/software/))

### What to do next

After the software is installed, connect a serial communications cable between the RS-232 connections on the L-Series control programming harness and an unused serial port on your computer. Run the Service Tool program and select the appropriate communications port. Once connected to the control, the status bar will display 'connected' and the Service Tool screen will populate with monitor parameters.



**WARNING** An unsafe condition could occur with improper use of these software tools. Only trained personnel should have access to these tools.

### Service Tool Help

More help on using Service Tool is available and included with the installation of the Service Tool product. Service Tool Help can be accessed from the Service Tool 'Contents' drop-down window selection under the Help menu located on the Main Window.

## Software Version Identification

The Service Tool software version can be found by selecting 'About' under the Help menu. The L-Series software version is identified as the 'Software Part Number' on the Service Tool Identification tab sheet. The Service Tool and Control must be connected to view this information. Refer to this version information in any correspondence with Woodward.

The L-Series embedded software part number (firmware) and revision can be found on the Identification tab of the Service Tool (see Figure 5-8).

## Service Tool Security

Various levels of security are available to protect application settings. One password is available which provides the ability to inhibit tampering of control settings. The individual protection settings include a general password protection on configuration reading (from the control), configuration loading (to the control), position calibration, position PID tuning, process PID tuning, and trim PID tuning.

## Monitoring the Driver

The Service Tool has six different tab sheets to monitor driver parameters. The tab sheet screens include:

- Overview (see Figure 5-3)
- Alarms (see Figure 5-4)
- Shutdowns (see Figure 5-5)
- Internal Shutdowns (see Figure 5-6)
- Simulated I/O (see Figure 5-7)
- Identification (see Figure 5-8)

Each screen will display the application relevant data on the upper portion of the Service Tool window. Example application specific displayed values are shown in Figure 5-3a–d.

### Process Setpoint

Displayed value of the process setpoint—in engineering units.

### Process Input

Displayed value of the actual process input—in engineering units.

### Position Setpoint

Displayed value of the position demand—in percent.

### Actual Position

Displayed value of the actual position—in percent.

### Trim Setpoint

Displayed value of the trim setpoint—in engineering units.

### Trim Input

Displayed value of the actual trim input—in engineering units.

### Open Loop Setpoint

Displayed value of the open loop setpoint—in percent.

## Mode

Displays the open-/closed-loop control mode status.

## Status Bar Indications

At the bottom of the Service Tool window is a status bar. The status bar has two sections. The bottom left section displays communication status and bottom right section displays alarm & shutdown status.

## Communication Status

This section of the status bar shows the status of communication between the service tool and the Swift Driver. For more information, see Establishing Communication.

- **Connected**—The Service Tool is connected to and communicating with the driver.
- **Not Connected**—The Service Tool is not connected to the driver.
- **Connecting**—The Service Tool is attempting to connect to the driver. This message is displayed when Connect is selected from the Communications menu or when attempting to re-establish communication to the driver. If the connection is lost it will continuously attempt to re-connect.

## Alarm Status

When highlighted (yellow), one or more alarms on the Alarms screen are active.

## Shutdown Status

When highlighted (red), one or more shutdowns on the Shutdowns or Internal Shutdowns screen are active.

## Overview Parameters Screen

To monitor the overview parameters, go to the Overview page on the main window. This screen dynamically populates based on the unit's configuration. If a function is not programmed, then it will not appear.

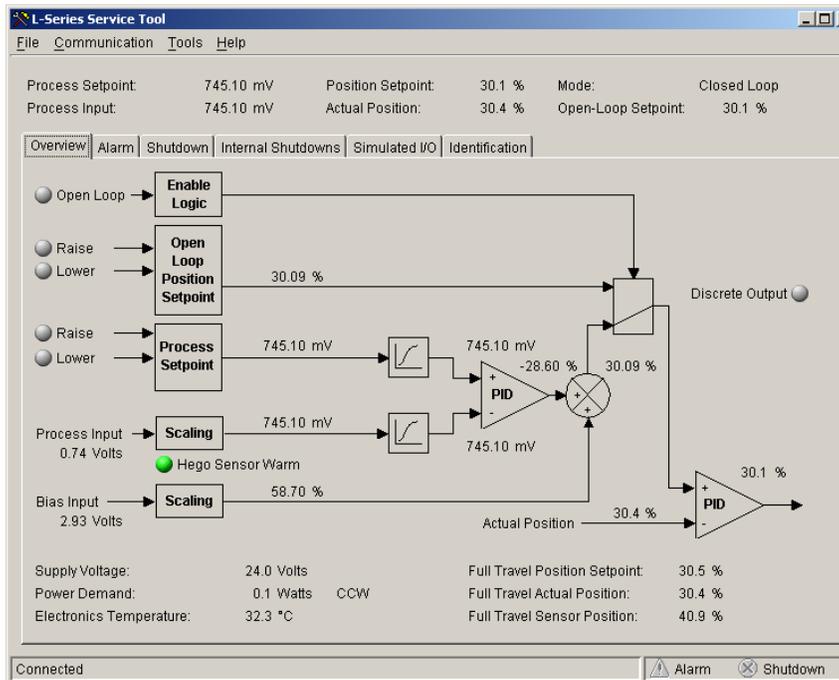


Figure 5-3a. Service Tool—Overview Tab with A/F Ratio Control Configured (5418-1681 firmware)

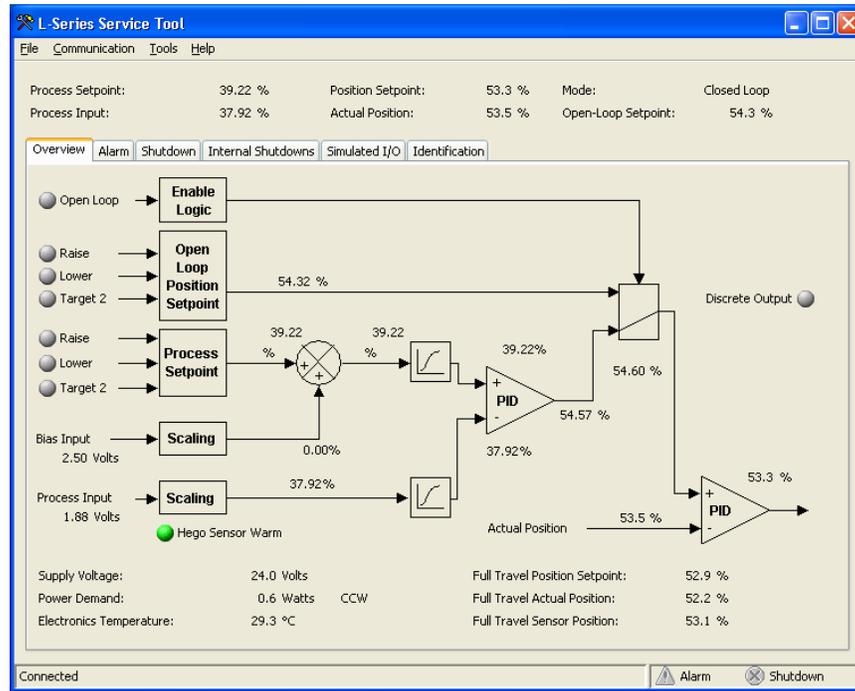


Figure 5-3b. Service Tool—Overview Tab with A/F Ratio Control Configured (5418-2834 firmware)

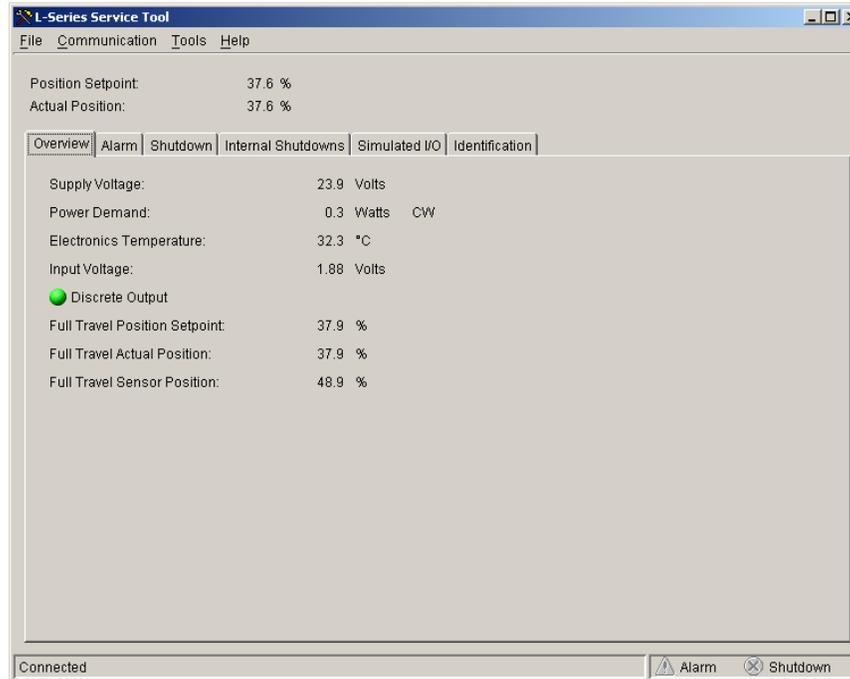


Figure 5-3c. Service Tool—Overview Tab with Position Control Configured

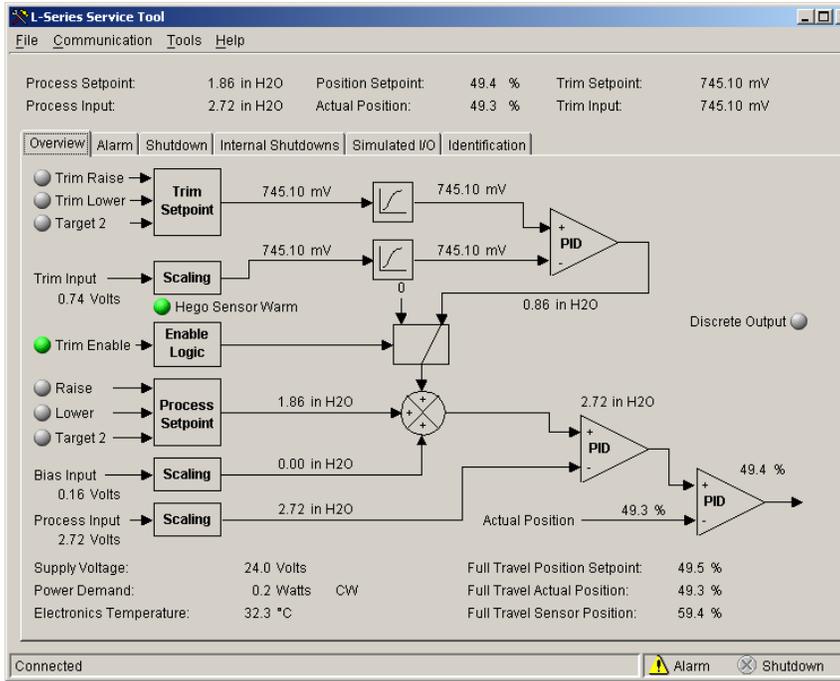


Figure 5-3d. Service Tool—Overview Tab with FA A/F Ratio Control Configured

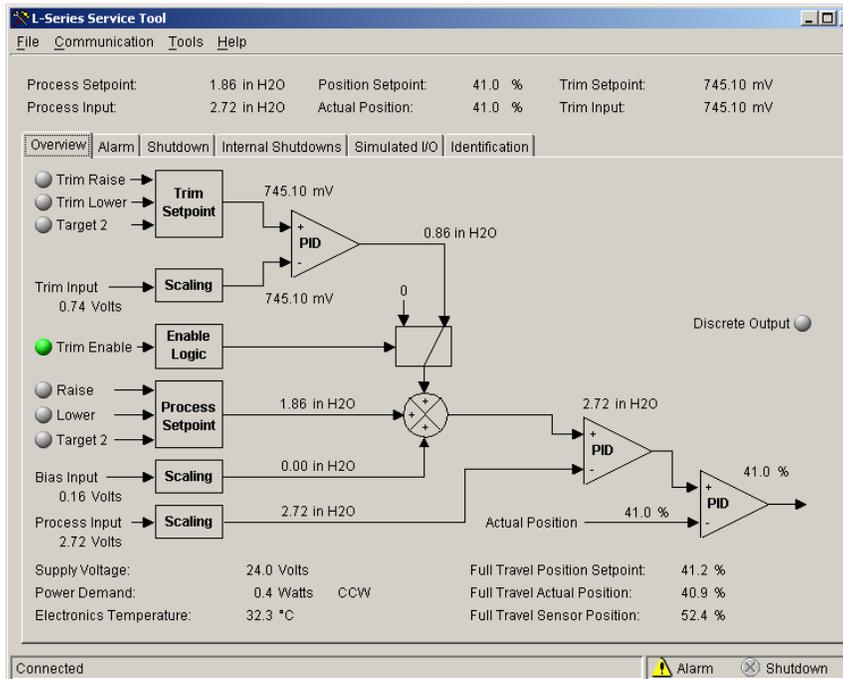


Figure 5-3e. Service Tool—Overview Tab with Process Control Configured

### Supply Voltage

Displayed value of the input power, in volts, as read by the processor.

**Power Demand**

Displayed value of the output signal, in watts, to the position driver (h-bridge), including drive direction (CW/CCW).

**Electronics Temperature**

Displayed value of the electronics temperature sensor, in degrees Celsius, as read by the processor. The temperature sensor is physically located between the electronics module and the LAT motor.

**Discrete Output**

On/Off status of the discrete output command. The indicator is illuminated when the channel is commanded to ON and grayed-out when the command signal is OFF.

**Full Travel Position Setpoint**

Indication of the position setpoint in terms of total overall unit travel. Useful if a less than full-travel user-calibrated range is used.

**Full Travel Actual Position**

Indication of the actual position in terms of total overall unit travel. Useful if a less than full-travel user-calibrated range is used.

**Full Travel Sensor Position**

Indication of the position in terms of total overall unit travel before linearization. This value will match the TPS output.

**Analog and Discrete Input**

Displays value of the actual analog input, in engr units, or the state of the discrete inputs. The discrete input indicator is illuminated when the input is ON and grayed-out when the input is OFF.

**Shutdown and Alarm Indications**

The Shutdown and Alarm screens display the status of both active and logged fault conditions. The logged indications provide a history of events even after the unit has been power-cycle of run again.



Indicates a logged alarm condition.



Indicates an active alarm condition.



Indicates a logged shutdown condition.



Indicates an active shutdown condition.

An active fault is one that is currently active or latched in the control. The latching/non-latching faults configuration setting factors into this indication. If the fault is latching, then an active fault could either be one that is still present or one that occurred but has not been reset. Latched faults can be cleared by cycling power on the L-Series control or by selecting the 'Reset Alarms and Shutdowns' button on any of the Alarm or Shutdown screens.

A logged fault is one that has occurred but is no longer active or latched in the control. Selecting the 'Reset Logged Alarms and Shutdowns' button on any of the Alarm or Shutdown screens permanently clears logged faults.

## Alarms Screen

To monitor the alarm conditions, go to the Alarms page on the main window. The values displayed on this screen dynamically change with the fault configuration. Refer to Chapter 4 for a complete listing and details of all the faults.

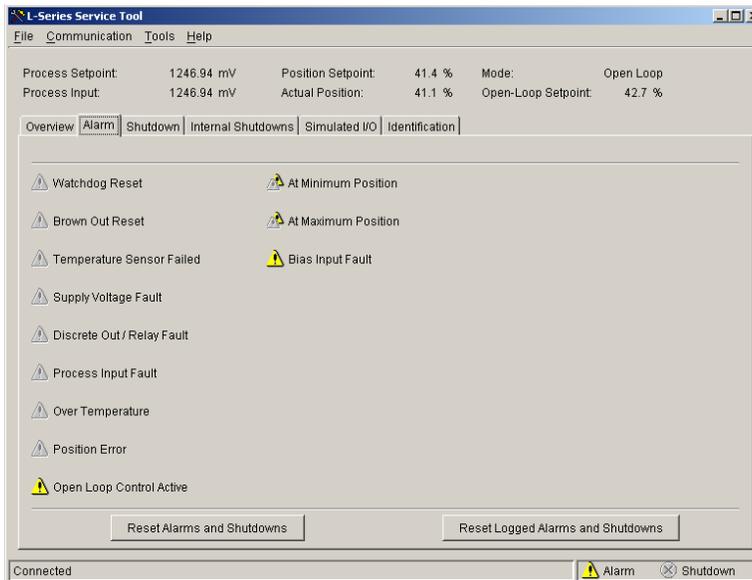


Figure 5-4a. Service Tool—Alarms Tab with A/F Ratio Configured

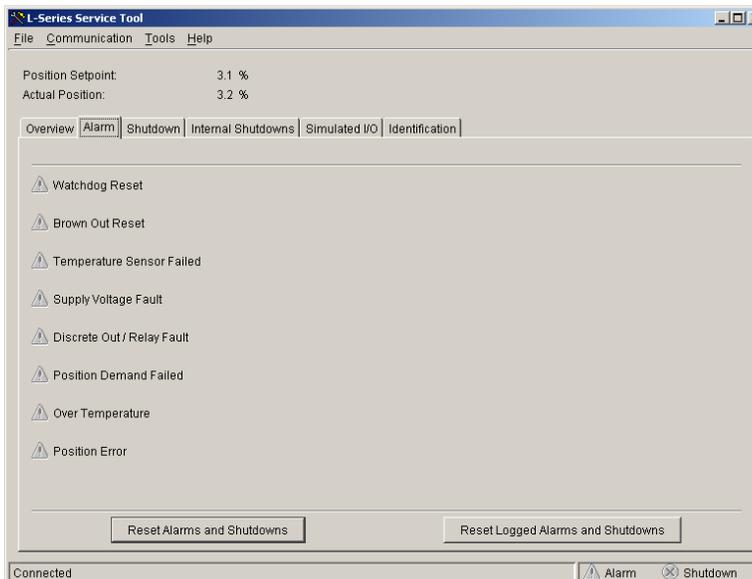


Figure 5-4b. Service Tool—Alarms Tab with Position Control Configured

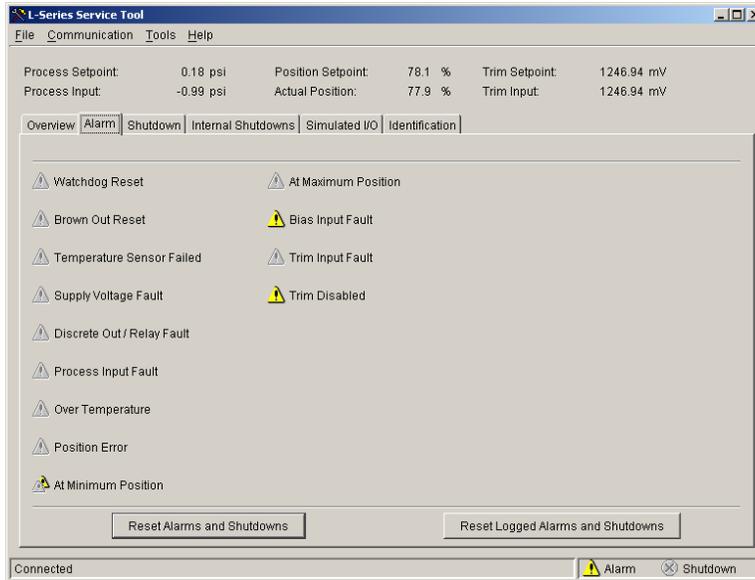


Figure 5-4c. Service Tool—Alarms Tab with FAPC or Process Control Configured

## Shutdowns and Internal Shutdowns Screens

To monitor the shutdown conditions, go to the Shutdowns and the Internal Shutdowns pages (Figures 5-5 and 5-6) on the main window. The values displayed on the Shutdowns screen dynamically change with the fault configuration. Refer to Chapter 4 for a complete listing and details of all the faults.

A reset command is available on these screens to clear any current alarms, if they are latched on. If a fault condition occurred but is no longer present, it will remain as a logged fault until cleared. The 'Reset Logged Alarms and Shutdowns' command will clear all logged faults.

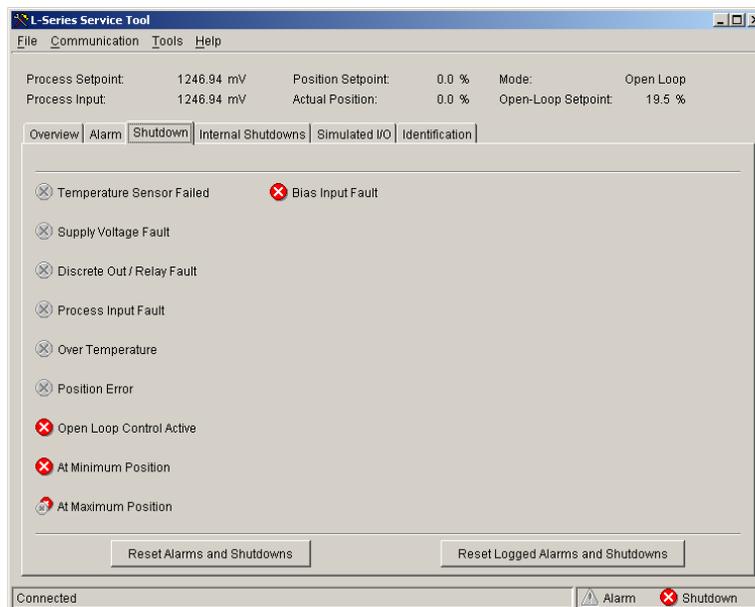


Figure 5-5. Service Tool—Shutdowns Tab

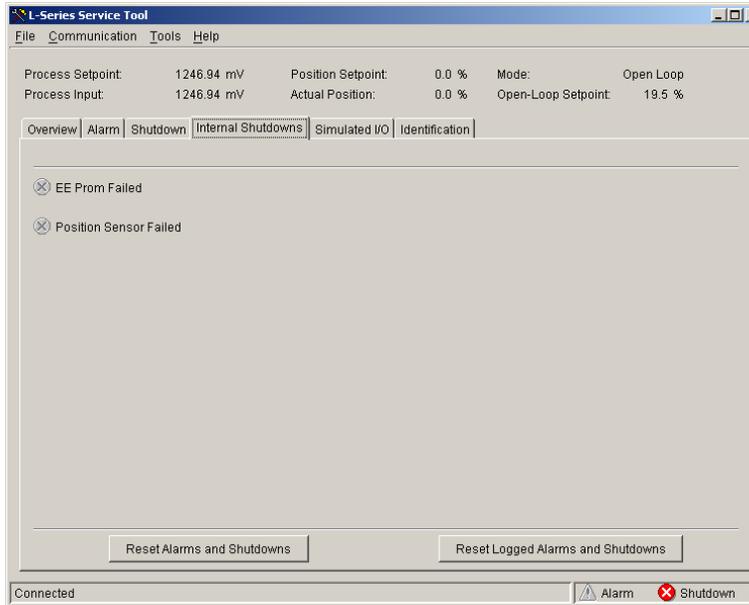


Figure 5-6. Service Tool—Internal Shutdowns Tab

### Simulated I/O Screen

While communicating to the service tool, Aux 3 and Aux 4 inputs are not functional since these input pins are used for both Input (analog or discrete) and for serial communications. This screen is provided to facilitate operational testing while connected to the Service Tool. The Aux 3 & 4 Simulated Analog inputs simulate a fixed-value analog input signal, in percentage, and the discrete inputs can be simulated as closed (checked) and open (unchecked) using the Simulated Discrete Input checkboxes.

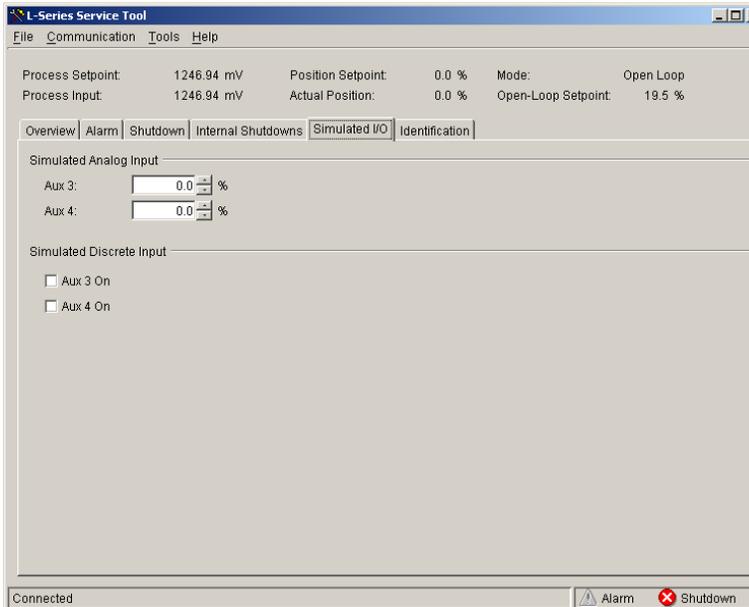


Figure 5-7. Service Tool—Simulated I/O Tab

## Identification Screen

To monitor the L-Series product identification, go to the Identification page on the main window. Information displayed includes the part number of the embedded L-Series software and the serial number of the unit.

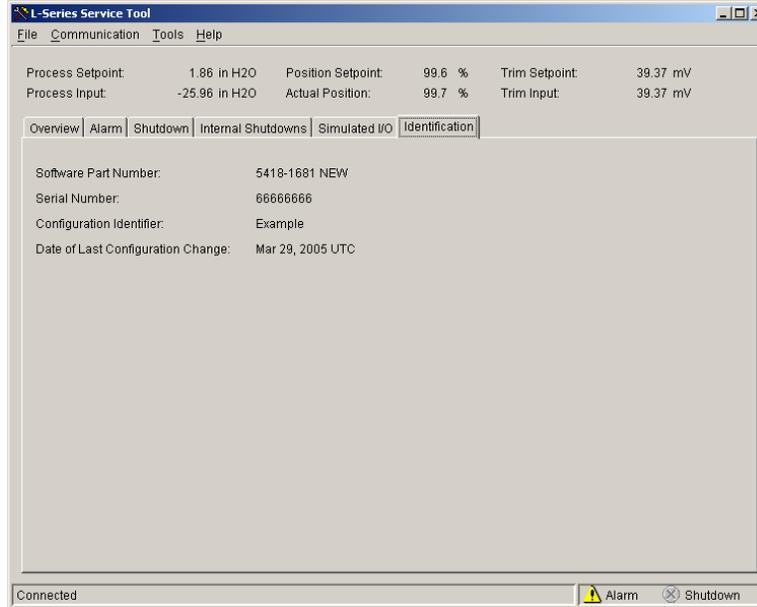


Figure 5-8. Service Tool—Identification Tab

# Chapter 6. Configuration

## Overview

The L-Series is configured using the Service Tool. Refer to Chapter 5 for Service Tool installation and connection instructions.

The L-Series can be configured either on-line or off-line. On-line configuration can only be performed when the Service Tool is connected to and communicating with the L-Series controller. Off-line configuration can be done at any time, however, settings will not take effect until they are loaded into the control.

### **WARNING**

An unsafe condition could occur with improper use of these software tools. Only trained personnel should have access to these tools.

### **NOTICE**

OEMs and end users are strongly encouraged and expected to develop and thoroughly test specific L-Series Process Control schemes for their engines under both normal and extreme operating conditions before widely applying a control scheme. While extensive testing has been performed on a limited number of engines to prove the L-Series Process Control functions, no attempt has been made to test the many and varied possible control schemes on a broad number of engines in various process control applications.

### **IMPORTANT**

Many applications are delivered pre-configured, calibrated, and tuned. These units do not require the use of the Service Tool.

### **IMPORTANT**

Configuration reading and loading can be individually password protected for security purposes. If security is applied, these features will not be accessible without the password.

The current L-Series controller configuration settings can be viewed at any time when connected to the control by opening the Configuration Editor (File/Open Control Configuration), assuming password protection is not active. See Figure 6-1.

### **IMPORTANT**

If using dynamics curves or fuel limiting curves, control power must be cycled after loading a new configuration before the new settings will take effect.

## OEM Configuration File Data

The OEM can save configuration file specific data with the service tool by selecting Properties under the File menu pull down. This is a text field and can be used to store data such as:

- Customer
- Engine Type
- Application Type
- Notes

## Configuring the Unit—On-Line

Unit configuration is summarized as follows:

1. Open the Configuration Editor Dialog by selecting 'File/Open Control Configuration'.
2. Edit the configuration settings.
3. Save the configuration file (optional). The first 8 characters of this file name are stored in the control and displayed on the Identification tab.
4. Load the configuration to the L-Series control.

### **IMPORTANT**

As changes are made to Configuration parameters, they are not used by the driver until a 'load' command is issued. Selecting the 'Cancel' button closes the Configuration Editor and does not make any changes to the driver.

## Configuring the Unit—Off-Line

Unit configuration is summarized as follows:

1. Open the Configuration Editor Dialog using the 'File/New Configuration' or 'File/Open Configuration File' options.
2. Edit the configuration settings.
3. Save the configuration to a file. At a later date simply open the configuration and load it into the control.

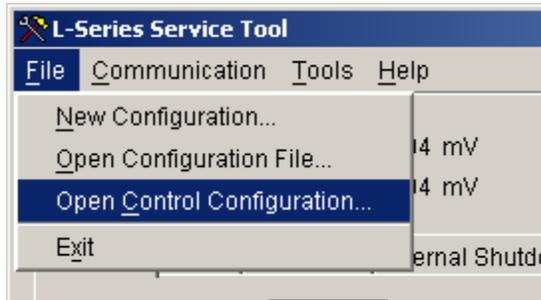


Figure 6-1. Configuration Selection Options

## Configuration Parameters

There are 7 different screens that display the configuration settings in the L-Series process controller: Overview, Process Control, Trim, Bias, Discrete I/O, Alarm/Shutdown, and Security. The settings and screens are dynamic, only displaying the parameters specific to the configured application.

## Discrete Input Configuration options

Each discrete input function must be mapped to a physical input. Options include:

- Always Off
- Aux1 (active closed)
- Aux2 (active closed)
- Aux3 (active closed)
- Aux4 (active closed)
- Aux5 (active closed)
- Aux1 (active open)
- Aux2 (active open)
- Aux3 (active open)
- Aux4 (active open)
- Aux5 (active open)
- Always On

Any unused function is typically turned off by selecting 'Always Off'.

Selecting 'Active Closed' for a function will activate a function whenever the aux input voltage is above the ON threshold (refer to the Specifications section for On and Off thresholds). Likewise, selecting 'Active Open' will activate the function when the aux input is below the OFF threshold. An "Active Closed" setting is recommended.

## Overview Tab

The overview tab provides application and position controller configuration settings.

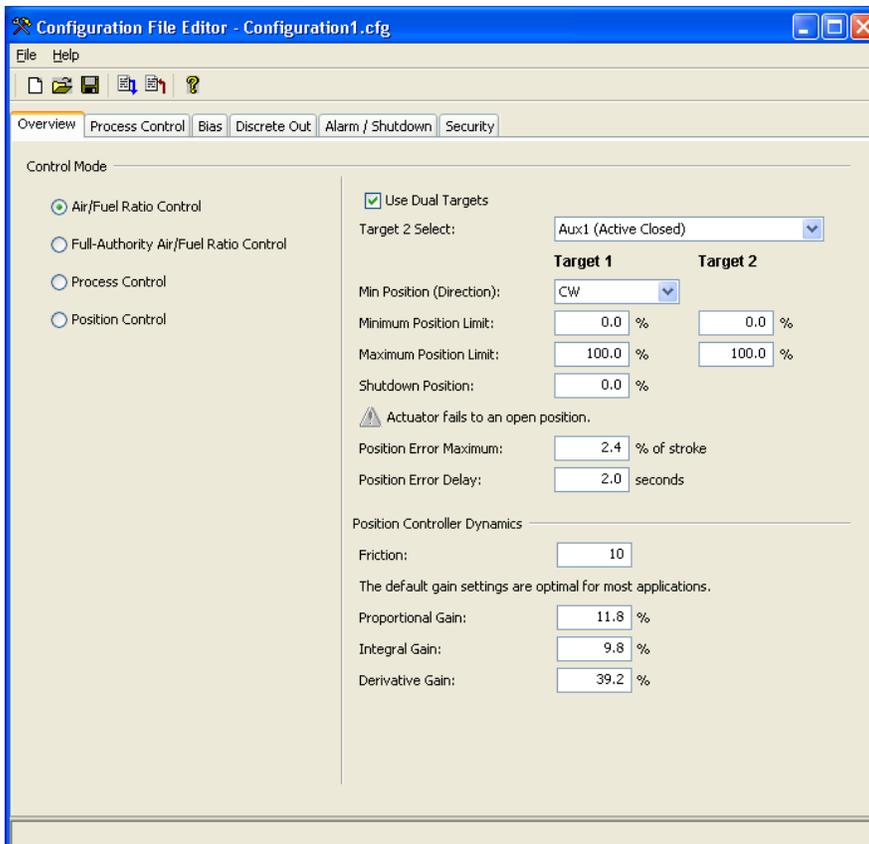


Figure 6-2. Configuration Editor—Overview TAB

**Control Mode**

Set to Air/Fuel Ratio Control, Full-Authority, Process or Position Control. This configuration setting determines the available application features.

**Use Dual Targets**

Check this box if 2 targets are desired. This applies to the open loop, process, and trim setpoints.

**Target 2 Select**

This selects the AUX input to be used for the Target 2 Select function.

**Minimum Position (Direction)**

Set to CW (clockwise) or CCW (counter-clockwise). This sets the minimum position direction as determined when looking at the end of the actuator shaft. See also the Dynamics tab settings (Process Control and Trim) for Inverse Direction options when using dual targets.

**Minimum Position Limit**

Sets the minimum allowed travel, in percent of stroke. Allowed values: 0–100% but must be greater than the minimum position

**Maximum Position Limit**

Sets the maximum allowed travel, in percent of stroke. Allowed values: 0–100% but must be less than the maximum position

**Shutdown Position**

Sets the position the maximum allowed travel, in percent of stroke. Allowed values: 0–100% but must be less than the maximum position

An alert is displayed (Actuator fails to an open position) whenever this value is not zero.

**Position Error Maximum**

Sets the magnitude of the position error fault. Allowed values: 0–100% of stroke

**Position Error Delay**

Sets the delay that the position error must persist before indicating a position error fault. Allowed values: 0–10 seconds

**Position Controller Configuration Settings**

The position controller controls the position of the shaft based on the position command setting from the process controller logic.

**IMPORTANT**

For most applications, the default gains do not need to be changed.

**Friction/Dither Setting**

Sets the position controller's friction and dither values. This parameter should be set to zero (no effect) while tuning the PID and then increased for optimum response. Increasing this setting increases both the dither amount and a nonlinear output component. If unsure, typical values would be between 10 and 25. Allowed values: 0–100.

**Proportional Gain**

Sets the position controller PID's proportional gain. Increased gain corresponds to increased PID output (higher proportional = faster response). This setting can also be dynamically adjusted using the PID Tuning screen. If unsure, a typical value would be 11.8 . Allowed values: 0–100%

**Integral Gain**

Sets the position controller PID's integral gain. Increased gain corresponds to increased PID output (higher integral = faster response). This setting can also be dynamically adjusted using the PID Tuning screen. If unsure, a typical value would be 9.8 . Allowed values: 0–100%

**Derivative Gain**

Sets the position controller PID's derivative gain. Increased gain corresponds to increased PID output (higher derivative = faster response). This setting can also be dynamically adjusted using the PID Tuning screen. If unsure, a typical value would be 39.2 . Allowed values: 0–100%

**Process Control Tab**

The process control tab provides the process configuration settings and includes sub-tab screens for Input, Setpoints, Dynamics, Open Loop, and Oxygen Settings.

**WARNING**

If used to control fuel pressure, use of an independent control of pressure is required. For example, an upstream pressure regulator, downstream pressure relief valve or a pressure switch controlling a fuel shut-off valve.

**IMPORTANT**

The gas shut-off valve should be turned ON after the engine starts cranking, to reduce stack-up pressure.

## Process Control—Input Tab

The process control input tab provides the process input and overall process scaling settings.

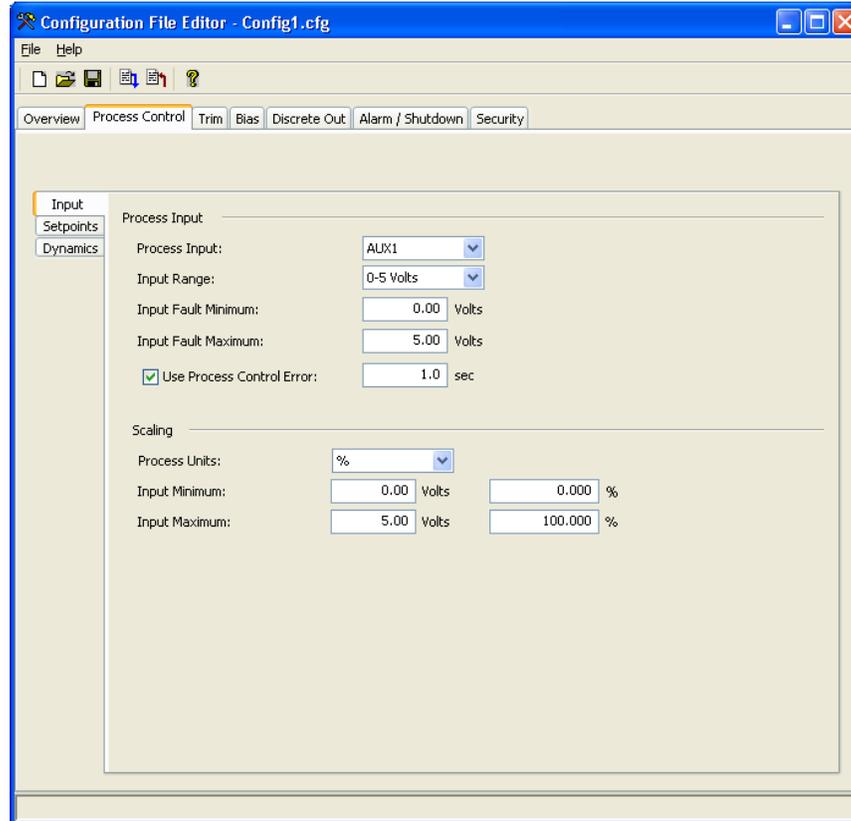


Figure 6-3. Configuration Editor—Process Control—Input TAB (5418-2834 firmware example)

### Process Input

Select the appropriate AUX input as the Process input. If this is a HEGO sensor input, then AUX1 configured as 0–1.25 V is recommended for proper operation.

Allowed values: AUX1, AUX2, AUX3, or AUX4.

### Input Range

Select the appropriate AUX1 Voltage range. Only displayed if the Process Input is configured as AUX1. Allowed values: 0–5 V or 0–1.25 V.

### Input Fault Minimum

Sets the voltage level of the process input fault, below this level is considered a fault. Allowed values: 0–5 V, but must be less than the Input Fault Maximum

### Input Fault Maximum

Sets the voltage level of the process input fault, above this level is considered a fault. Allowed values: 0–5 V, but must be greater than the Input Fault Minimum

**Use Process Control Error (5418-2834 firmware only)**

Check this box if the use of the process control error is desired. This error is a general indication of a malfunction of the process control that can be used to shut down the unit and/or drive the discrete output. This is a latching fault that, when set, indicates the process error (input-setpt) has not changed sign (+/-) for longer than the configurable error delay. It is enabled when in closed loop control, disabled when in open loop.

**Process Control Error Delay (5418-2834 firmware only)**

Amount of time before a Process Control Error is set.  
Allowed values: 0–428 s.

**Process Units**

Select the appropriate units of measure for the Process controller.  
Allowed values: (none), %, Volts, mV, KW, psi, kg/cm<sup>2</sup>, in H<sub>2</sub>O, mbar, bar, in Hg, mm Hg, kPa, atm, °C, °F, Nm<sup>2</sup>, gpm, cfm, #/hr, kg/hr, l/hr, %O<sub>2</sub>, lambda or Phi.

**Input Minimum (Volts)**

Sets the voltage level of the minimum process input, used in conjunction with the Input Minimum in engineering units to determine the process scaling. Allowed values: 0–5 V, but must be less than the Input Maximum

**Input Minimum (process units)**

Sets the engineering units of the process input corresponding to the voltage value of the Input Minimum (Volts). Allowed values: must be less than the Input Maximum

**Input Maximum (Volts)**

Sets the voltage level of the maximum process input, used in conjunction with the Input Maximum in engineering units to determine the process scaling. Allowed values: 0–5 V, but must be greater than the Input Minimum

**Input Maximum (process units)**

Sets the engineering units of the process input corresponding to the voltage value of the Input Maximum (Volts). Allowed values: must be greater than the Input Minimum

## Process Control—Setpoints Tab

The process control setpoints tab provides the process setpoint and rate settings.

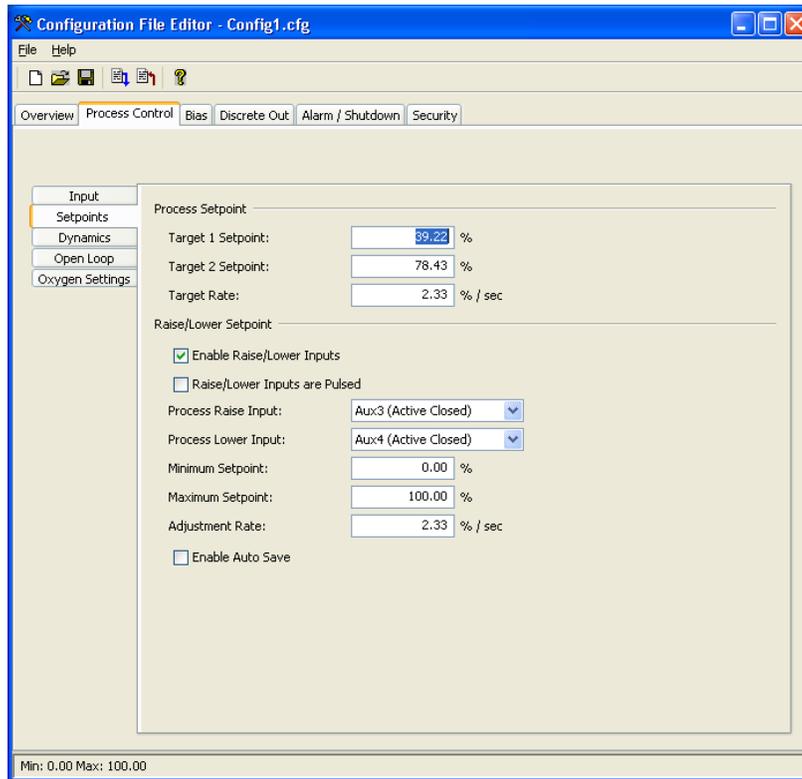


Figure 6-4. Configuration Editor—Process Control—Setpoints TAB

### Target (1) Setpoint

The target setpoint, in process units, when process control is enabled and target 1 is selected. Allowed values: limited by both 0 V to 1.25 V/5 V process input value (interpolated, on Input tab) and Setpoint Min to Max (if Raise/Lower is used)

### Target 2 Setpoint

The target setpoint, in process units, when process control is enabled and target 2 is selected. Only displayed if Dual Targets is configured. Allowed values: limited by both 0 V to 1.25 V/5 V process input value (interpolated, on Input tab) and Setpoint Min to Max (if Raise/Lower is used)

### Target Rate

The setpoint rate used when ramping to a target setpoint, in process units/sec. Allowed values: range is calculated based on input scaling

### Enable Raise/Lower Inputs

Select this checkbox to allow setpoint manipulation with raise and lower commands.

### Raise/Lower Inputs are Pulsed

Select this checkbox if the discrete inputs are to move the setpoint a finite amount each time the input is activated. The amount is determined by the configured Adjustment Rate. Only displayed if Enable Raise/Lower Inputs is configured.

**Process Raise Input**

Select the appropriate AUX input for this discrete input function. Only displayed if Enable Raise/Lower Inputs is configured.

**Process Lower Input**

Select the appropriate AUX input for this discrete input function. Only displayed if Enable Raise/Lower Inputs is configured.

**Minimum Setpoint**

The smallest setpoint allowed when using the Lower command. Only displayed if Enable Raise/Lower Inputs is configured. Allowed values: must be less than the Maximum Setpoint and must be less than the smallest Target Setpoint and must be greater than the 0 V input value (interpolated)

**Maximum Setpoint**

The highest setpoint allowed when using the Raise command. Only displayed if Enable Raise/Lower Inputs is configured. Allowed values: must be greater than the Minimum Setpoint and must be greater than the highest Target Setpoint and must be less than the 1.25 V/5 V input value (interpolated)

**Adjustment Rate**

Specifies the ramping rate for the process setpoint Raise or Lower functions. Only displayed if the Raise/Lower function is configured. Allowed values: range is calculated based on input scaling

**Enable Auto Save**

Select this checkbox to automatically save the adjusted setpoint as the default. Only displayed if Enable Raise/Lower Inputs is configured.

**Process Control—Dynamics Tab**

The process control dynamics tab provides process controller dynamics settings. The dynamic settings can also be adjusted on-line from the Edit Process Dynamics screen.

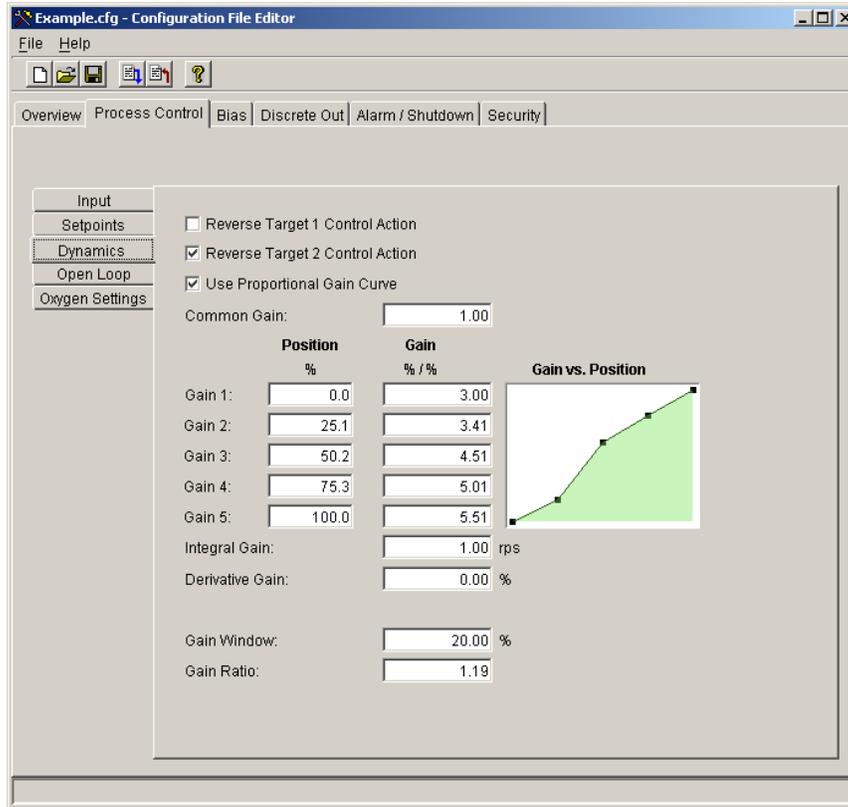


Figure 6-5a. Configuration Editor—Process Control—Dynamics TAB (5418-1681 firmware)

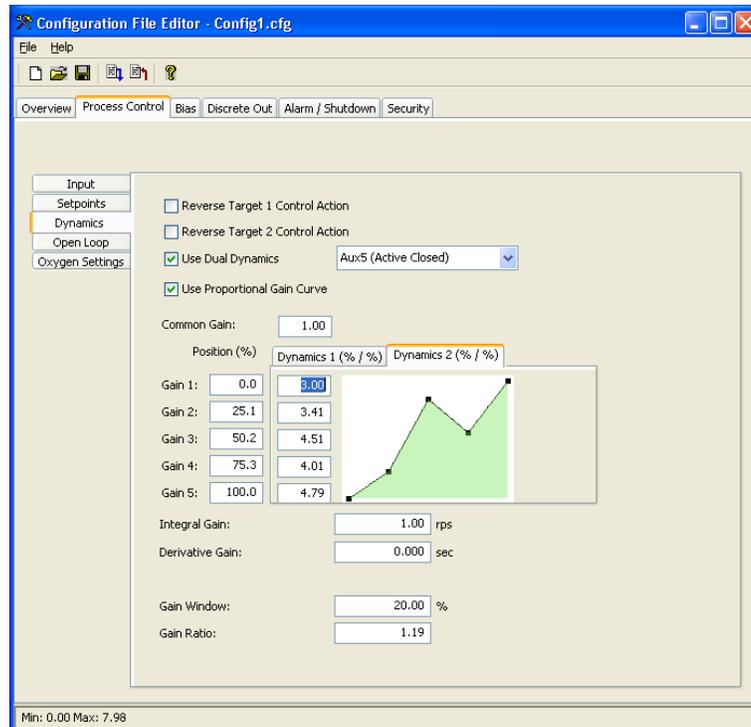


Figure 6-5b. Configuration Editor—Process Control—Dynamics TAB (5418-2834 firmware)

**Reverse (Target 1) Control Action**

Select this checkbox only when an increase in the PID output, and thus actuator position, will decrease the value of the process input. If a Dual Target function is used, this action is applicable when Target 1 is selected.

**Reverse Target 2 Control Action**

Select this checkbox only when an increase in the PID output, and thus actuator position, will decrease the value of the process input. Only displayed when Dual Targets is configured. If a Dual Target function is used, this action is applicable when Target 2 is selected.

**Use Dual Dynamics (5418-2834 firmware only)**

Selects between a single set or two sets of dynamics for the process PID proportional gain. Checking the box selects two sets. When dual dynamics is used (checked), the input drop-down box appears, which will determine the aux input used to activate the second set of dynamics.

**Use Proportional Gain Curve**

This selects between a single gain vs. a 5-point gain curve. Checking the box selects the 5-point curve.

**Proportional Gain (%/process units) (5418-2834 firmware only)**

Sets the PID proportional gain value. Only displayed if Use Proportional Gain Curve is NOT selected. Allowed values: 0–7.98 %/process units

**Proportional Gain 2 (%/process units)**

Sets the PID proportional gain value when dynamics 2 is active. Only displayed if Use Dual Dynamics is selected and Use Proportional Gain Curve is NOT selected. Allowed values: 0–7.98 %/process units

**Common Gain**

Process control PID common gain. This setting is a multiplier on the entire gain curve settings. A Common Gain setting of 1 provides no adjustment. Only displayed if Use Proportional Gain Curve is selected. Allowed values: 0.3–7.98

**Position (%)**

Position breakpoints for the gain curve. Only displayed when Use Proportional Gain Curve is selected. Allowed values: Each point [5] must be larger than the previous and less than the next value, in increments of 0.4 percent. Range: 0–100%

**Gain or Dynamics 1 (%/process units)**

Sets the proportional gain value [5] based on the position when dynamics 2 is not active or when dual dynamics is not used. Only displayed when Use Proportional Gain Curve is configured. Allowed values: 0–7.98 %/process units

**Dynamics 2 (%/process units) (5418-2834 firmware only)**

Sets the proportional gain value [5] based on the position when dynamics 2 is active. Only displayed if Use Dual Dynamics is selected and when Use Proportional Gain Curve is configured. Allowed values: 0–7.98 %/process units

**Integral**

Process control PID integral term in repeats per second. Allowed values: 0–7.98 repeats/s

**Derivative**

Process control PID derivative term in seconds. Allowed values: 0–0.41 s

**Droop**— *Not displayed if Air/Fuel Ratio is configured*

Process control droop based on actuator position, in percentage of process setpoint. Allowed values: 0–100 %

**Gain Window**

Process control PID gain window, in process units. When the process error is greater than the setting, the Gain is multiplied by the Gain Ratio. Allowed values: must be greater than zero. The maximum is calculated based on input scaling.

**Gain Ratio**

Process control PID gain ratio. When the process error is greater than the window, the Gain is multiplied by the Gain Ratio. To disable the dual gain feature, set the Gain Ratio to 1.

Allowed values: 1–7.94

**Process Control—Open Loop Tab**

The process control open loop tab provides the open loop position and rate settings. This tab is only displayed if the unit is configured as an Air/Fuel Ratio controller.

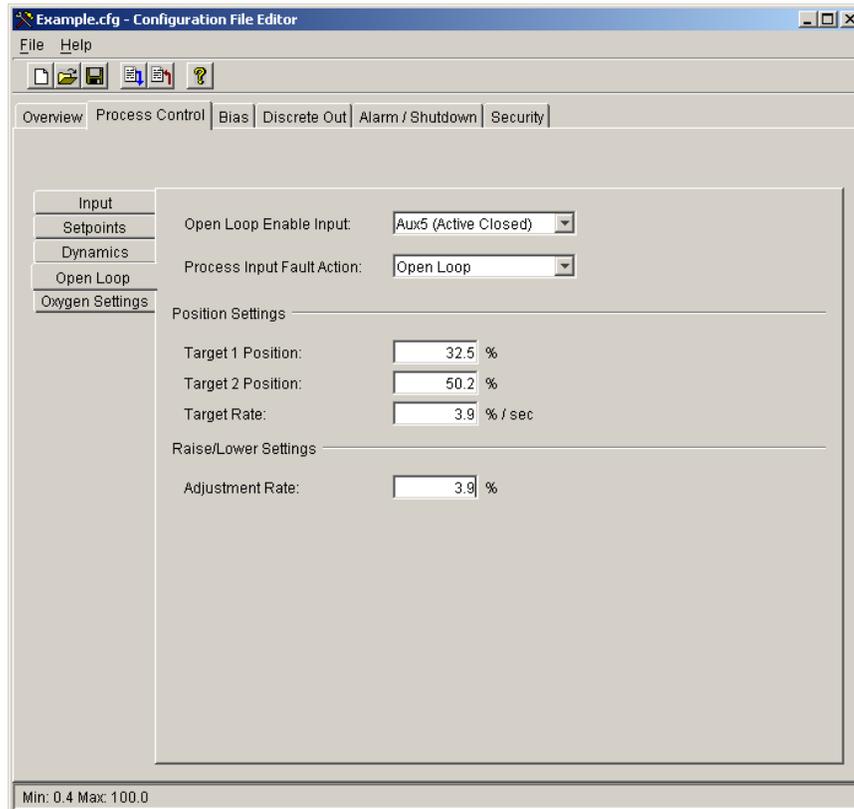


Figure 6-6. Configuration Editor—Process Control—Open Loop TAB

**Open Loop Enable Input**

This selects the AUX input to be used for the Open Loop Enable function.

**Process Input Fault Action (5418-1681 firmware only)**

This selects whether to use the Open Loop position setting or the Bias Control input when a process input fault is detected.

**Target (1) Position**

The target position setpoint when open loop is enabled, if the Use Dual Targets is configured and Target 1 is selected. Allowed values: 0–100 %

**Target 2 Position**

The target position setpoint when open loop is enabled and target 2 is selected. Only displayed if the Use Dual Targets is configured. Allowed values: 0–100 %

**Target Rate**

The setpoint used when ramping to a target setpoint.  
Allowed values: Range is 0.2 - 59.4 %/sec

**Adjustment Rate**

Specifies the ramping rate for the open loop setpoint Raise or Lower functions. Only displayed if the Raise/Lower function is configured. Allowed values: 0.4-100 %/sec

**Process Control—Oxygen Settings Tab**

The process control oxygen settings tab provides the closed loop threshold and setpoint perturbation settings. This tab is only displayed is the unit is configured as an Air/Fuel Ratio controller.

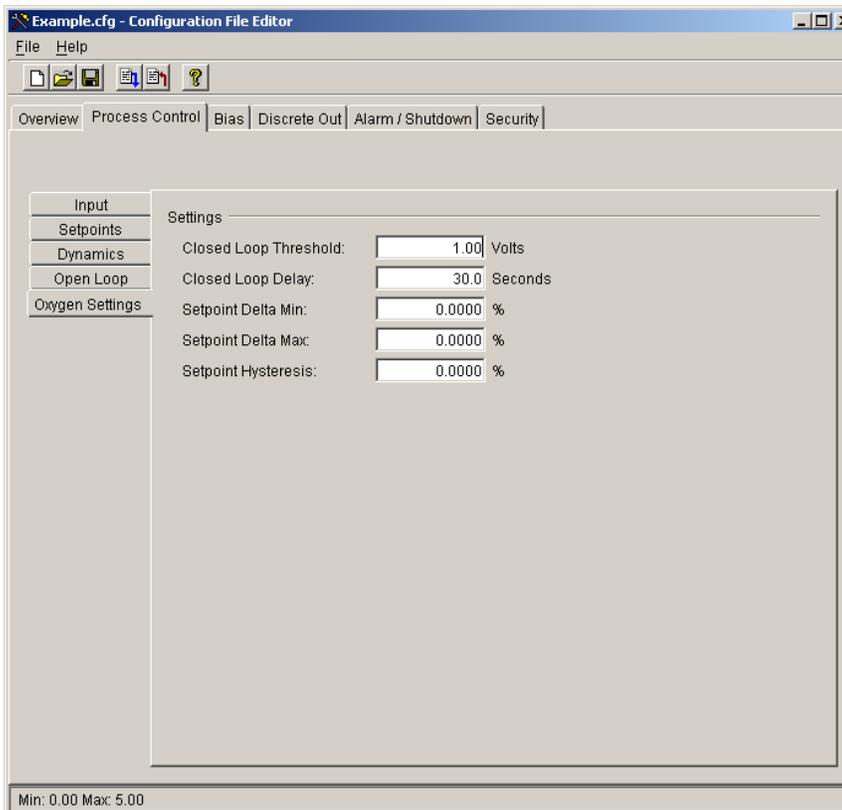


Figure 6-7. Configuration Editor—Process Control—Oxygen Settings TAB

**Closed Loop Threshold**

Below this level, for the delay time configured, the HEGO sensor is considered warm and ready for control. Allowed values: 0–1.25 V or 0–5 V, whichever is configured.

**Closed Loop Delay**

Delay before the HEGO sensor is considered to be warm and ready for control, once power is applied and input level is below the Closed Loop Threshold. Allowed values: 0-300 sec

**Setpoint Delta Min**

Amount added to or subtracted from the process setpoint when operating at the minimum process input level to provide catalyst perturbation. Set to zero to disable this function. Allowed values: The range is calculated based on input scaling

**Setpoint Delta Max**

Amount added to or subtracted from the process setpoint when operating at the maximum process input level to provide catalyst perturbation. Set to zero to disable this function. Allowed values: The range is calculated based on input scaling

**Setpoint Hysteresis**

Process delta amount to change catalyst perturbation direction. Set to zero to disable this function. Allowed values: must be less than the Setpoint Delta Min and Max settings

**Trim Control Tab**

The trim control tab provides the trim configuration settings and includes sub-tab screens for Input, Setpoints, Dynamics, and Oxygen Settings. This tab is only displayed if the unit is configured as a Full-Authority Air/Fuel Ratio Control or Process Control.

## Trim Control—Input Tab

The trim control input tab provides the trim input and overall scaling settings.

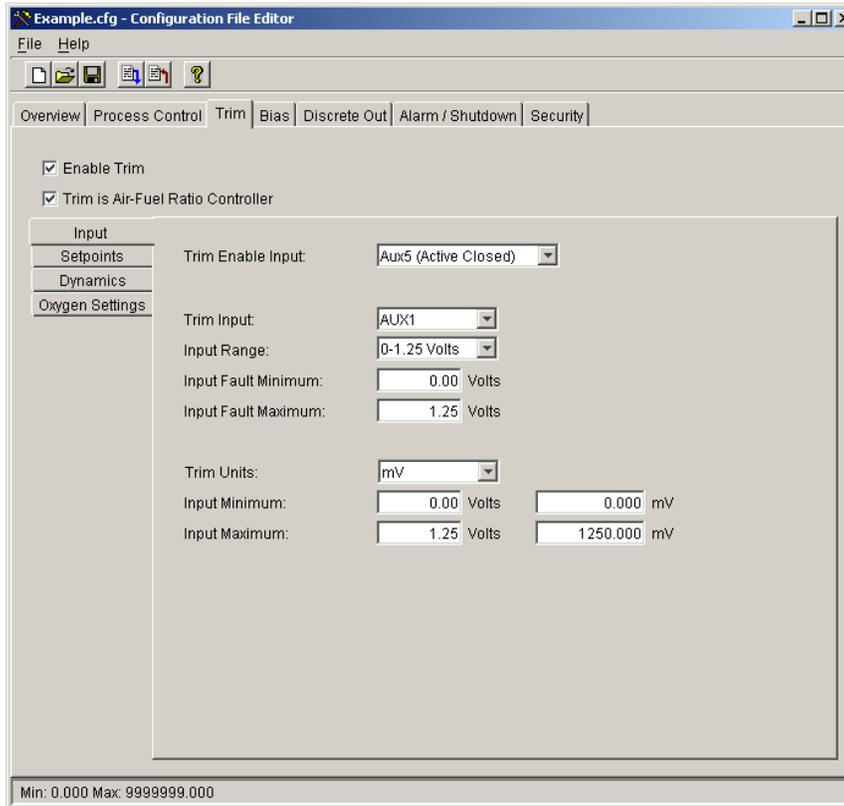


Figure 6-8. Configuration Editor—Trim Control—Input TAB

### Enable Trim

Select this checkbox to active the Trim function.

### Trim is Air/Fuel Ratio Controller

Select this checkbox if Trim is to be used to control Air/Fuel Ratio. Only displayed when configured as a Full-Authority Air/Fuel Ratio controller.

### Trim Enable Input

Select the appropriate AUX input for this discrete input function.

### Trim Input

Select the appropriate AUX input as the trim input. If this is a HEGO sensor input, then AUX1 configured as 0–1.25 V is recommended for proper operation.

Allowed values: AUX1, AUX2, AUX3, or AUX4.

### Input Range

Select the appropriate AUX1 Voltage range. Only displayed if the trim Input is configured as AUX1. Allowed values: 0–5 V or 0–1.25 V.

### Input Fault Minimum

Sets the voltage level of the trim input fault, below this level is considered a fault. Allowed values: 0–5 V or 0–1.25 V—must be less than the Input Fault Maximum

**Input Fault Maximum**

Sets the voltage level of the trim input fault, above this level is considered a fault. Allowed values: 0–5 V or 0–1.25 V—must be greater than the Input Fault Minimum

**Trim Units**

Select the appropriate units of measure for the trim controller.  
Allowed values: (none), %, Volts, mV, KW, psi, kg/cm<sup>2</sup>, in H<sub>2</sub>O, mbar, bar, in Hg, mm Hg, kPa, atm, °C, °F, Nm<sup>2</sup>, gpm, cfm, #/hr, kg/hr, l/hr, %O<sub>2</sub>, lambda or Phi.

**Input Minimum (Volts)**

Sets the voltage level of the minimum trim input, used in conjunction with the Input Minimum in engineering units to determine the trim scaling.  
Allowed values: 0–5 V or 0–1.25 V—must be less than the Input Maximum

**Input Minimum (trim units)**

Sets the engineering units of the trim input corresponding to the voltage value of the Input Minimum (Volts). Allowed values: must be less than the Input Maximum

**Input Maximum (Volts)**

Sets the voltage level of the maximum trim input, used in conjunction with the Input Maximum in engineering units to determine the trim scaling.  
Allowed values: 0–5 V or 0–1.25 V—must be greater than the Input Minimum

**Input Maximum (trim units)**

Sets the engineering units of the trim input corresponding to the voltage value of the Input Maximum (Volts). Allowed values: must be greater than the Input Minimum

## Trim Control—Setpoints Tab

The trim control setpoints tab provides trim controller setpoint and rate settings.

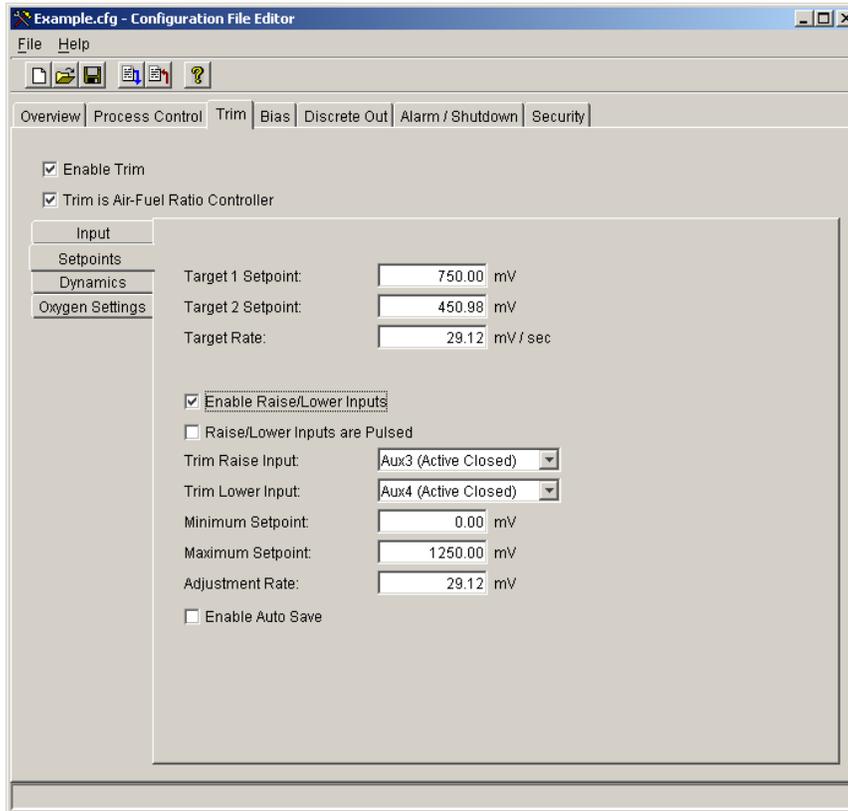


Figure 6-9. Configuration Editor—Trim Control—Setpoints TAB

### Target (1) Setpoint

The target setpoint when Trim control is enabled if Dual Targets is configured and Target 1 is selected. Allowed values: limited by both 0 V to 1.25 V/5 V trim input value (interpolated, on Input tab) and Setpoint Min to Max (if Raise/Lower is used)

### Target 2 Setpoint

The target setpoint when target 2 is selected. Only displayed if Dual Targets is configured.

Allowed values: limited by both 0 V to 1.25 V/5 V trim input value (interpolated, on Input tab) and Setpoint Min to Max (if Raise/Lower is used)

### Target Rate

The setpoint used when ramping to a target setpoint.

Allowed values: range is calculated based on input scaling

### Enable Raise/Lower Inputs

Select this checkbox to allow setpoint manipulation with raise and lower commands.

**Raise/Lower Inputs are Pulsed**

Select this checkbox if the discrete inputs are to move the setpoint a finite amount each time the input is activated. The amount is determined by the configured Adjustment Rate. Only displayed if Enable Raise/Lower Inputs is configured.

**Trim Raise Input**

Select the appropriate AUX input for this discrete input function. Only displayed if Enable Raise/Lower Inputs is configured.

**Trim Lower Input**

Select the appropriate AUX input for this discrete input function. Only displayed if Enable Raise/Lower Inputs is configured.

**Maximum Setpoint**

The highest setpoint allowed when using the Raise command. Only displayed if Enable Raise/Lower Inputs is configured. Allowed values: must be greater than the Minimum Setpoint and must be greater than the highest Target Setpoint and must be less than the 1.25 V/5 V input value (interpolated)

**Minimum Setpoint**

The smallest setpoint allowed when using the Lower command. Only displayed if Enable Raise/Lower Inputs is configured. Allowed values: must be less than the Maximum Setpoint and must be less than the smallest Target Setpoint and must be greater than the 0 V input value (interpolated)

**Adjustment Rate**

Specifies the ramping rate for the trim setpoint Raise or Lower functions. Only displayed if the Raise/Lower function is configured. Allowed values: range is calculated based on input scaling

**Enable Auto Save**

Select this checkbox to automatically save the adjusted setpoint as the default in non-volatile memory. Only displayed if Enable Raise/Lower Inputs is configured.

## Trim Control—Dynamics Tab

The trim control dynamics tab provides trim controller dynamics settings. The dynamic settings can also be adjusted on-line from the Edit Trim Dynamics screen.

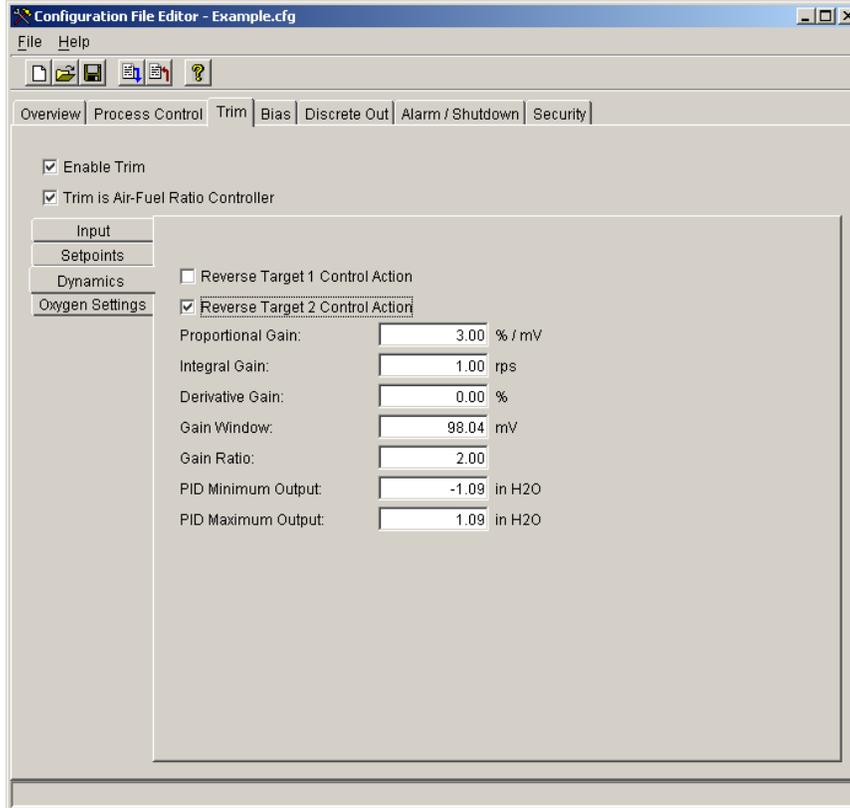


Figure 6-10. Configuration Editor—Trim Control—Dynamics TAB

### Reverse (Target 1) Control Action

Select this checkbox if an increase in the PID output, and thus Process Setpoint, will decrease the value of the trim input. If the Use Dual Targets is configured, this action is applicable when Target 1 is selected.

### Reverse Target 2 Control Action

Select this checkbox if an increase in the PID output, and thus Process Setpoint, will decrease the value of the trim input when Target 2 is selected. Only displayed if Use Dual Targets is configured.

### Proportional Gain (%/trim units)

Sets the PID proportional gain value. Only displayed if Use Proportional Gain Curve is NOT selected. Allowed values: 0–7.98 %/trim units

### Integral

Trim control PID integral term in repeats per second. Allowed values: 0–7.98 repeats/s

### Derivative

Trim control PID derivative term in seconds. Allowed values: 0–1.66 s

**Gain Window**

Trim control PID gain window, in trim units. When the trim error is greater than the window, the Gain Ratio multiplies the Proportional Gain. Allowed values: range is calculated based on trim input scaling.

**Gain Ratio**

Trim control PID gain ratio. When the trim error is greater than the window, the Gain Ratio multiplies the Proportional Gain. To disable the dual gain window, set the Gain Ratio to 1.  
Allowed values: 1–7.94

**PID Minimum Output**

The Trim PID output is added to the Process setpoint. This setting determines the amount this PID output will affect the Process setpoint when the PID is at minimum (0%). Allowed values: must be less than the PID Maximum Output; scaling is based on the process input scaling.

**PID Minimum Output**

This setting determines the amount this PID output will affect the Process setpoint when the PID is at maximum (100%). Allowed values: must be greater than the PID Minimum Output; scaling is based on the process input scaling.

**Trim Control—Oxygen Settings Tab**

The trim control oxygen settings tab provides closed loop and setpoint perturbation functions for HEGO or UEGO control. This tab only appears when Full Authority Air/Fuel Ratio Control is configured and the Trim is Air/Fuel Controller box is selected.

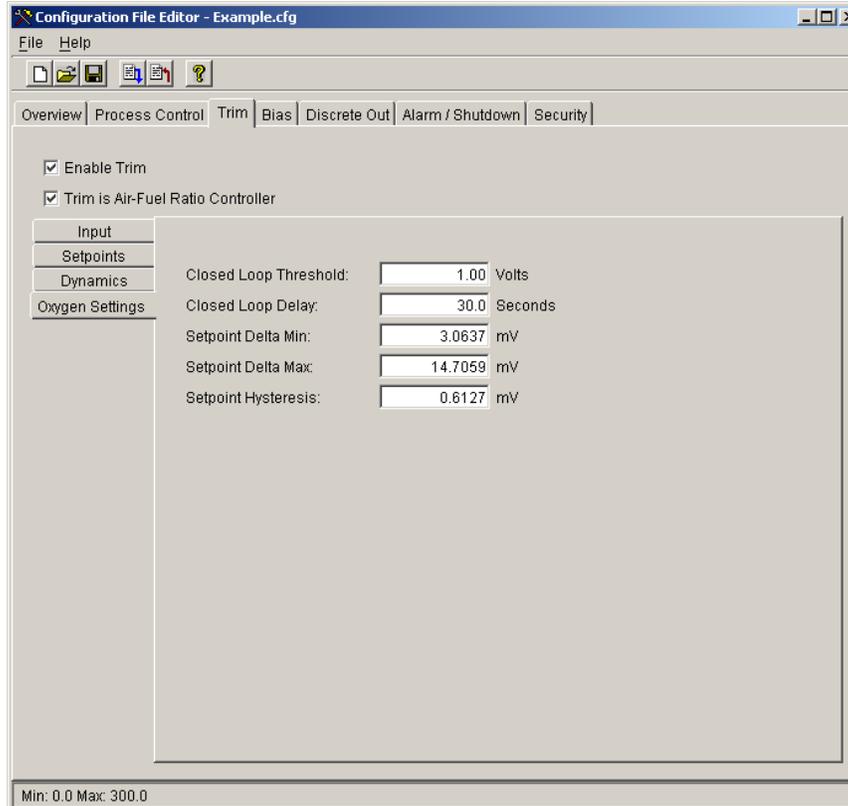


Figure 6-11. Configuration Editor—Trim Control—Oxygen Settings TAB

**IMPORTANT**

**O<sub>2</sub> sensor warm settings (Closed Loop Threshold and Delay) must be set according to the O<sub>2</sub> sensor characteristics.**

**Closed Loop Threshold**

Below this level, for the delay time configured, the oxygen sensor is considered warm and ready for control. Allowed values: 0–1.25 V or 0–5 V, whichever is configured.

**Closed Loop Delay**

Delay before the oxygen sensor is considered to be warm and ready for control, once power is applied and input level is below the Closed Loop Threshold. Allowed values: 0-300 sec

**Setpoint Delta Min**

Amount added to or subtracted from the trim setpoint at the minimum trim input level to provide catalyst perturbation. Set to zero to disable this function. Allowed values: The range is calculated based on input scaling

**Setpoint Delta Max**

Amount added to or subtracted from the trim setpoint at the maximum trim input level to provide catalyst perturbation. Set to zero to disable this function. Allowed values: The range is calculated based on input scaling

**Setpoint Hysteresis**

Trim delta amount to change catalyst perturbation direction. Set to zero to disable this function. Allowed values: must be less than the Setpoint Delta Min and Max settings

**Bias Tab**

The bias tab provides bias settings. This tab only appears if configured as an Air/Fuel Ratio, Full-Authority Air/Fuel Ratio or Process Controller.

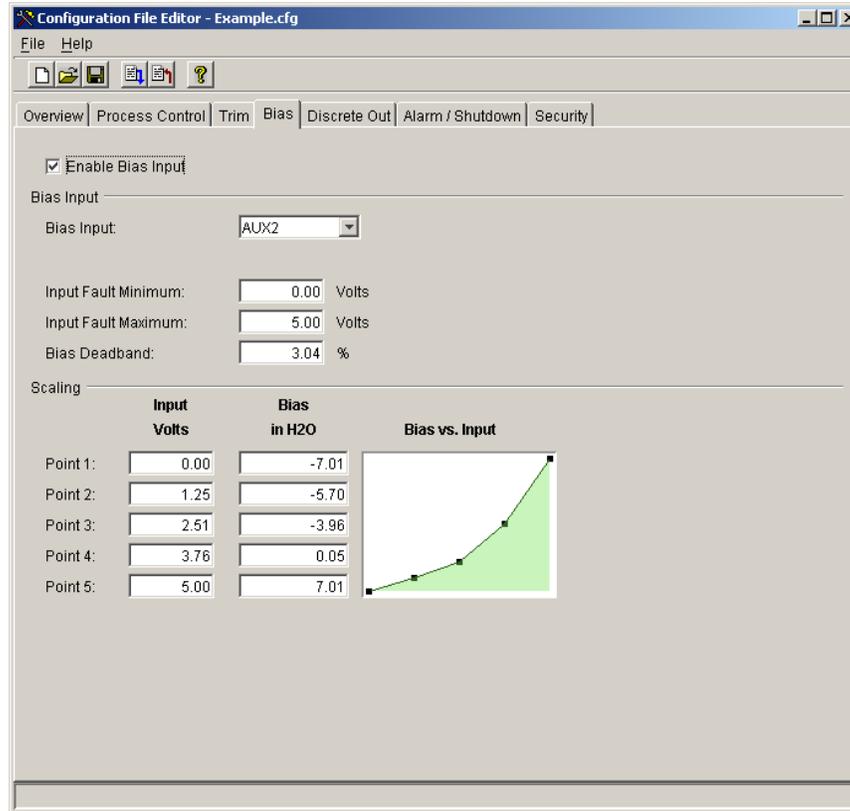


Figure 6-12a. Configuration Editor—Bias TAB (5481-1681 firmware)

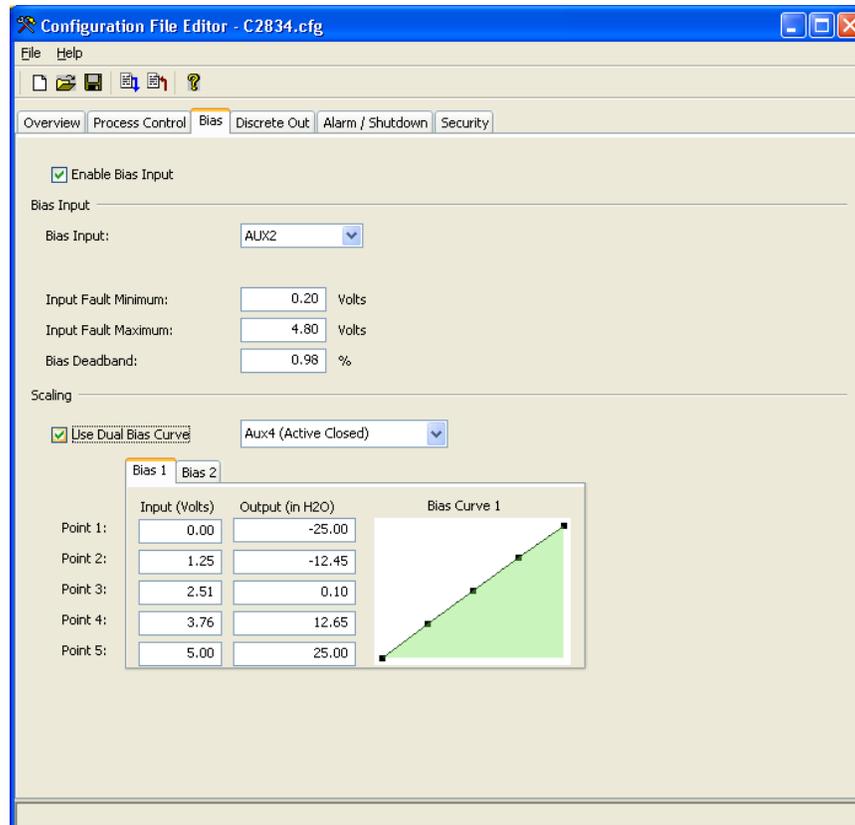


Figure 6-12b. Configuration Editor—Bias TAB (5418-2834 firmware)

**Enable Bias Input**

Select this checkbox to activate the Bias function.

**Bias Input**

Select the appropriate AUX input to use as the Bias input.

Allowed values: AUX1, AUX2, AUX3, AUX4.

**Input Range**

Select the appropriate AUX1 Voltage range. Only displayed if the Bias Input is configured as AUX1. Allowed values: 0–5 V or 0–1.25 V.

**Input Fault Minimum**

Sets the voltage level of the bias input fault, below this level is considered a fault. Allowed values: 0–5 V or 0–1.25 V—must be less than the Input Fault Maximum

**Input Fault Maximum**

Sets the voltage level of the bias input fault, above this level is considered a fault. Allowed values: 0–5 V or 0–1.25 V—must be greater than the Input Fault Minimum

**Bias Deadband**

Sets the amount of deadband on the bias input. The setting is  $\pm$  percentage of bias range. Allowed values: 0-25% of the bias range

**Use Dual Bias Curve (5418-2834 firmware only)**

Selecting this checkbox enables the use of two selectable bias curves.

When checked, the input configuration choice appears

**Input (Volts)**

Input breakpoints for the bias curve. Allowed values: Each point [5] must be larger than the previous and less than the next value. Range: 0–5 V or 0–1.25 V

**Bias or Bias 1 ( in Process units)**

Sets the process setpoint bias amount [5 points] based on the input signal, in process units, when bias 2 is not active or when dual bias curve is not used. Allowed values: limited  $\pm 25\%$  of the process setpoint range

**Bias 2 ( in Process units) (5418-2834 firmware only)**

Sets the process setpoint bias amount [5 points] based on the input signal, in process units, when bias 2 is active. Allowed values: limited  $\pm 25\%$  of the process setpoint range

## Position Control Tab

The Position Control tab provides Position Control settings. This tab only appears if configured as a Position Controller.

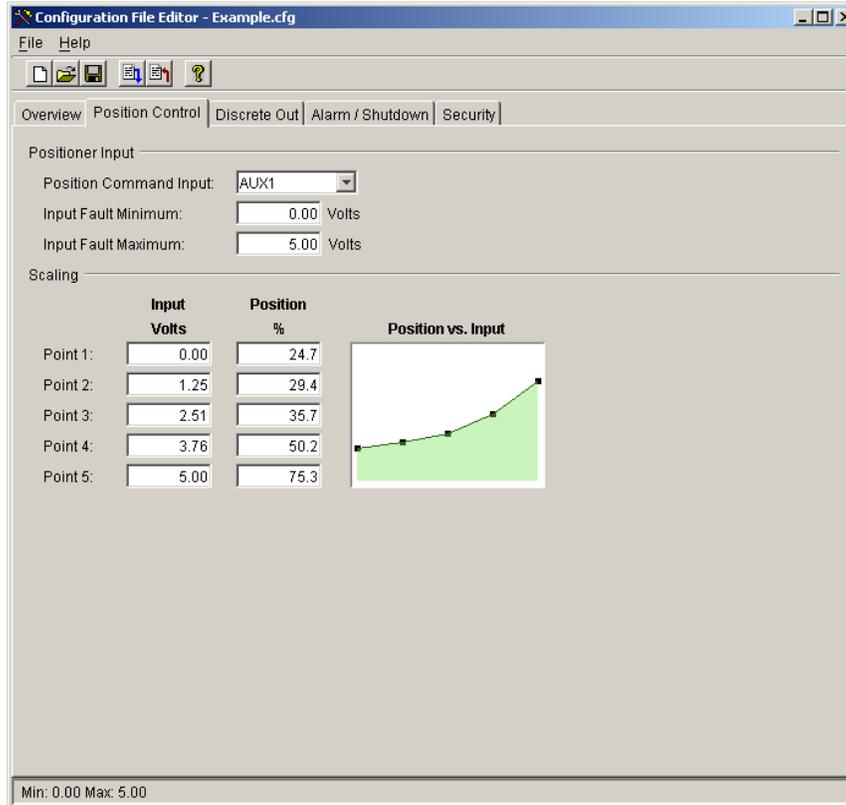


Figure 6-13. Configuration Editor—Position Control TAB

### Position Command Input

Select the appropriate AUX input as the position command input. The input is always expected to be 0–5 V. Allowed values: AUX1, AUX2, AUX3, AUX4.

### Input Fault Minimum

Sets the voltage level of the position command input fault, below this level is considered a fault. Allowed values: 0–5 V

### Input Fault Maximum

Sets the voltage level of the position command input fault, above this level is considered a fault. Allowed values: 0–5 V

### Input (Volts)

Input breakpoints for the position command curve. Allowed values: Each point [5] must be larger than the previous and less than the next value. Range: 0–5 V

### Position (%)

Sets the position command [5] based on the input signal. Allowed values: 0–100 %

## Discrete Out Tab

The discrete out tab provides options for the discrete output.

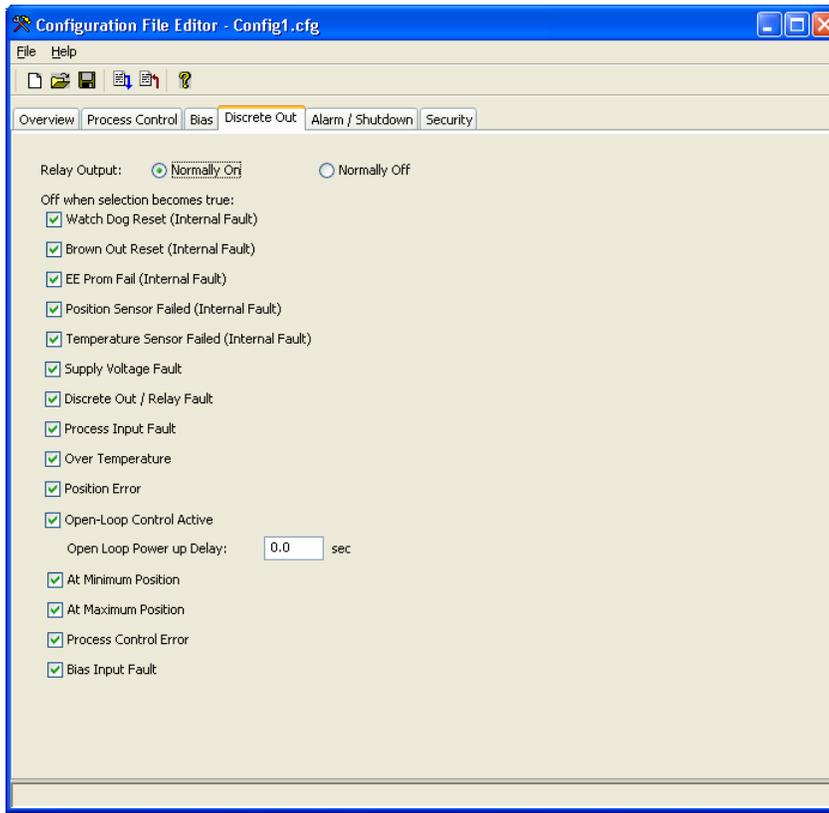


Figure 6-14. Configuration Editor—Discrete Out TAB

## Output Settings

### Relay Output Configuration

The relay output can be configured to one of the following:

**Normally On**—Sets the relay driver to a normally on mode that turns off for any of the faults selected. This is the preferred, failsafe output configuration.

**Normally Off**—Sets the relay driver to a normally off mode that turns on for any of the faults selected.



**It is recommended that the Relay Output be configured for the failsafe 'Normally On' mode, to ensure maximum fault protection and annunciation. Failure to follow these guidelines could, under exceptional circumstances, lead to personal injury and/or property damage.**

### Relay Output Fault Selections

The list of faults displayed can be individually selected to activate the relay output. Any of the selected faults will either turn the output Off if configured for Normally On or turn the output On if configured for Normally Off when a fault is detected.

**Open Loop Power up Delay (5418-2834 firmware only)**

Sets the delay on the Open Loop Active condition indication, in seconds, after the unit powers up before activating the discrete output. This setting is available to hold off a malfunction indicator lamp on power up, where open loop mode is normal (not an engine problem). This option only appears when the Open-Loop Control Active box is selected. Range: 0–428 s



**It is recommended that all faults be configured to activate the discrete output, this ensures maximum fault annunciation.**

**Alarm / Shutdown Tab**

The Alarm/Shutdown tab provides alarm and shutdown configuration settings.

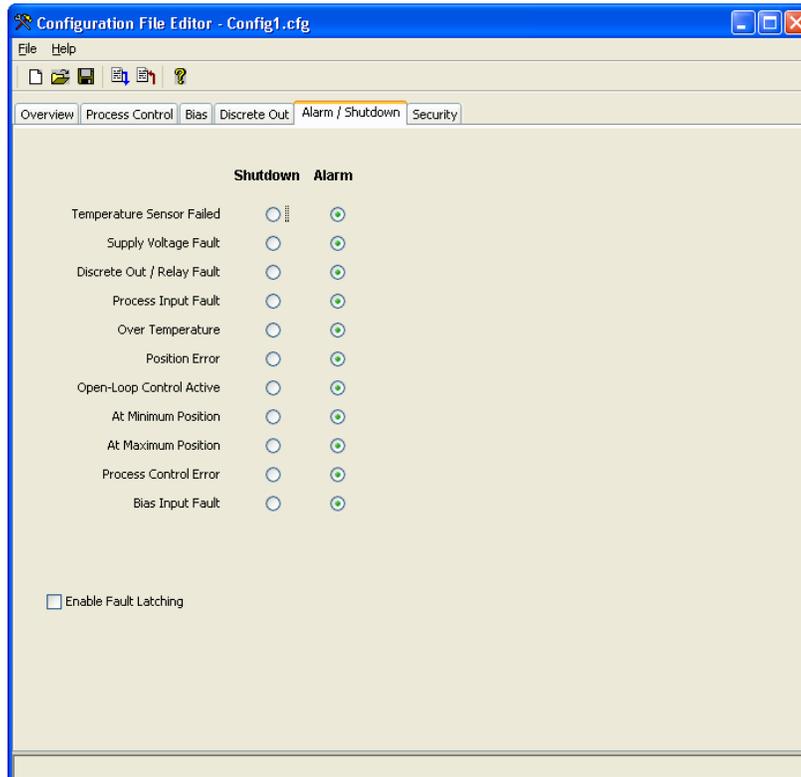


Figure 6-15. Configuration Editor—Alarm/Shutdown Tab

**Alarm / Shutdown Fault Settings****Fault Selection (Shutdown or Alarm)**

Set the desired action for each of the faults from the list. Setting the selection to a Shutdown will position the output to the configured Shutdown Position (see Overview tab). Setting the selection to an Alarm will allow the unit to attempt to continue running. For details on each of these fault conditions, refer to the Fault section in the manual (Chapter 4).

- Temperature Sensor Failed
- Supply Voltage Fault
- Discrete Out / Relay Fault
- Process Input Fault
- Over Temperature

- Position Error
- Open-Loop Control Active
- At Minimum Position
- At Maximum Position
- Process Control Error (5418-2834 firmware only)
- Bias Input Fault
- Trim Input Fault
- Trim Disabled

The following conditions are dedicated shutdown conditions.

- EE Prom Fail
- Position Sensor Failed

The following conditions are dedicated alarm conditions.

- Watch Dog Reset
- Brown Out Reset



**WARNING** It is recommended that all faults be configured as shutdowns and selecting 'Enable Fault Latching', this ensures maximum fault protection and prevent erratic on/off fault behavior.

#### Enable Fault Latching

Set to either latching (checked) or non-latching. When set to latching, a reset command or a power cycle must be issued to clear the fault. When non-latching is configured, as the fault condition goes away the control will be ready for operation. The fault log will indicate any faults that have occurred and subsequently cleared.

## Security Tab

The security tab provides the security configuration settings. To use any security, the Read Configuration security must be configured for use. Once selected, the Security Password must be set (Figure 6-16). One common password is used for all security selections. The password entry is prompted whenever a secured function is selected by the user.

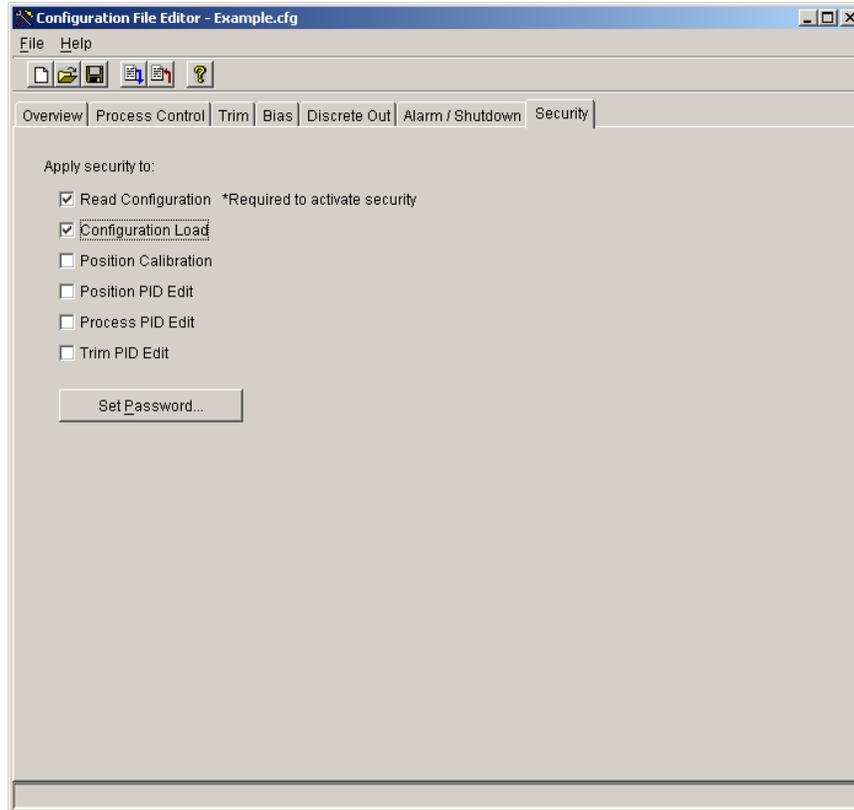


Figure 6-16. Configuration Editor—Security Tab

## Security Configurations

All checked features will have the security password enforced prior to allowing the function. Unchecked features will not be prompted with a password.

### Read Configuration

When checked, requires a password before the configuration can be read from the L-Series control (protects Open From Control execution).

This is the minimum level of protection and is required in order to use any other security option.

### Configuration Load

When checked, requires a password before a configuration can be loaded into the L-Series control (protects Load to Control execution).

### Position Calibration

When checked, requires a password before the position calibration mode can be entered (protects Manual and Automatic Position Calibration menu options).

**Position PID Edit**

When checked, requires a password before allowing tuning to the position PID (protects Edit Position PID menu option).

**Process PID Edit**

When checked, requires a password before allowing tuning to the process PID (protects Edit Process Dynamics menu option).

**Trim PID Edit**

When checked, requires a password before allowing tuning to the trim PID (protects Edit Trim Dynamics menu option).

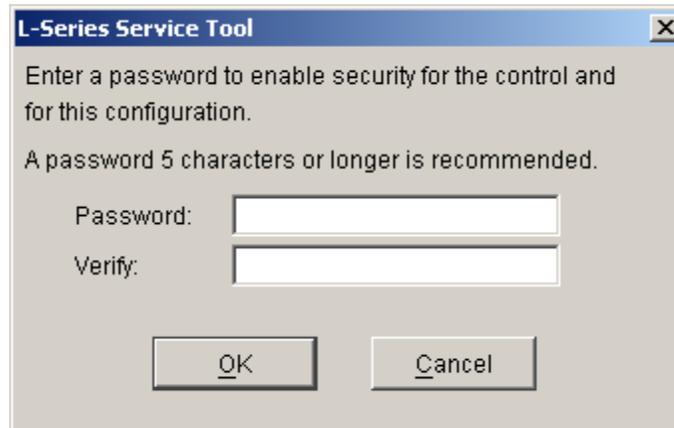


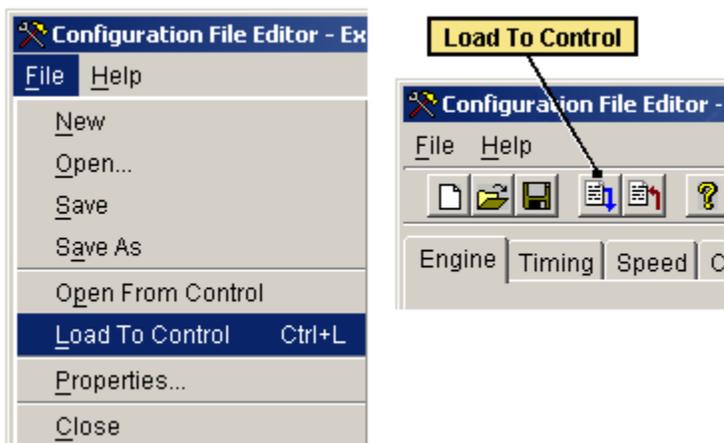
Figure 6-17. Security Tab Set Password Pop-up

**IMPORTANT**

Remember your password. There is no backdoor access. If needed, the control must be returned for repair to blank your password. Initially a password is not requested until a password has been loaded to the control. Once a password configuration is loaded, this password is stored and requested before allowing another configuration load. When a new configuration with a different password is loaded, the new configuration password becomes the new stored password.

**Loading the Configuration (Save)**

Select the File/'Load to Control' option from the menu or Blue Arrow icon on the Configuration Editor to load the changes into the control. The L-Series process must be zero prior to allowing a 'Load' command. This feature can be optionally password protected.



## Load Configuration File to Control

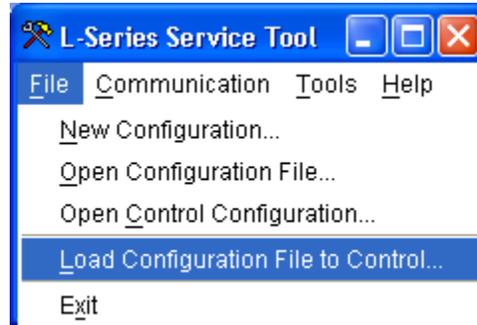


Figure 6-14. Direct Load of Configuration File

The 'Load Configuration File to Control' option under the File menu allows loading a configuration file to a control without opening it. Thus, a password-protected configuration file can be downloaded without entering the password while preserving the configuration's security.

If the control that is being downloaded to already contains a configuration with password protection enabled for configuration loads, that password is still required.

This option is only available in Service Tool version 2.1 and newer.

# Chapter 7.

## Setup and Tuning

### Introduction

The L-Series is configured using the Service Tool, refer to Chapter 5 for Service Tool installation and connection instructions. This chapter covers the process of tuning and servicing the control via the L-Series Service Tool. It is assumed that the control has already been installed on the engine.

An application requires the following setup steps. In many applications these steps have already been performed by the OEM.

- Configure the L-Series control (configuration is covered in Chapter 6).
- Tune the Process controller loop PID.
- Tune the Trim controller loop PID.

The following optional features are also available:

- Calibrate the Position Feedback range.
- Verify Position feedback calibration.
- Tune the Position controller loop PID. For most applications, the default gains do not need to be changed.

#### **WARNING**

An unsafe condition could occur with improper use of these software tools. Only trained personnel should have access to these tools.

#### **IMPORTANT**

Setup and tuning features can be individually password protected for security purposes. If security is applied, these features will not be accessible without the password.

#### **IMPORTANT**

Many applications are delivered pre-configured, calibrated, and tuned. For most applications, the default gains do not need to be changed. Min Position and Fail Direction should be checked.

## Tuning the Process PID

The Service Tool can be used to tune the Process PID or to just trend/monitor the process PID output. The Process PID Dynamics screen (Figure 7-1) is opened by selecting 'Edit Process Dynamics' under the 'Tools' menu.

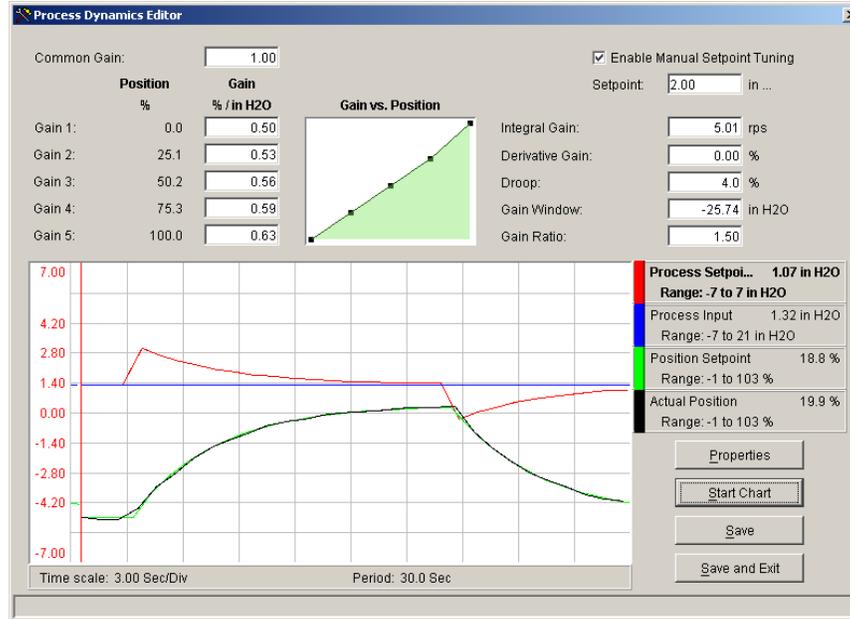


Figure 7-1. Service Tool—Process Dynamics

Pressing the Properties button pops open the Properties Window. From this window the user can adjust the trending window properties including the process range, update rate and display range.

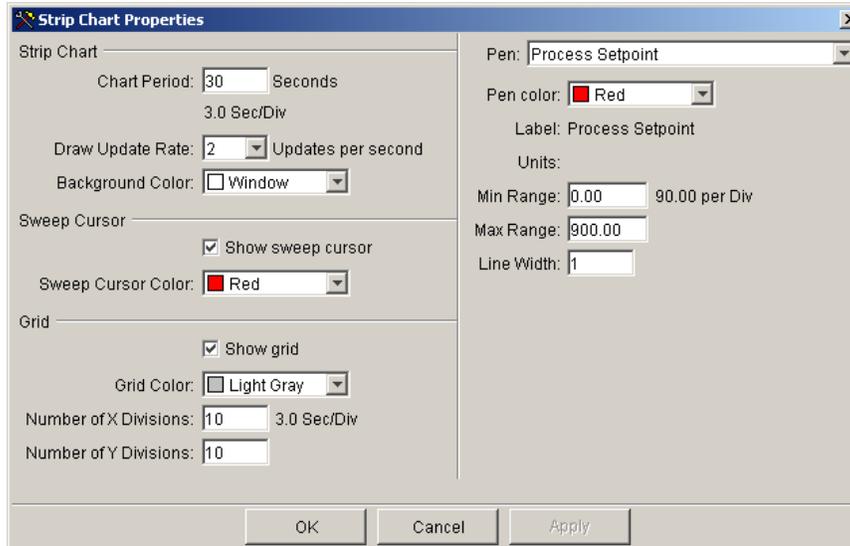


Figure 7-2. Service Tool—Properties Window

## Tuning the Trim PID

The Service Tool can be used to tune the Trim PID or to just trend/monitor the process PID output. The Trim PID Dynamics screen (Figure 7-3) is opened by selecting 'Edit Trim Dynamics' under the 'Tools' menu.

Pressing the Properties button pops open the Properties Window. From this window the user can adjust the trending window properties including the range, update rate and display range.

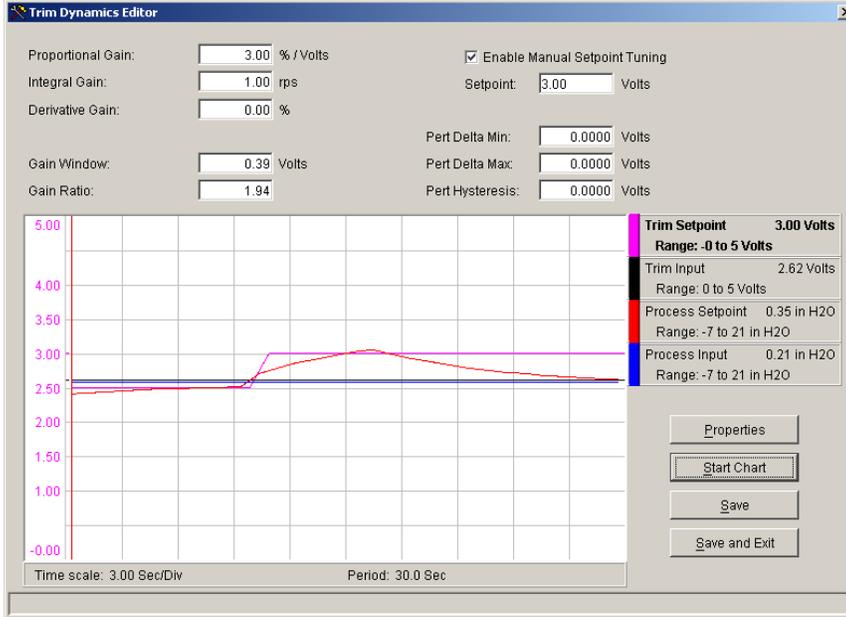


Figure 7-3. Service Tool—Trim Dynamics

## Tuning the Position PID

The Position PID tuning screen (Figure 7-4) is opened by selecting 'Edit Position PID' from the 'Tools' menu. The Service Tool can be used to tune the Position PID or to just trend/monitor the position PID output. In addition, the L-Series controller can be put into a manual control mode from this screen by selecting the "Enable Manual Position Tuning" checkbox. Once in manual mode, the position setpoint box is highlighted and the value displayed is actively positioning the output. Use this command to create step changes for the PID and monitor the response using the displayed trend.

Pressing the Properties button pops open the Properties Window (Figure 7-4). From this window the user can adjust the trending window properties including the update rate and display range.

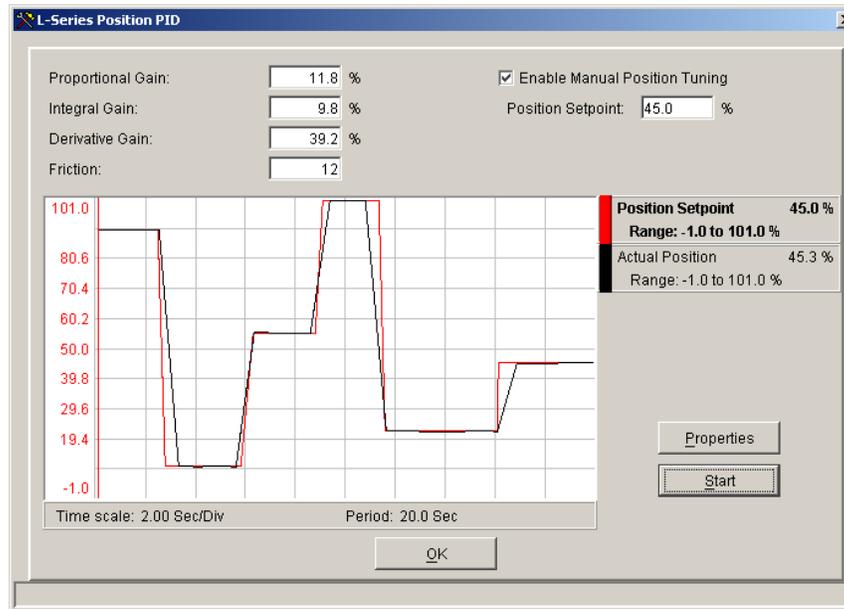


Figure 7-4. Service Tool—PID Tuning Window

## Position Calibration and Verification

Position calibration is available to map the position command input to the actual rotational travel of the unit. It is only used when the full travel of the actuator is constrained or limited such that 0 to 60 degrees of travel is not used. For example, an application-specific position calibration could map 0–100% position command to 10–40 degrees actual rotation.

There are two methods available to perform a position calibration: Automatic or Manual. If the application has hard stops that correspond to the actual min/max travel, then either Auto or Manual methods can be used—although auto is easier. If hard stops are not available, then the auto method will give invalid results and the manual method must be followed.

The Service Tool can be used to calibrate the control to end user stops (physical or soft) or to verify the position calibration. To get to the Position Calibration screens select the desired function from Position Calibration under the Tools menu selection.

<b>IMPORTANT</b>	<b>Position Calibration is only used when the full travel of the actuator is constrained or limited such that 0 to 60 degrees of travel is not used.</b>
------------------	--



Figure 7-5. Service Tool—Manual Position Calibration selection

## Calibration Sequence Overview

The following outlines the basic steps required to execute the position calibration.

### Automatic Mode

1. Select Automatic Position Calibration Mode.
2. Select CW or CCW Direction.
3. L-Series automatically rotates in both CW and CCW directions until the stops are detected. The values are then captured and stored.
4. When completed, cycle the power on the L-Series.
5. It is recommended that a Position Verification be performed to confirm the calibration is correct. See Position Verification below.

### Manual

1. Determine the rotational travel limits. This can be done by positioning the unit to the minimum and maximum positions and recording the position settings.
2. Select Manual Position Calibration Mode.
3. Select Direction.
4. Enter the pre-determined rotational travel limits values.
5. When completed, cycle the power on the L-Series.
6. It is recommended that a Position Verification be performed to confirm the calibration is correct. See Position Verification below.

## Position Verification

The Position Verification screen (Figure 7-6) is opened by selecting 'Verify Position' from the 'Position Calibration' drop-down under the 'Tools' menu. When the Verify Position screen is entered, the control is put into position control and the position is set to the position the control was at when the screen was entered. The screen displays the "User" Requested Position, Actual Position, Minimum Position, and Maximum Position. These User Positions are calculated from the user-calibrated stops.

The Full Travel Actual Position is the full stroke factory position without user stops after software linearization. The Full Travel Sensor Position is the full stroke factory position without user stops before software linearization. The Full Travel Sensor Position will match the TPS Output Signal.

The Verify Position screen can be used to check the calibration or to get the minimum and maximum position values for the manual calibration. If the Enable Requested Position Tuning box is checked the valve can be positioned anywhere from 0 to 100% of the user minimum and maximum stops by entering a value into the Requested Position. If the Enable Requested Position Tuning box is unchecked the valve will go limp and can be physical positioned by hand.

### **IMPORTANT**

**If the full factory position calibration range is not being used (the Manual or Automatic Calibration has been performed) and the minimum position direction is changed, the calibration must be run again for the Verify Position mode to work correctly.**

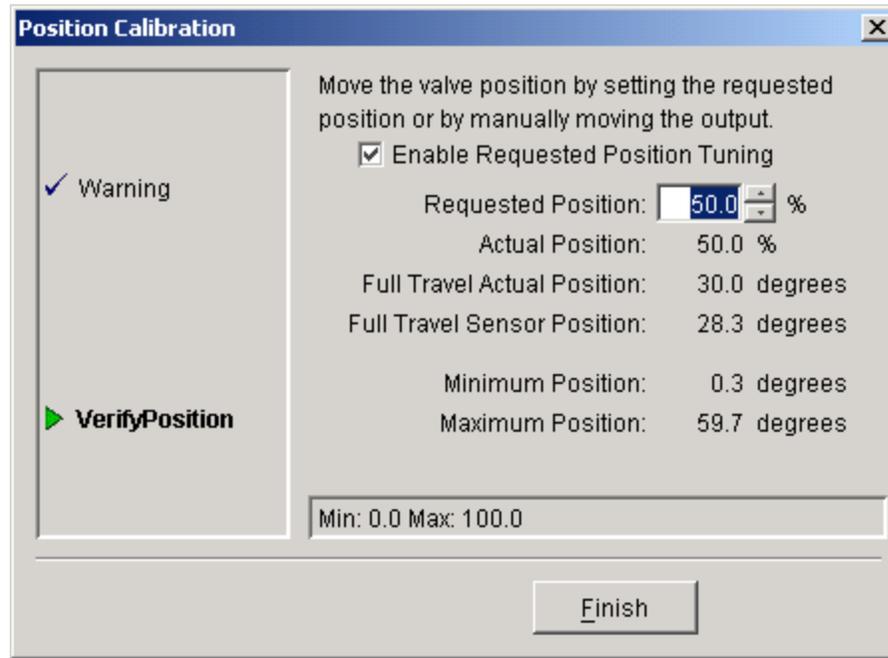


Figure 7-6. Service Tool—Verify Position Calibration

## Manual

The Manual position calibration screen (Figure 7-7) is opened by selecting 'Manual' from the 'Position Calibration' drop-down under the 'Tools' menu. The manual calibration mode is used to set the minimum position and fail direction and to calibrate the valve to user soft stops (inside of any physical stops). The first screen to appear when entering the manual mode is used to set the minimum position and fail direction. This setting must be correct before manually calibrating the valve.

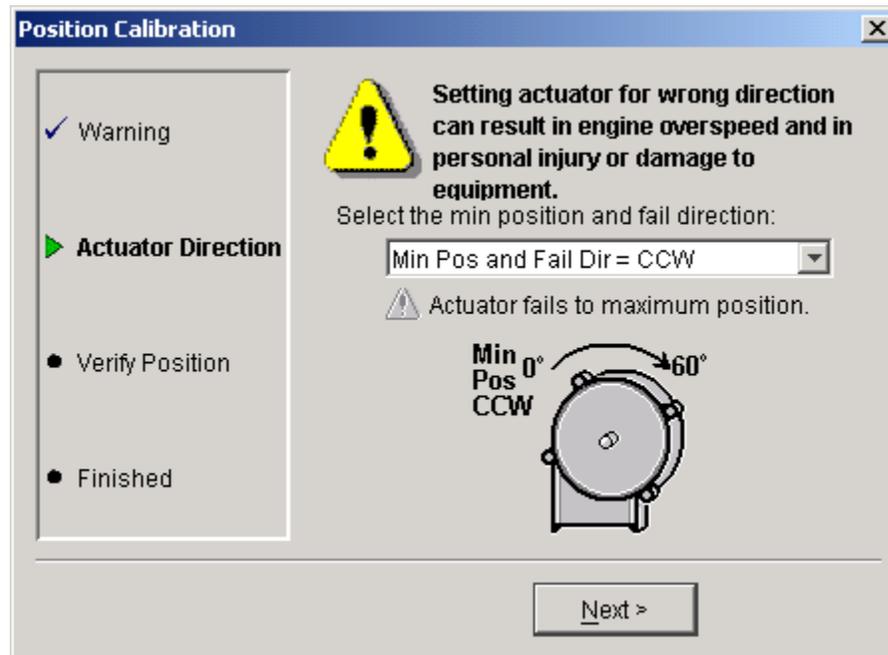


Figure 7-7. Service Tool—Manual Position Calibration

The next screen is used to set the minimum and maximum positions for the user soft stops. To find the minimum and maximum soft stops use the verify position mode described above to position the valve and use the Full Travel Actual Position reading for minimum and maximum position values.

**IMPORTANT**

After leaving this mode, power must be cycled for the new settings to take effect.

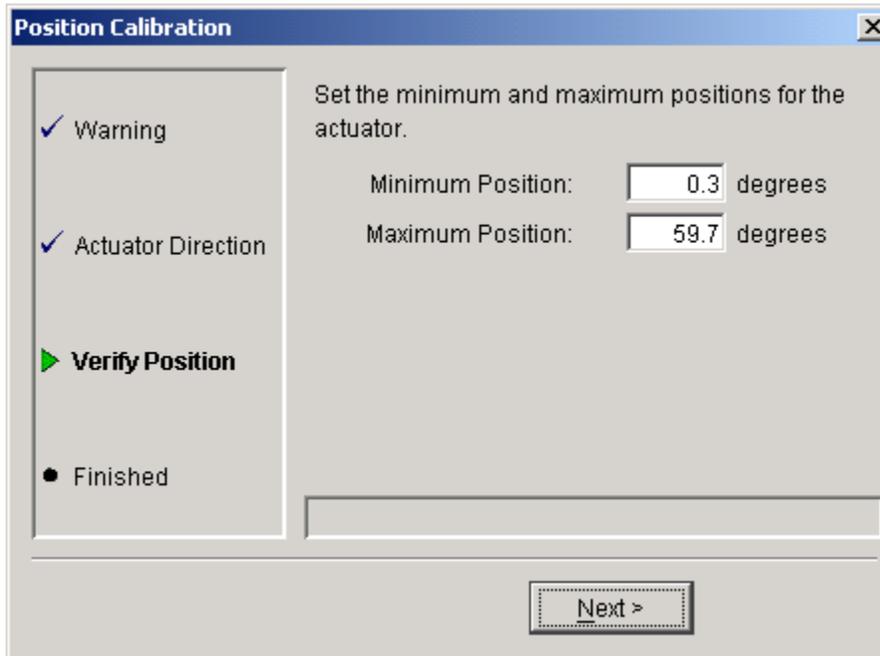


Figure 7-8. Service Tool—Manual Position Calibration Settings

**Automatic**

The Automatic position calibration screen (Figure 7-9) is opened by selecting 'Automatic' from the 'Position Calibration' drop-down under the 'Tools' menu. The automatic calibration mode is used to set the minimum position and fail direction and to calibrate the valve to user physical stops (mechanical hard stops). Like the manual mode, the first screen to appear is used to set the minimum position and fail direction. This setting must be correct before automatic calibration is performed.

After setting minimum position and fail direction the screen below will appear. The control is now moving first to the CCW stop and then to the CW stop to get the physical minimum and maximum positions.

**IMPORTANT**

After leaving this mode, power must be cycled for the new settings to take effect.

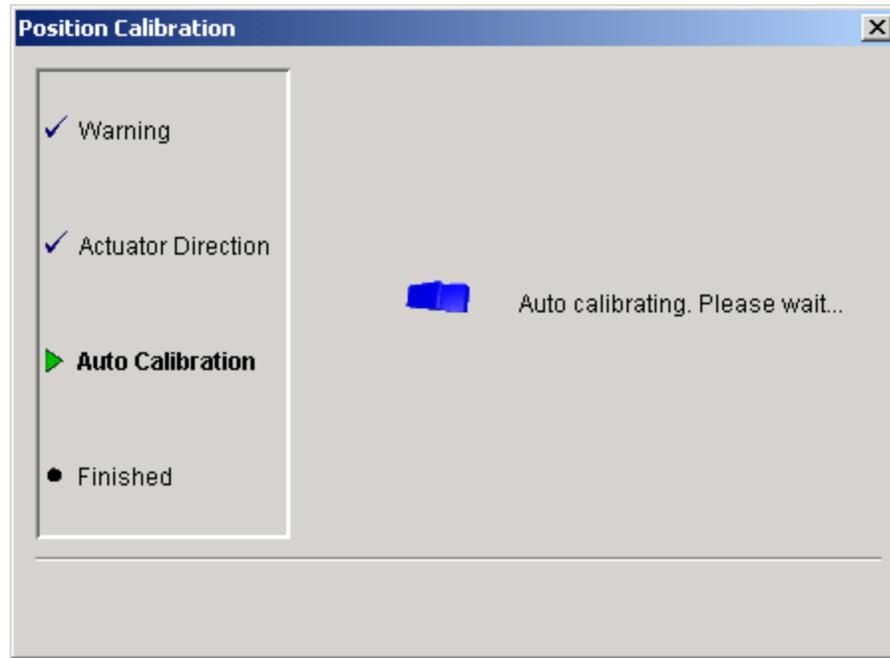


Figure 7-9. Service Tool—Auto Position Calibration

# Chapter 8.

## Troubleshooting

### Introduction

This chapter presents several broad categories of application failures typically experienced in the field, possible causes, and some tests used to verify the causes. Because the exact failure experienced in the field is the product of the mechanical/electrical failure combined with the configuration file resident in the control, it is left as the OEM's responsibility to create a more detailed troubleshooting chart for the end user. Ideally, this end-user troubleshooting chart will contain information about mechanical, electrical, engine, and load failures in addition to the possible governor failures. For more detailed information about governor system failure modes and effects, contact Woodward for a copy of the system DFMEA.

The troubleshooting scenarios listed below assume that the end user has a digital multimeter at his disposal for testing voltages and checking continuity, and assume that the application has been engineered and tested thoroughly.

There are four parts to the troubleshooting section:

- General Troubleshooting
- Engine/Generator Troubleshooting
- Troubleshooting Alarm/Shutdown Diagnostic Flags
- Input/Output (I/O) Troubleshooting

#### **WARNING**

The actions described in this troubleshooting section are not always appropriate in every situation. Always make sure that any action taken will not result in loss of equipment, personal injury, or loss of life.

#### **WARNING**

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.

#### **WARNING**

The L-Series wiring must be in accordance with North American Class I, Division 2 or Zone 2 wiring methods as applicable, and in accordance with the authority having jurisdiction.

#### **CAUTION**

The L-Series is used on prime movers that typically have a high noise level. Always use appropriate hearing protection while working around the L-Series.

## General System Troubleshooting Guide

The following is a general troubleshooting guide for areas to check which may present potential difficulties. By making these checks appropriate to your engine/turbine before contacting Woodward for technical assistance, your system problems can be more quickly and accurately assessed.

- Is the wiring correct?
- Is the direction of the stroke correct?
- Is the direction of the failsafe shutdown correct?
- Does the valve move through its proper stroke smoothly?
- Does the valve travel its full stroke?
- Can mid-stroke be obtained and held?
- Does the valve fully seat (close)?
- Does the valve fully open?

Problem	Possible Cause	Suggested Test/Correction
Discrete output not working	Wiring fault.	Check the wiring leading to pin 9 for open connections or misconnections.  Verify that pin 9 is not connected directly to input power or ground.
	Configuration.	Using the Service Tool, verify that the faults and shutdowns are selected properly and that the output is configured for expected operation (either normally "on" or normally "off").
Service Tool not communicating—'Not Connected' status indicated	Wiring fault.	Check AUX3 and AUX4 for loose or misconnected connections.
	The Service tool is disconnected.	Verify harness setup and connections (see Chapter 4).
	The wrong communication port has been selected.	Check that Service Tool is running.  Verify the port setting is correct.  Check fuse, wiring, and battery voltage.  Connect the service tool by using the connect menu.
Service Tool not communicating—'Error message displayed on PC when trying to connect	Old version of Service Tool or file corruption or bad install.	Re-install Service Tool, get the latest version from the Woodward web site ( <a href="http://www.woodward.com">www.woodward.com</a> )
Service Tool will not accept password	Cap Lock is on.	Password is case sensitive, make sure you enter the password correctly using upper and lower case.  If password is lost contact the OEM for retrieval.

## Troubleshooting Diagnostic Fault Flags

Error Flag	Description	Possible Source	Possible Action
Supply Voltage Failure	<p>The power supply voltage is higher than the diagnostic limits.</p> <p>The Power supply voltage is lower than the diagnostic limits.</p>	<p>Bad or damaged battery.</p> <p>Defective battery charging system.</p> <p>Incorrect setting of power supply voltage level.</p> <p>Power supply wiring too long or too thin. Control will flag low voltage during higher power uses.</p>	<p>Replace battery.</p> <p>Fix battery charging system.</p> <p>Set correct voltage levels on power supply.</p> <p>Make sure wiring is of the correct thickness and length according to manual.</p>
Temperature Sensor Failed	This error is set if the temperature inside the control is higher or lower than allowed by the specifications.	<p>Control has been placed in an environment that is too hot or too cold.</p> <p>The internal temperature sensor is defective. This can be determined by checking the temperature of the unit and comparing this to the service tool value of the electronics temperature.</p>	<p>Lower temperature by adding cooling, heat shielding, moving the unit, etc.</p> <p>Increase temperature by adding heat.</p> <p>Return unit to Woodward for repair.</p>
Process Input Fault	This diagnostic flag will be set if the process input is not within the configured voltage range.	<p>Damaged, loss of process or wiring.</p> <p>Damaged connector.</p> <p>Incorrect installation of process sensor.</p> <p>Incorrect configuration of process sensor.</p>	<p>Fix wiring or replace.</p> <p>Verify process signal shielding recommendations (chapter 3) have been followed.</p> <p>Verify process input is wired correctly..</p> <p>Fix connector or replace.</p> <p>Verify value displayed on Service Tool for input, if Aux 1 or Aux 2 is configured.</p> <p>Correct the process sensor installation. See process sensor installation manual.</p> <p>Verify configuration settings.</p>
Position Error	Indicates demanded position and the actual position are outside the configured limits.	<p>Incorrect position controller dynamics or friction setting.</p> <p>Binding or excessive friction in the actuator linkage, or stops are set inside the desired range of travel.</p>	<p>Check/tune position dynamics using the Service Tool.</p> <p>Perform a position calibration.</p> <p>Check all mechanical linkages and stops.</p> <p>Verify Configuration errors settings.</p>
Open Loop Active	Indicates the control mode is open loop.	Process input failed or sensor not warm or open loop selection is active.	Check input failed indication. Check sensor warm indication, if AFR. Check if the open loop control selection is active.

Error Flag	Description	Possible Source	Possible Action
Process Control Error	The 'process input – setpoint' is not changing signs, indicating a control system problem.	Incorrect process controller dynamics or delay setting in the process error. Verify basic functions of the controller.  Binding or excessive friction in the actuator linkage, or stops are set inside the desired range of travel.	Check/tune process dynamics using the Service Tool. Verify delay setting. Verify values of input and setpoint; are they moving, is the PID output moving, is the position command output moving, is the shaft moving.  Perform a position calibration.  Check all mechanical linkages and stops.
Position Sensor Failure	If the internal position sensor is outside the diagnostic limits.	Internal failure of position sensor.	Return unit to Woodward.
Bias Input Fault	This diagnostic flag will be set if the bias input is not within the configured voltage range.	Damaged, loss of process or wiring.  Damaged connector.  Incorrect installation of bias signal.  Incorrect configuration of the input.	Fix wiring or replace.  Verify process signal shielding recommendations (chapter 3) have been followed.  Verify the input is wired correctly..  Fix connector or replace.  Verify value displayed on Service Tool for input, if Aux 1 or Aux 2 is configured.  Correct the input installation.  Verify configuration settings.
Trim Input Fault	This diagnostic flag will be set if the trim input is not within the configured voltage range.	Damaged, loss of process or wiring.  Damaged connector.  Incorrect installation of trim signal.  Incorrect configuration of the input.	Fix wiring or replace.  Verify process signal shielding recommendations (chapter 3) have been followed.  Verify process input is wired correctly..  Fix connector or replace.  Verify value displayed on Service Tool for input, if Aux 1 or Aux 2 is configured.  Correct the trim input installation.  Verify configuration settings.
Trim Disabled	Indicates Trim control is not enabled.	Trim input failed or sensor not warm or trim enable not active.	Check input failed indication. Check sensor warm indication, if trim is AFR. Check is the trim enable is active.
Internal Shutdown	All internal shutdowns will set this flag.	The Control is defective.	Return unit to Woodward.

Error Flag	Description	Possible Source	Possible Action
EEPROM Failure	The software can't write to the EEPROM.  The software can't read from the EEPROM.	The Control is defective.	Return unit to Woodward.
Brown Out Reset	The power up reset flag will be set every time power to the Control has been lost and is restored.	Normal power up of the Control.  Loss of power or intermittent power supply wiring.  Power supply wiring to long or to thin. ISC will reset during transient power uses.	No action needed. Possibly reset control.  Check wiring for bad or loss connection.  Make sure wiring is of the correct thickness and length according to manual.
Watchdog Reset	The watchdog has reset the Control.	After software update, the software watchdog will reset the Control.  The software is disrupted by EMI or an internal component failure.	This is a normal situation. Reset the error code and reset the stored errors.  This is an abnormal situation. Return the unit to Woodward.
Overtemperature	High internal temperature.	Detection of high of temperature.	Check ambient temperature around Control.  Verify temperature reading using service tool.  If the temperatures seem normal, could indicate a problem with the temperature sensor.
Relay Fail Short	Control detected a fault in the discrete out wiring.	Incorrect or intermittent wiring problem.	Check wiring for bad or loss connection.

## Electrical Troubleshooting Guide

### Analog Input

If an Analog Input is not functioning properly, verify the following:

- Measure the input voltage.
- Verify the input is properly configured.
- Check the values seen by the L-Series driver using the Service Tool and verify that it matches the input signal.
- Verify that there are no or minimal ac components to the Analog Input signal. AC components can be caused by improper shielding.
- Check the wiring. If the inputs are reading 0 or the engineering units that correspond to 0 V, look for loose connections and disconnected / misconnected cables/connections.
- Check the software configuration to ensure that the input is configured properly as the Demand Source.

### Discrete Input

If a discrete input is not functioning properly, verify the following:

- Measure the input voltage on the terminal block. It should be in the range of 10–28 Vdc.
- Check the status of the input from the Overview screen of the Service Tool.
- Check the wiring, looking for loose connections or misconnected cables.
- Verify the input is properly configured.

### Alarm or Shutdown Conditions

If the L-Series control has any alarm or shutdown conditions, refer to Chapter 4 for details on the exact cause of the condition. The Service Tool must be used to determine the cause of any shutdown or alarm condition.

### Discrete Output

If the discrete output is not functioning properly, verify the following:

- Measure the output voltage on the terminal block. It should be in the range of 10–28 Vdc when the output is off/false. The voltage will be in this range only if all shutdowns are false, assuming it is configured as Off for Fault. This can be verified through the Service Tool.
- Check the wiring, looking for loose connections or disconnected / misconnected cables.
- Verify the configuration of the output.

### Service Tool

If the service tool is not functioning properly, review the installation information in Chapter 5. Verify the following:

- Check the wiring, looking for loose connections or disconnected / misconnected cables.
- Check that Service Tool is running. Verify the Port setting is correct.
- Follow on-screen error messages. Re-install software as needed. The latest version of software is available for download from the Woodward web site ([www.woodward.com](http://www.woodward.com)).

# Chapter 9.

## Product Support and Service Options

### Product Support Options

**IMPORTANT** There are no serviceable parts on the L-Series.

If you are experiencing problems with the installation, or unsatisfactory performance of a Woodward product, the following options are available:

1. Consult the troubleshooting guide in the manual.
2. Contact the **OE Manufacturer or Packager** of your system.
3. Contact the **Woodward Business Partner** serving your area.
4. Contact Woodward technical assistance via email ([EngineHelpDesk@Woodward.com](mailto:EngineHelpDesk@Woodward.com)) with detailed information on the product, application, and symptoms. Your email will be forwarded to an appropriate expert on the product and application to respond by telephone or return email.
5. If the issue cannot be resolved, you can select a further course of action to pursue based on the available services listed in this chapter.

**OEM or Packager Support:** Many Woodward controls and control devices are installed into the equipment system and programmed by an Original Equipment Manufacturer (OEM) or Equipment Packager at their factory. In some cases, the programming is password-protected by the OEM or packager, and they are the best source for product service and support. Warranty service for Woodward products shipped with an equipment system should also be handled through the OEM or Packager. Please review your equipment system documentation for details.

**Woodward Business Partner Support:** Woodward works with and supports a global network of independent business partners whose mission is to serve the users of Woodward controls, as described here:

- A **Full-Service Distributor** has the primary responsibility for sales, service, system integration solutions, technical desk support, and aftermarket marketing of standard Woodward products within a specific geographic area and market segment.
- An **Authorized Independent Service Facility (AISF)** provides authorized service that includes repairs, repair parts, and warranty service on Woodward's behalf. Service (not new unit sales) is an AISF's primary mission.
- A **Recognized Engine Retrofitter (RER)** is an independent company that does retrofits and upgrades on reciprocating gas engines and dual-fuel conversions, and can provide the full line of Woodward systems and components for the retrofits and overhauls, emission compliance upgrades, long term service contracts, emergency repairs, etc.

A current list of Woodward Business Partners is available at [www.woodward.com/directory](http://www.woodward.com/directory).

### Product Service Options

Depending on the type of product, the following options for servicing Woodward products may be available through your local Full-Service Distributor or the OEM or Packager of the equipment system.

- Replacement/Exchange (24-hour service)
- Flat Rate Repair
- Flat Rate Remanufacture

**Replacement/Exchange:** Replacement/Exchange is a premium program designed for the user who is in need of immediate service. It allows you to request and receive a like-new replacement unit in minimum time (usually within 24 hours of the request), providing a suitable unit is available at the time of the request, thereby minimizing costly downtime.

This option allows you to call your Full-Service Distributor in the event of an unexpected outage, or in advance of a scheduled outage, to request a replacement control unit. If the unit is available at the time of the call, it can usually be shipped out within 24 hours. You replace your field control unit with the like-new replacement and return the field unit to the Full-Service Distributor.

**Flat Rate Repair:** Flat Rate Repair is available for many of the standard mechanical products and some of the electronic products in the field. This program offers you repair service for your products with the advantage of knowing in advance what the cost will be.

**Flat Rate Remanufacture:** Flat Rate Remanufacture is very similar to the Flat Rate Repair option, with the exception that the unit will be returned to you in “like-new” condition. This option is applicable to mechanical products only.

## Returning Equipment for Repair

If a control (or any part of an electronic control) is to be returned for repair, please contact your Full-Service Distributor in advance to obtain Return Authorization and shipping instructions.

When shipping the item(s), attach a tag with the following information:

- return number;
- name and location where the control is installed;
- name and phone number of contact person;
- complete Woodward part number(s) and serial number(s);
- description of the problem;
- instructions describing the desired type of repair.

## Packing a Control

Use the following materials when returning a complete control:

- protective caps on any connectors;
- antistatic protective bags on all electronic modules;
- packing materials that will not damage the surface of the unit;
- at least 100 mm (4 inches) of tightly packed, industry-approved packing material;
- a packing carton with double walls;
- a strong tape around the outside of the carton for increased strength.

### **NOTICE**

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

## Replacement Parts

When ordering replacement parts for controls, include the following information:

- the part number(s) (XXXX-XXXX) that is on the enclosure nameplate;
- the unit serial number, which is also on the nameplate.

## Engineering Services

Woodward's Full-Service Distributors offer various Engineering Services for our products. For these services, you can contact the Distributor by telephone or by email.

- Technical Support
- Product Training
- Field Service

**Technical Support** is available from your equipment system supplier, your local Full-Service Distributor, or from many of Woodward's worldwide locations, depending upon the product and application. This service can assist you with technical questions or problem solving during the normal business hours of the Woodward location you contact.

**Product Training** is available as standard classes at many Distributor locations. Customized classes are also available, which can be tailored to your needs and held at one of our Distributor locations or at your site. This training, conducted by experienced personnel, will assure that you will be able to maintain system reliability and availability.

**Field Service** engineering on-site support is available, depending on the product and location, from one of our Full-Service Distributors. The field engineers are experienced both on Woodward products as well as on much of the non-Woodward equipment with which our products interface.

For information on these services, please contact one of the Full-Service Distributors listed at [www.woodward.com/directory](http://www.woodward.com/directory).

## Contacting Woodward's Support Organization

For the name of your nearest Woodward Full-Service Distributor or service facility, please consult our worldwide directory at [www.woodward.com/directory](http://www.woodward.com/directory), which also contains the most current product support and contact information.

You can also contact the Woodward Customer Service Department at one of the following Woodward facilities to obtain the address and phone number of the nearest facility at which you can obtain information and service.

<b>Products Used in Electrical Power Systems</b>		<b>Products Used in Engine Systems</b>		<b>Products Used in Industrial Turbomachinery Systems</b>	
<b>Facility</b>	<b>Phone Number</b>	<b>Facility</b>	<b>Phone Number</b>	<b>Facility</b>	<b>Phone Number</b>
Brazil	+55 (19) 3708 4800	Brazil	+55 (19) 3708 4800	Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727	China	+86 (512) 6762 6727	China	+86 (512) 6762 6727
Germany:		Germany	+49 (711) 78954-510	India	+91 (129) 4097100
Kempen	+49 (0) 21 52 14 51	India	+91 (129) 4097100	Japan	+81 (43) 213-2191
Stuttgart	+49 (711) 78954-510	Japan	+81 (43) 213-2191	Korea	+82 (51) 636-7080
India	+91 (129) 4097100	Korea	+82 (51) 636-7080	The Netherlands	+31 (23) 5661111
Japan	+81 (43) 213-2191	The Netherlands	+31 (23) 5661111	Poland	+48 12 295 13 00
Korea	+82 (51) 636-7080	United States	+1 (970) 482-5811	United States	+1 (970) 482-5811
Poland	+48 12 295 13 00				
United States	+1 (970) 482-5811				

## Technical Assistance

If you need to contact technical assistance, you will need to provide the following information. Please write it down here before contacting the Engine OEM, the Packager, a Woodward Business Partner, or the Woodward factory:

### General

Your Name \_\_\_\_\_

Site Location \_\_\_\_\_

Phone Number \_\_\_\_\_

Fax Number \_\_\_\_\_

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### Prime Mover Information

Manufacturer \_\_\_\_\_

Engine Model Number \_\_\_\_\_

Number of Cylinders \_\_\_\_\_

Type of Fuel (gas, gaseous, diesel,  
dual-fuel, etc.) \_\_\_\_\_

Power Output Rating \_\_\_\_\_

Application (power generation, marine,  
etc.) \_\_\_\_\_

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### Control/Governor Information

#### Control/Governor #1

Woodward Part Number &amp; Rev. Letter \_\_\_\_\_

Control Description or Governor Type \_\_\_\_\_

Serial Number \_\_\_\_\_

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#### Control/Governor #2

Woodward Part Number &amp; Rev. Letter \_\_\_\_\_

Control Description or Governor Type \_\_\_\_\_

Serial Number \_\_\_\_\_

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#### Control/Governor #3

Woodward Part Number &amp; Rev. Letter \_\_\_\_\_

Control Description or Governor Type \_\_\_\_\_

Serial Number \_\_\_\_\_

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### Symptoms

Description \_\_\_\_\_

*If you have an electronic or programmable control, please have the adjustment setting positions or the menu settings written down and with you at the time of the call.*

## Appendix A.

# Acronyms/Abbreviations

A/F	air-to-fuel ratio
AUX	auxiliary
CRC	circular redundancy check
DFMEA	design failure modes and effects analysis
EEPROM	electrically-erasable programmable read-only memory
EMC	electro-magnetic compatibility
F-A or FAPC	Full Authority controller
F/A	fuel-to-air ratio
HEGO	heated exhaust gas oxygen sensor (stoichiometric)
GUI	graphic user interface
I/O	inputs/outputs
IGN	ignition signal
Isoch	isochronous
ITB	integrated throttle body
L-Series	Woodward electronic engine governor that contains both a rotary actuator and a controller circuit board
MPU	magnetic pick up
O <sub>2</sub>	oxygen sensor
OEM	original equipment manufacturer
POS or POSN	position
PWM	pulse-width modulated
rpm	revolutions per minute
RS-232	a communications standard
SPD	speed
TPS	throttle position sensor
UEGO	universal exhaust gas oxygen sensor (wide range)

## Appendix B.

# L-Series Controller Specifications

Power Supply	12/24 V systems (10–32 Vdc) reverse polarity protection, 2.5 A max
Power Consumption	32 W maximum
Torque	Nominal: 0.34 N·m (0.25 lb-ft) at 25 °C Maximum Transient (at 105 °C): 0.20 N·m (0.15 lb-ft) Minimum Continuous (at 105 °C): 0.14 N·m (0.10 lb-ft)
Mass/Weight	425 g (15 oz)
Power-Up to Operation Time	<250 ms
<b>Performance</b>	
Process Control Accuracy	±2% of full scale
<b>Environment</b>	
Ambient Operating Temperature	–40 to +105 °C (–40 to +221 °F)
Storage Temperature	–40 to +125 °C (–40 to +257 °F)
EMC	EN61000-6-2: Immunity for Industrial Environments EN61000-6-4: Emissions for Industrial Environments SAE J1113-21: Radiated Immunity (100 V/m) SAE J1113-11: Conducted Transient Immunity—Pulse 5b Suppressed Load Dump (45 V)
Humidity	US MIL-STD 810E, Method 507.3, Procedure III
Salt Spray	US MIL-STD 810E, Method 509.3, Procedure I
Shock	MS1-40G 11 ms sawtooth
Random Vibration	Random: 0.3 G <sup>2</sup> /Hz, 10–2000 Hz (22.1 Grms) 3 h/axis Sine: 5 G 2.5 mm peak-to-peak, 5–2000 Hz, 3 h/axis, 90 min dwells, 1 octave/min
Drop	SAE J1211, Paragraph 4.8.3 (modified)
Thermal Shock	SAE J1455, Paragraph 4.1.3.2
Ingress Protection	IP56 per EN60529

### Reliability and Quality Goals

The L-Series control system has a reliability target of 17 500 hours MTBF. It also has a quality goal of less than 25 PPM when measuring out-of-the-box defects. This quality goal is a target based on continuous improvement.

**AUX 1 Analog Input**

Parameter	Value
Input Type	0–5 V or 0–1.25 Vdc Input
Input Scaling	0 V = 0% and 5 V = 100% range in 0–5 V mode. 0 V = 0% and 1.25 V = 100% range in 0–1.25 V (HEGO) mode.
Max Input (Full Scale)	5 V $\pm$ 1% or 1.25 V $\pm$ 1%
Min Input	0.1 V $\pm$ 1% of Full Scale of Full Scale
Isolation	None
Transient Protection	According to EMC norm
Input Impedance	10 k $\Omega$ in 0–5 V mode 166 k $\Omega$ in HEGO mode
Anti-Aliasing Filter	1 anti-aliasing pole at 0.5 ms (338 Hz)
Resolution	10 bits
Accuracy	$\pm$ 1.6% of full scale over the temperature range of –40 to +125 °C, including drift
I/O Latency	6.5 ms
Calibration Method	2-point linear software calibration
Out of Range Signal	none
Overvoltage Protection	Input protected against 32 Vdc steady state

**AUX 2–4 Analog Input**

Parameter	Value
Input Type	0–5 V, Single-Ended Input
Input Scaling	0 V = 0% and 5 V = 100% range
Max Input (Full Scale)	5 V $\pm$ 1%
Min Input	0 V $\pm$ 1% of Full Scale
Isolation	None
Transient Protection	According to EMC norm
Input Impedance	499 k $\Omega$
Anti-Aliasing Filter/AUX 2	1 anti-aliasing pole at 0.5 ms (338 Hz)
Anti-Aliasing Filter/AUX 3–4	1 anti-aliasing pole at 0.001 ms (159 kHz)
Resolution	10 bits
Accuracy	$\pm$ 1.3% of full scale over the temperature range of –40 to +125 °C, including drift
I/O Latency	6.5 ms
Calibration Method	2-point linear software calibration
Out of Range Signal	none
Overvoltage Protection	Input protected against 32 Vdc steady state

**Discrete Input**

Parameter	Value
Aux 1 Input Current	0.5 mA @ 5 Vdc
Aux 2,3,4 Input Current	10 $\mu$ A @ 5 V
Aux 5 Input Current	10 $\mu$ A @ 5 V
Input Type	Ground referenced discrete input
Max Voltage from + Connection	32 V (power input voltage)
Isolation	None, Intended for use with external relay or other dry contact
Input Threshold (AUX 1)	> 3.1 Vdc = "ON"; < 0.8 Vdc = "OFF"
Input Thresholds (AUX 2-4)	> 2 Vdc = "ON"; < 0.8 Vdc = "OFF"
Input Thresholds (AUX 5)	> 2.737 Vdc = "ON"; < 2.263 Vdc = "OFF"
Input Impedance (AUX 1)	10 k $\Omega$
Input Impedance (AUX 2-4)	499 k $\Omega$
Input Impedance (AUX 5)	499 k $\Omega$

**Discrete Output**

Parameter	Value
Output Type	Low-side output driver
Max Contact Voltage (Open)	32 V
Max Current	0.5 A
Max Contact Voltage at 0.5 A (Closed)	1.5 V
Max Delay Time for Opening Contact	6.5 ms
Default at Power Up	Configurable in software
Error Condition	Configurable in software
OK Condition	Configurable in software
Driving Inductive Loads	Yes, internally protected low-side switch
Protection	Utilizes circuitry that will open the contact when output contacts are short-circuited. Self-resetting when fault is removed

**TPS Output**

Parameter	Value
Output Type	0.75–4.25 V, single-ended
Output Scaling	0.75 V = full CCW position and 4.25 V = full CW position
Isolation	None
3 db Circuit Bandwidth	350 Hz
Transient Protection	According to EMC norm
Output Impedance	2.8 k $\Omega$ ( $\pm 1\%$ )
Accuracy	$\pm 10\%$ of full scale, @ 25 °C
Temperature Drift	$\pm 0.4\%$ over the full temperature range
I/O Latency	n/a—direct from position sensor
Calibration Method	Sensor-in-place factory calibration. 2-point linear
Out of Range Signal	< 0.25 V or > 4.75 V
Overvoltage Protection	Output protected against 32 Vdc, steady-state; if >28 V is applied to pin 2, a position-related error will be annunciated

**RS-232 Serial Communication Service Port**

Parameter	Value
Isolation	None
Baud Rate	Fixed 19.2 Kbaud
Electrical Interface	Outputs are TTL level. Requires external transceiver for conversion to RS-232 levels for proper communication !!
Pinout	Tx = pin 4, Rx = pin 6, Gnd = pin 3
Maximum Cable Length	10 m (33 ft), not meant for permanent connection (for service only)
Cable Type	Straight-through (no crossover)

**Electronics Temperature Sensor**

Parameter	Value
Accuracy	$\pm 2$ °C at 25 °C ambient $\pm 3$ °C over full range (–40 to +125 °C)
I/O Latency	6.5ms

Software Execution Rates

Software Routine	Nominal Software Execution Rate
Position Control Algorithms	1.6 ms
Process Input & Control Algorithms	6.5 ms
Trim Input & Control Algorithms	26 ms
Bias	6.5 ms
Analog Input Logic	6.5 ms
Serial Port	background task
Discrete Inputs	6.5 ms
Discrete Output	6.5 ms
Diagnostics	6.5 ms

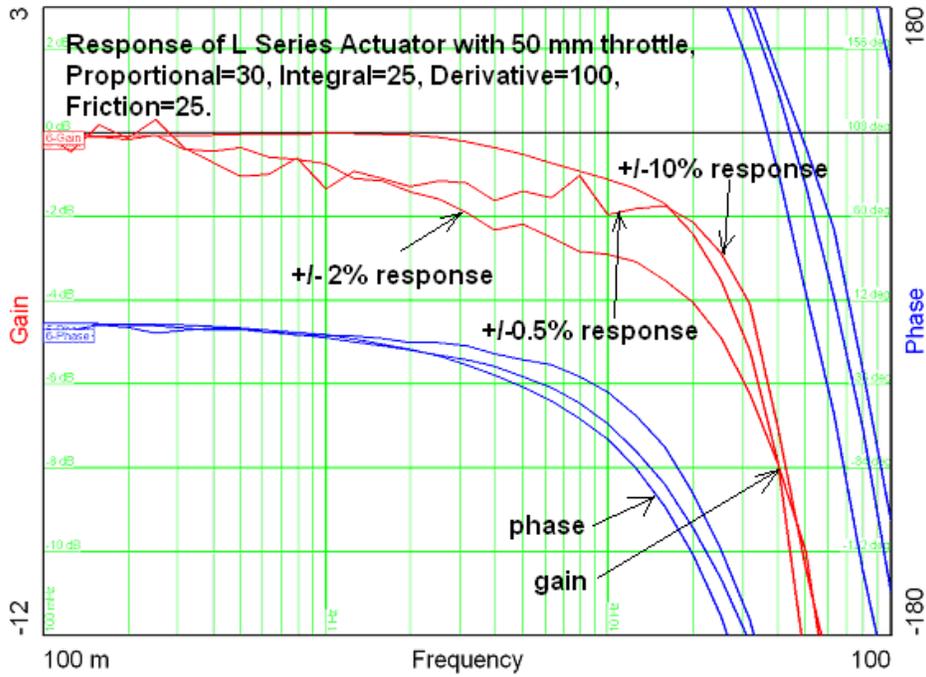


Figure B-1. Bode Plot of L-Series Response

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## Revision History

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**Changes in Revision K—**

- Added equation, table, and chart for the Cv vs. Angle for the L-Series Trim Valve (Chapter 1)

# Declarations

## DECLARATION OF CONFORMITY

According to EN 45014

**Manufacturer's Name:** WOODWARD GOVERNOR COMPANY (WGC)  
Industrial Controls Group

**Manufacturer's Address:** 1000 E. Drake Rd.  
Fort Collins, CO, USA, 80525

**Model Name(s)/Number(s):** L-Series  
8404-xxxx and similar

**Conformance to Directive(s):** 89/336/EEC COUNCIL DIRECTIVE of 03 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility and all applicable amendments.

**Units marked and conforming to ATEX conform to Directive:** 94/9/EC COUNCIL DIRECTIVE of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres

**Markings on units conforming to ATEX:** II 3 G, EEx nA II T3X, IP56

**Applicable Standards:** EN61000-6-4, (2001): EMC Part 6-4: Generic Standards - Emissions for Industrial Environments  
EN61000-6-2, (2001): EMC Part 6-2: Generic Standards - Immunity for Industrial Environments  
EN60079-15, (2003) Electrical apparatus for explosive gas atmospheres – Part 15: Type of protection 'n'

We, the undersigned, hereby declare that the equipment specified above conforms to the above Directive(s).

### MANUFACTURER

Signature



Dan Gear

Full Name

Engineering Manager

Position

WGC, Fort Collins, CO, USA

Place

Date

2/17/06

# Declaration of Incorporation

Woodward Governor Company  
1000 E. Drake Road  
Fort Collins, Colorado 80525  
United States of America

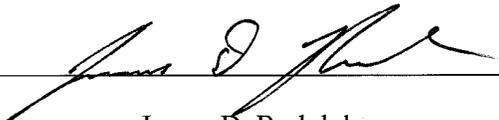
**Product: L-Series Actuator**  
**Part Number: 6300-1005 and similar**

The undersigned hereby declares, on behalf of Woodward Governor Company of Loveland and Fort Collins, Colorado, that the above-referenced product is in conformity with the following EU Directives as they apply to a component:

**98/37/EEC (Machinery)**

This product is intended to be put into service only upon incorporation into an apparatus/system that itself will meet the requirements of the above Directives and bears the CE mark.

## MANUFACTURER

Signature	
Full Name	James D. Rudolph
Position	Engineering Manager
Place	WGC, Fort Collins, CO, USA
Date	11/13/07

We appreciate your comments about the content of our publications.

Send comments to: [icinfo@woodward.com](mailto:icinfo@woodward.com)

Please reference publication **26251K**.



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as well as authorized distributors and other authorized service and sales facilities throughout the world.

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