WOODWARD

OEM/Dealer Manual

LCS ITB
LC-50

Installation, Programming, & Troubleshooting

Manual 26135 (Revision F)

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

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.

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.

This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, be sure to check the Woodward website:
www.woodward.com/pubs/current.pdf
The revision level is shown at the bottom of the front cover after the publication number. The latest version of most publications is available at:
www.woodward.com/publications
If your publication is not there, please contact your customer service representative to get the latest copy.

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.

NOTICE

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.

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*.

Revisions—Text changes are indicated by a black line alongside the text.

Contents

Illustrations and Tables

Chapter 1.
General Information

Purpose and Scope

The purpose of this manual is to provide OEMs with the necessary background information for applying the LCS ITB and LC-50 control to gas/gasoline reciprocating engines. Topics covered include mechanical installation, electrical wiring, software programming, 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.

Intended Applications

The LCS ITB and LC-50 controls are designed primarily for various industrial applications, including but not limited to generator sets, welders, portable refrigeration units, irrigation pumps, chipper shredders, and mobile industrial gas or gasoline reciprocating engines. Key environmental characteristics of these applications include industrial operating temperatures (–40 to +85 °C/–40 to +185 °F), European CE EMC requirements (10 V/m), minimal electrical transients (2 J load dump), and lower operating voltages (12 V) (must be fed from a Class 2 power source).

Introduction

The LCS ITB and LC-50 provide a building block approach to total engine management. The modular designs consist of a die-cast aluminum throttle body, a mixer, and a fully programmable integrated digital speed control and bi-directional actuator. The LCS ITB incorporates the Woodward LCS speed control with a throttle plate. The LC-50 adds a venturi style annular ring mixer to the LCS ITB. The units provide a number of speed setting, speed biasing, control, fuel limiting, diagnostic, and datalink functions. The controller is available in two versions, one for generator applications (G version) and one for industrial applications (I version).

A simplified block diagram of the control's functionality is shown in Figure 1-1. In most applications, the OEM will enable at least one function from each category of functions to create a valid control configuration. The functionality and characteristics of the control can be tailored using a laptop computer loaded with the Woodward Service Tool software.

The functions available are briefly described below. Chapter 2 contains a detailed description of each function and feature.

Speed setting functions include:
- Single speed select—Sets the speed set point to a single initial speed when power is first applied
- 50/60 Hz select—Selects between two speed set points when power is first applied to the governor (G version only)
- Idle/rated select—Selects, ramps, and delays between two speed set points while the engine is running
- Three-speed select—Selects and ramps between three speed set points while the engine is running (I version only)
- Raise/lower adjust—Ramps between two speed limits based on signal inputs while the engine is running (G version only)

Speed biasing functions include:
- Isochronous—Does not bias the current speed set point in any way
- Droop—Biases the current speed set point by a negative percentage based on actuator position (G version only)
- Aux biasing—Biases the current speed set point by a percentage based on an analog input voltage
- Isoch/droop select—Selects between isochronous and droop operation when power is first applied (G version only)
- Aux bias/droop select—Selects between aux biasing and droop operation when power is first applied (G version only)
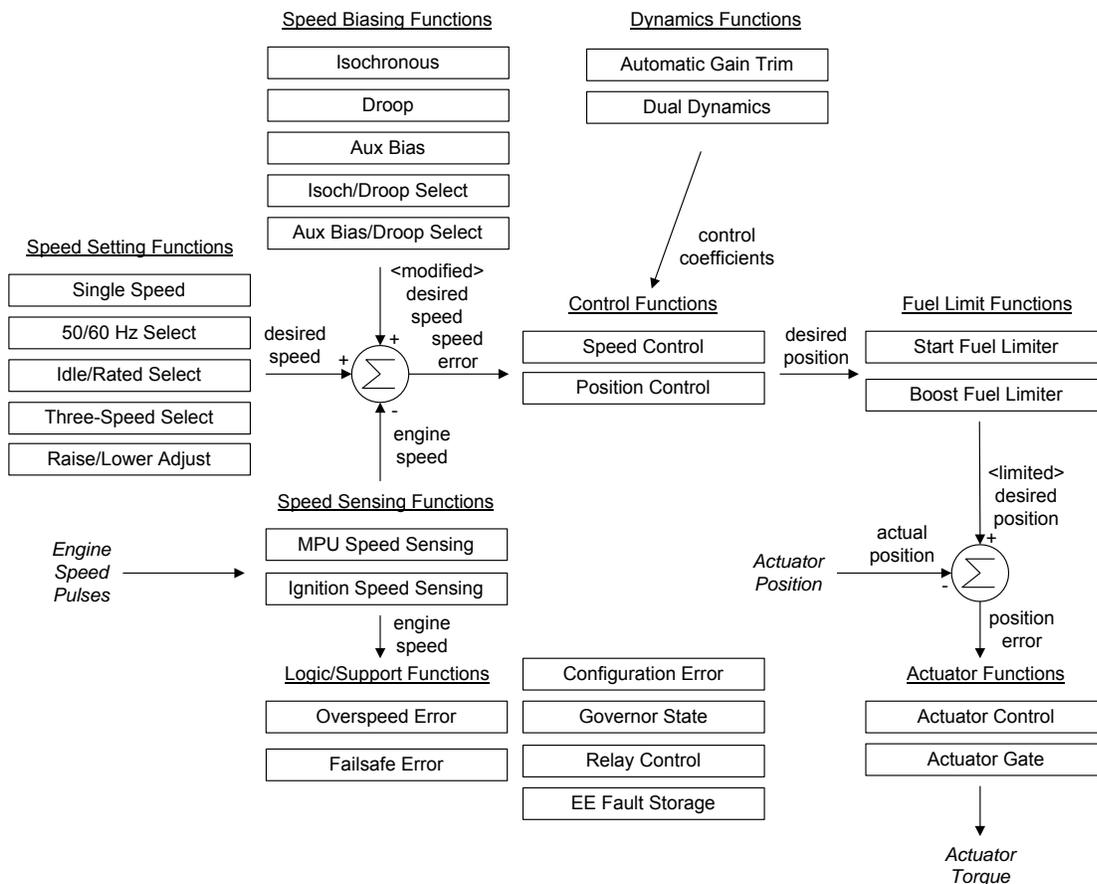
Figure 1-1. Block Diagram of LCS Integrated Speed Control

Speed sensing functions include:
- MPU speed sensing—Converts flywheel or gear speed pulses into engine speed in rpm
- Ignition speed sensing—Converts ignition coil fly back pulses into engine speed in rpm

Control functions include:
- Speed control—Commands a desired actuator position based on the set point versus engine speed error
- Position control—Commands a desired actuator position based on an analog input voltage

Dynamics functions include:
- Dual dynamics select—Selects between two sets of speed control coefficients while the engine is running
- Automatic gain trim—Monitors engine performance and trims speed control gain settings based on programmable criteria

Fuel limiter functions include:
- Start fuel limiter—Limits the desired actuator position during engine cranking and initial acceleration
- Boost fuel limiter—Limits the desired actuator position based on an analog voltage from a MAP sensor (G version only)

Actuator control functions include:
- Actuator control—Commands an actuator torque based on the desired versus actual actuator position
- Actuator gate—Overrides the actuator control during power up or error conditions

Logic and support functions include:
- Overspeed error—Detects when the actual engine speed exceeds a threshold
- Failsafe error—Detects a loss of the speed signal input
- Configuration error—Detects when a configuration has not been downloaded into the control
- Relay control—Controls the relay output driver during error conditions
- Fault storage—Stores a fault code in EEPROM whenever an error condition has occurred
- Governor state—Tracks the state of the engine (off, crank, start, run, or error) based on error detection functions and actual engine speed

Service Tool Software

Because the LCS ITB and LC-50 are digital control systems with no externally accessible adjustments, a suite of companion software tools is available to help the OEM with every phase of application development, manufacturing, and field service. The LCS ITB and LC-50 Service Tool Software is a Microsoft Windows based GUI (graphic user interface). The Service Tool Software is compatible with Windows 95/98/NT/00 and gives the OEM the ability to:

- Tune the control with the engine running during application development
- Create configuration files for downloading into multiple controls
- Download configuration files during the manufacturing process
- Extract and view fault codes for field diagnosis
- Update control dynamics during field service

One distribution of the software service tool is available from Woodward (software part number 9927-1000). This part number defaults to the dealer distribution—tools need for field support only. The OEM distribution—tools for development, manufacturing, and field support—is available by obtaining a license (part number 8928-5002). Detailed descriptions of software installation are available in Chapter 4.

Chapter 2.
System Description /
Application Overview

System Operation

The LCS ITB and LC-50 controls are ready for operation immediately (within 0.25 second) when the power supply is connected. Power may be connected to the control at the same time the engine starter motor is engaged. Upon starting, the engine will immediately go to the speed value determined by the features that have been enabled by the Configuration Table. The actuator will drive the throttle to maintain adequate steady state and transient speed control performance.

Upon an engine shutdown command, the engine shutdown solenoid or solenoid valve in the gas fuel supply should be de-activated and the power supply disconnected from the speed control. The signal to this solenoid should be sent directly from the engine control panel and should be independent of the LCS ITB or LC-50 control.

Overview of Control Application Process

Figure 2-1 shows the typical application process used with the LCS ITB and LC-50 control. There are essentially three phases of application—development, production, and field support.

During the development phase, the OEM's engineers create a specification that calls out the features, functions, and desired performance of the final application. Then various online data gathering exercises are performed to collect critical dynamics, load, and position data from the governor. This data, along with pre-determined parameter enable, is put into an application configuration file, and the file is downloaded into a sample set of prototype assemblies. Various application tests are carried out to check the robustness of the empirical data prior to releasing it for production. The empirical data obtained to this point is specific to a given engine/driven load combination. Once, known, all other parameters can be set up in an office environment using the GUI tools.
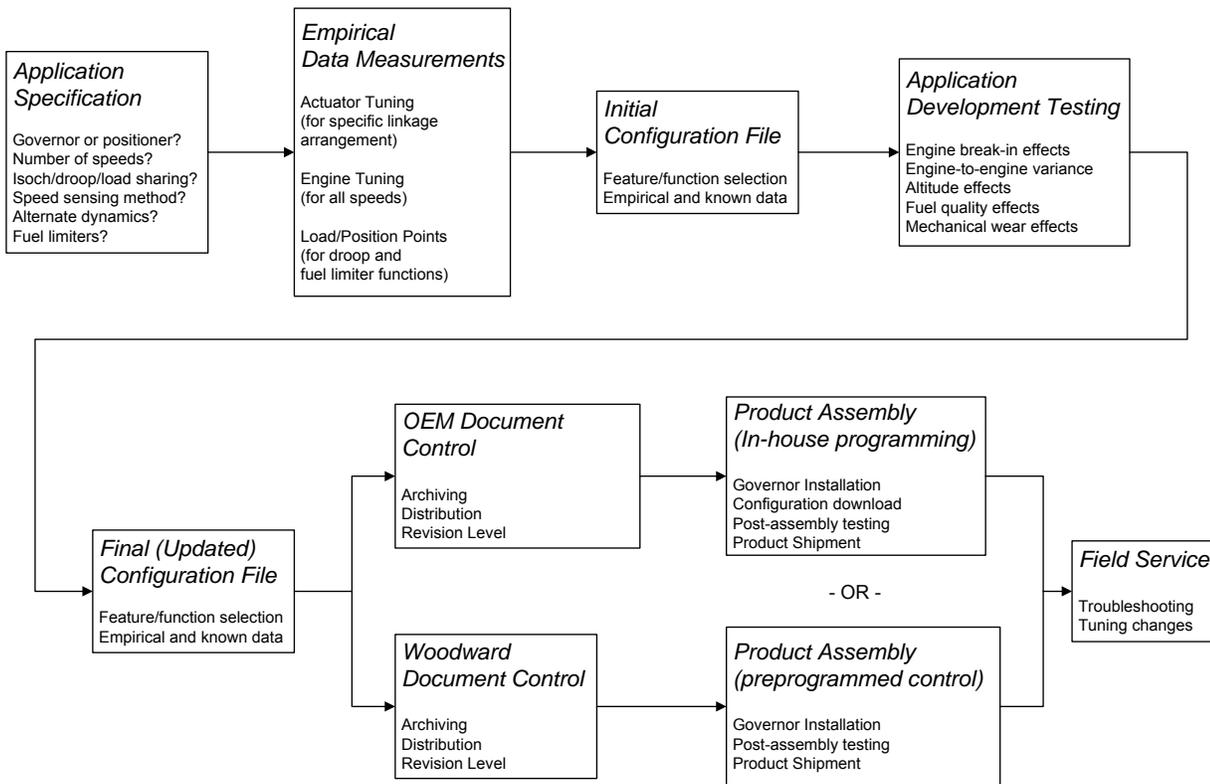
Figure 2-1. Typical Governor Application Process

The OEM can choose either to download configuration files at the OEM's facility, or to purchase pre-programmed governors from Woodward. If the choice is to download the configuration files at the OEM's facility, the OEM is responsible for all aspects of controlling the data. If the choice is to purchase a pre-programmed control, Woodward has responsibility for controlling the data in its document control system, and the OEM will be responsible for communicating software modifications to Woodward.

After the application is assembled, it is tested, shipped, and installed at its final destination. If any additional field service is required, a dealer network uses the dealer distribution of the tool set to check fault codes or update dynamics settings.

Hardware Configuration Application Process

The first step is to choose the appropriate hardware for the application. An ITB, a mixer, and a version of the actuator must be selected. The ITBs and mixers come in five different sizes.

For both the LCS ITB and LC-50, the user must choose the appropriately sized ITB for the application. The chart below illustrates how to choose the proper size. The intersection of the operating rpm and the engine displacement will fall in a specific ITB band. For example, a 4.0 L engine that will run at 2000 rpm, would need a 43 mm ITB, as that point falls between the two lines for the 43 mm (square marker lines.)

If the application will have multiple speed set points, some judgment needs to be used to appropriately size the throttle. In general, the highest speed where the engine will spend any significant percentage of its time, or the highest speed where efficiency (or power) is important, should be used for sizing.
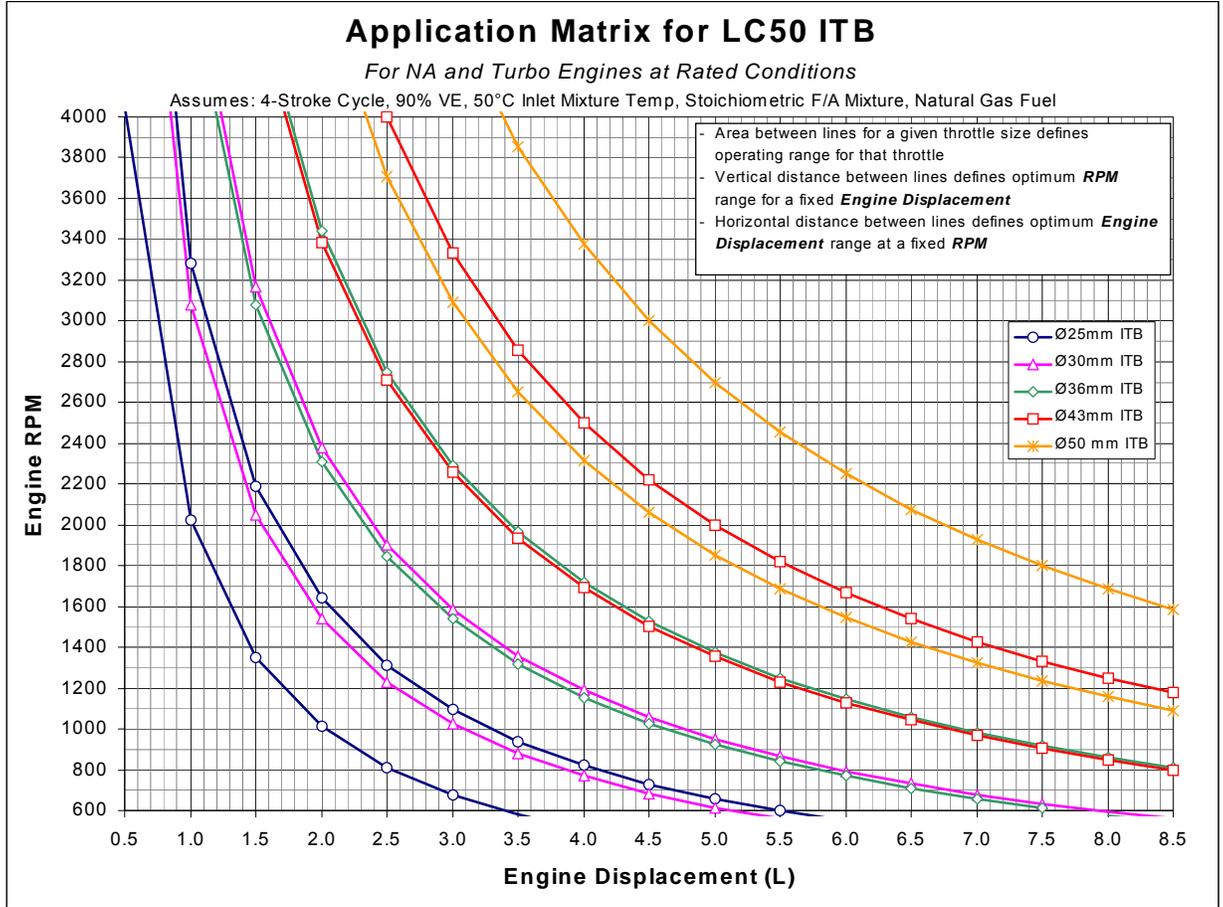
Figure 2-2. Application Matrix

If the application is an LC-50 product, there are appropriately sized mixers for each throttle size. A complete gaseous fuel delivery system requires:
- a fixed main adjustment screw (MAS) or closed-loop trim valve
- a zero-pressure regulator (ZPR)
- a fuel shut-off valve

The mixer supplied with the LC-50 is a venturi style mixer. By locally increasing the air speed in a pipe, the static pressure at the location of the restriction will be lower than the pressure before this restriction. When a number of orifices are made in the circumference of the venturi, the medium to be mixed (natural gas) will be drawn into the venturi throat. If the pressure of the gas is kept equal to the pressure before the venturi, the gas will be mixed with the air in a constant ratio. The pressure is kept equal to the air pressure directly before the mixer, by means of a zero pressure regulator and a compensation line. The venturi mixer is maintenance free.

A main adjustment screw or closed-loop trim valve is provided to adjust the required air/fuel ratio by means of an adjustable restriction in the fuel line between the zero pressure regulator and the venturi mixer.

The compensation line ensures that the gas pressure is kept equal to the air pressure before the venturi mixer. When no compensation line is used, the outlet pressure of the ZPR will not be balanced as the air filter becomes dirty. As the air filter gets dirty, there is an increased pressure drop after the air filter, and the air/fuel ratio will become richer.

Controller Selection

Once the ITB and mixer have been selected, an actuator/controller version must be chosen. The LCS control has an electrical connector with a 12 pin Deutsch DT configuration (reference DT04-12PA) integrally molded into its housing. Seven pins are assigned to specific functions and cannot be changed. The OEM can define the remaining five pins through the Configuration File. There is a limited amount of flexibility to provide analog input, discrete input, or output functionality. The features available are described in detail on the following pages.

The tables below show the possible assignments for each auxiliary-based function in the control. An X indicates that a particular auxiliary is always used when the function is enabled. A P or an A for a specific function denotes a primary or alternate auxiliary input assignment for the function. This P and A arrangement is intended to maximize flexibility in the feature set.

Generator Version

Function	Aux 1 Pins 8 & 5	Aux 2 Pin 10	Aux 3 Pin 4	Aux 4 Pin 6
Isochronous Load Sharing	X			
Remote Speed Setting	X			
MAP Fuel Limiting	X			
50/60 Hz Select	A			P
Lower Speed		X		
Raise Speed			X	
Isoch Speed Ctrl/Droop Select		A		P
Aux Bias / Droop Select	X	A		P
Dual Dynamics Select			A	P
Idle/Rated Select		X		

Industrial Version

Function	Aux 1 Pins 8 & 5	Aux 2 Pin 10	Aux 3 Pin 4	Aux 4 Pin 6
Isochronous Load Sharing	X			
Remote Speed Setting	X			
Dual Dynamics Select			A	P
Idle/Rated Select		X		
Three Speed Select		X	X	X

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 will at a minimum pick one feature from each of the following areas: speed setting, speed biasing, speed sensing, and control functions. From the dynamics functions area the user can set as many or as few as is necessary for stable operation. The user can choose all or none of the fuel limiter functions, actuator control functions, and logic functions depending on the application.

SPEED SETTING
Single Speed Select—This is the default setting for the controller. If no other features are enabled, the engine will run at one set speed.

50/60 Hz Select (G version only)—This feature allows the user to switch the speed set point between a primary and secondary engine rated speed. A discrete input is used to toggle between the two set speeds. The user can define whether this input comes into AUX1 or AUX4. When the engine is started with the input at the low state (ground), the controller controls to the primary speed setting and uses dynamics for the primary speed. When the engine is started with the pin in the high state (12V), the controller will run at the secondary speed setting with the corresponding second speed dynamics. Any state changes on the AUX pin will be ignored once the engine is running. The state is determined only when power is first applied to the governor.

Related configuration file parameters: 50/60 Hz select, 50/60 Hz Aux, speed 1, speed 2, and primary dynamics for both speeds

Idle/Rated Select (G version only)—This feature allows the user to toggle the speed set point between an idle and a rated speed. The toggle is accomplished through an input into AUX2. When the AUX pin is in its low state, the engine runs at idle speed with the primary set of dynamics. When the AUX pin is in the high state, the engine runs at the higher rated speed with the corresponding dynamics. The user can toggle between the two speed settings at any time during operation. Transition rates between the two speeds can be controlled at a user defined ramp rate if desired. If the user defined ramp rate is 0, the new set speed is instantly engaged. When the AUX pin transitions from high to low (rated to idle), a programmable time delay is executed before the desired speed is ramped from rated to idle. For example in welder applications it may be desirable to have a time delay before decelerating from rated to idle (to allow some time to change the welding rod).

Related configuration file parameters: idle/rated select, rated to idle delay, speed 1, speed 2, primary dynamics for both speeds, speed decrease rate, speed increase rate

Three-Speed Select (I version only)—Some refrigeration applications may find it useful to have three engine speeds available: a highest speed for quick cool down when warm goods are put into a container, a lowest speed to maintain the load's temperature once it has been cooled, and an intermediate speed for increased cooling if the container door is opened to move goods in or out. Typically, the discrete inputs for each of these speeds will come from an automatic thermostat, and only one will be high at a time. Mobile access platform (scissor lift) applications may also require three engine speeds, which correspond to three basic operating modes: static lift, transient lift, and mobile vehicle travel.

AUX2, AUX3, and AUX4 are used to select between three speeds. If none of the inputs are tied to +12 V, the current speed and control dynamics are used by the Speed Control function. If AUX2 is tied to +12 V, the desired speed is speed 1 with the corresponding gain dynamics. If AUX3 is high, the desired speed is speed 2 with the corresponding gain dynamics. If AUX4 is tied to +12V, the desired speed is speed 3 with the third set of gain dynamics. Transition rates between the three speeds can be controlled at a user defined ramp rate if desired. Any ramp rate set at 0 causes the desired speed to be set to the speed reference instantly. AUX2, AUX3, and AUX4 must be associated with the lowest, middle, and highest engine speeds, respectively. If more than one AUX input is tied to +12 V, the lower of the two speeds is selected.

Related configuration file parameters: 3 speed select, speed 1, speed 2, speed 3, primary dynamics for all speeds, speed decrease rate, speed increase rate

Raise/Lower Adjust (G version only)—This feature allows the user to change the speed set point with external discrete inputs.

Related configuration file parameters: raise / lower speed, speed decrease rate, speed increase rate, speed adj lower limit, speed adj upper limit

Lower—This AUX2 discrete input acts directly on the internal speed set point within the LCS ITB and LC-50, and will progressively decrease the speed set point down to a programmable lower limit at a programmable rate for as long as the input is in a high state. When this input goes low, the speed reference will remain fixed at the last setting reached the instant the input went low.

Raise—This AUX3 discrete input acts directly upon the internal speed set point within the LCS ITB and LC-50, and will progressively increase the speed reference up to a programmable upper limit at a programmable rate for as long as the input is in a high state. When this input goes low, the speed reference will remain fixed at the last setting reached the instant the input went low.

SPEED BIASING
Isochronous—This is the default speed biasing function if none of the other speed biasing functions are selected. This maintains the engine at one speed setting throughout operation regardless of load.

Droop—This feature allows for a change in speed set point with a change in load. This feature is primarily used when the generator is connected to a utility bus or paralleled with another genset on an isolated bus. In this situation, the utility will determine the frequency of the alternator. Should the governor speed reference be less than the utility frequency, power in the utility bus will flow to the alternator and motor the unit. If the governor speed is even fractionally higher than the frequency of the utility, the governor will go to full load in an attempt to increase the bus speed. Since the definition of a utility is a frequency that is too strong to influence, the engine will remain at full fuel.

Isochronous governor control is impractical when paralleling with a utility because a speed setting above utility frequency, by however small an amount, would call for full fuel since the actual speed could not reach the reference speed. Similarly, if the setting were even slightly below actual speed, the fuel would go to fuel off position.

Droop provides one solution to this problem. Droop causes the governor speed reference to decrease as load increases. An actuator position feedback device is employed within the LCS ITB and LC-50 to monitor actuator position. Setting Droop to 0% means the control will provide isochronous operation. The desired engine speed reduces with the following formula:

$$\frac{\text{speed reference} * \text{droop percentage} * (\text{actual position} - \text{no load actuator position})}{(\text{full load actuator position} - \text{no load actuator position})}$$

The speed offset calculation requires valid information in the droop percentage, no load actuator position, and full load actuator position parameters.

Related configuration file parameters: constant droop, droop percentage, no load act pos, full load act pos

Aux Biasing (Isochronous Load Sharing)—This feature allows the user to alter the speed set point with an external signal. This input comes into AUX1, and is programmable as either a 0–5 V input or ±3V input. This function modifies the desired engine speed with the following formula:

speed reference * bias percentage * offset AUX1 input voltage

The bias percentage is a programmable value up to approximately ±7%. When AUX1 is configured as a 0–5 V input, 5 V corresponds to the full bias percentage in a positive direction; 0 V corresponds to the full bias percentage in a negative direction; and 2.5 V corresponds to no bias. This analog input should be provided by a voltage transmitter via twisted, shielded wire pairs.

When AUX1 is configured as a ±3 V input, +3 V corresponds to the full bias percentage in a positive direction; –3 V corresponds to the full bias percentage in a negative direction. This analog input will be available to interface with Woodward's standard Load Sharing Module. This auxiliary input acts directly on the LCS ITB and LC-50 speed reference and biases it by a programmable amount up to approximately ±7% in direct proportion to the ±3.0 Vdc signal. This input will be active only when the LCS ITB and LC-50 is selected for isochronous operation and should be provided via twisted, shielded wire pairs.

Isochronous Speed Control/Droop Select—This discrete input toggles between the Isochronous and Droop features. The function looks at the state of AUX4 or AUX2 (user-defined) at power up, as well as the state of the input as defined by the user. The state of this AUX input is evaluated when power is first applied. Any state changes after the engine is running are ignored.

The user can program the aux input state that enables droop. This is done by programming droop polarity to aux high (12 V) or aux low (ground). For example, if droop polarity is programmed to aux high, then droop will be active when the aux pin is in the high state.

Related configuration file parameters: aux bias, bias percentage, aux 1 type, aux 1 level

Aux Bias/Droop Select—This discrete input toggles between auxiliary biasing (also known as isochronous load sharing) and droop. The function looks at the state of AUX4 or AUX2 (user-defined) at power up, as well as the state of the input as defined by the user.

The user can program the aux input state that enables droop. This is done by programming droop polarity to aux high (12 V) or aux low (ground). For example, if droop polarity is programmed to aux high, then droop will be active when the aux pin is in the high state.

Related configuration file parameters: aux bias / droop select, droop percentage, aux biasing percentage, no load act pos, full load act pos, droop polarity, droop aux, aux 1 type, aux 1 level

SPEED SENSING
Magnetic Pickup (MPU)—The MPU input has been designed for variable reluctance speed sensors and not Hall-effect devices. The frequency range of the MPU input is: 100 Hz to 12 000 Hz (designed to accept at least 14 000 Hz to provide a margin of safety). The required minimum peak-to-peak voltage is 2 V @ 100 Hz and 25 V @ 12 kHz.

This function expects engine speed pulses present on pins 11 (MPU+) and 3 (MPU–). The number of flywheel or gear teeth that pass the magnetic pickup for one crankshaft revolution must be programmed into events per engine rev in the configuration file.

Related configuration file parameters: mpu, flywheel teeth

Ignition—The LCS ITB and LC-50 control will accommodate a 2–333 Hz signal from an ignition input for 1, 2, 3, 4, 5, 6, and 8 cylinder engines with speed set points between 1200 and 3600 rpm. The LCS ITB and LC-50 controls can accommodate 2- and 4-cycle engines. For standard coil ignition, the source may be the negative terminal of the coil primary. For distributorless or DIS (Direct Ignition System) systems, the source for the ignition pulses may be two ignition leads from the spark controller connected to MPU+ (pin 11) and MPU– (pin 3). Take care not to reverse MPU+/– on a DIS system, or no speed will be sensed.

This function requires engine speed pulses present on pin 12 (IGN) of the control. The type of engine (2-stroke or 4-stroke) and the number of cylinders (1 to 8) must also be programmed in this parameter byte.

Related configuration file parameters: ignition, cylinders count, strokes

CONTROL FUNCTIONS
Speed Control—This function is the governor function. It calculates the difference between the desired speed and the actual measured engine speed, and adjusts the desired actuator position as a result. Speed setting functions and alternate dynamics functions are responsible for selecting the active speed set point and set of dynamics for this function. The user must choose either this function or the position control function. They cannot both be enabled.

Position Control—Commands a desired actuator position based on an analog input voltage. This function requires AUX1 is configured as a 0–5 V analog input. This function also requires that the Actuator Control and Actuator Gate functions are turned on. This function does not require the Governor State function to be enabled. The Position Control function essentially overrides the Governor State function and translates a 0–5 V input into a desired position for the Actuator Control function.

IMPORTANT	The accuracy of the internal LCS position sensor is nominally ±10% of full travel, and under some conditions can be ±20% of full travel. If you are not using the full stroke of the actuator, this will magnify the existing error of the LCS position sensor. Position-based features need to be used cautiously and calibrated carefully. In summary, if you need better than ±10 degrees of accuracy for position-based features, mechanical alternatives should be considered.

Related configuration file parameters: position control, aux 1 type, aux 1 level

DYNAMICS FUNCTIONS
A variety of dynamics or gains are available for tuning the engine and throttle response. The user can use as few or as many as desired. The response of the throttle blade, or position control, is controlled by PID (proportional, integral, and derivative) control terms. The speed control of the engine is controlled by reset, gain, and compensation terms. Multiple sets of speed control dynamics parameters are available for each engine speed. For the generator version, four distinct sets of dynamics are available. The industrial version of the software has 6 sets of dynamics available.

Three-Point Gain Curve—The engine speed control gain is set up as a three-point gain curve versus position to adjust for linearity of the throttle body and engine response. For example, at low throttle positions a small change in throttle angle can cause a large kW change, while at high throttle positions it can take a large change in throttle angle to produce a relatively small change in kW out. The three-point gain curve corrects for this characteristic. The position breakpoints are common for all speeds and dynamics. Typical values are

Gain 1	25
Gain 2	40
Gain 3	100
Gain Position 1	25
Gain Position 2	30
Gain Position 3	40

Related configuration file parameters: gain 1, gain 2 and gain 3 for primary and alternate dynamics as required, gpos 1, gpos 2, gpos 3

Dual Dynamics—This feature allows for toggling between two sets of user-defined dynamics or gains. The two sets of gains are referred to as the primary and alternate dynamics. This feature is mainly used for dual fuel engine applications where engine response can change from operation on one gaseous fuel to another. This feature may also be used for generator sets to allow different dynamics for standalone and parallel operation. When this input is low, the primary set of dynamics is used. When this input goes high, the dynamic set points will immediately change to alternate dynamics and remain there until the input is returned to the low state. When this feature is active, the LCS ITB and LC-50 react to state changes at the user defined AUX3 or AUX4 while the engine is running. Primary and alternate dynamics exist for each speed setting.

Related configuration file parameters: alternate reset and gains for each speed being used

Automatic Gain Trim—To correct for engine power variation and its effect on governor performance, the LCS includes an automatic gain adjustment function that trims the gain of the controller based on steady-state and transient engine speed performance measurements. Based on performance criteria programmed into the LCS and the stability or load transient performance of the engine, the function will increase or decrease the currently active gain setting. This function can be used to combat the effects of engine break-in, engine-to-engine variance, altitude, temperature, and fuel quality. This function is not intended to mask serious engine faults, like broken spark plugs, large vacuum leaks, or other such failures. The automatic gain adjustment function can be disabled.

This function continuously monitors the speed of the engine relative to the currently active speed reference. If this function observes a steady-state speed band that exceeds a programmable set point, then the currently active gain parameter is decremented by a programmable amount until a programmable minimum gain setting is reached. If this function observes a transient offspeed that exceeds a programmable set point, then the currently active gain parameter is incremented by a programmable amount until a programmable maximum gain setting is reached.

Related configuration file parameters: gain decrement, gain increment, minimum gain, maximum gain, steady state, transient

The auto gain feature requires significant testing to configure properly. For details on how to complete this testing, please contact Woodward.

IMPORTANT	Enabling the auto gain feature without performing the proper testing can cause engine instability.

FUEL LIMITER FUNCTIONS

IMPORTANT	The accuracy of the internal LCS position sensor is nominally ±10% of full travel, and under some conditions can be ±20% of full travel. Position-based features need to be used cautiously and calibrated carefully.

Start Fuel Limiter—A Start Fuel Limiter feature is included within the LCS control. It sets the throttle valve partially open during cranking and while the engine is accelerating to its desired speed set point in order to minimize overshoot of the speed set point. The action of this start fuel limiter is as follows:

When power is applied to the LCS system, its actuator remains in the minimum fuel position until the starter is engaged and actual engine speed exceeds a user defined start speed threshold. As soon as the engine speed exceeds this threshold, the actuator will position at the start fuel limit. The engine continues to accelerate. When the actual engine speed exceeds the user defined run speed threshold, the start fuel limit is removed, the governor is free to use the entire position range, and the failsafe and overspeed limiters are activated. The run speed threshold is typically 75% to 90% of the minimum desired operating speed.

The Start Fuel Limiting function is automatically reset whenever power is removed from the LCS control. The Start Fuel Limit feature can be disabled in the Configuration Table so that the feature is not used.

Related configuration file parameters: start fuel limiter, start spd thresh, start fuel limit

Boost Fuel Limiter (MAP fuel limiting)—This analog input should come from a manifold air pressure (MAP) or turbo boost pressure transducer so that the fuel delivered to the engine can be limited as a function of pressure. A two-slope Fuel Limit vs. Transducer Voltage (air pressure) curve—having three definable points—can be programmed into the Configuration Table to provide the desired fuel limit functionality. Note that the transducer should be powered from the LCS control to avoid a ratiometric calibration issue that would affect the accuracy of this function. Pressure transducers can be obtained from Woodward.

This feature can be useful when using a non-wastegated turbo to avoid overloading the engine. As the MAP reaches an overboost condition, the LCS will close the throttle down as indicated in the figure. A MAP sensor can be more economical than a waste-gated turbo; however, a wastegated turbo may spool up faster.

Related configuration file parameters: boost fuel limiter, boost pressure 1-3, boost fuel limit 1-3

Max boost and steady-state throttle position at max transient overload (110% load).

Throttle closes completely at any higher boost or overload.

Throttle is allowed to open completely up to max boost at 100% load.
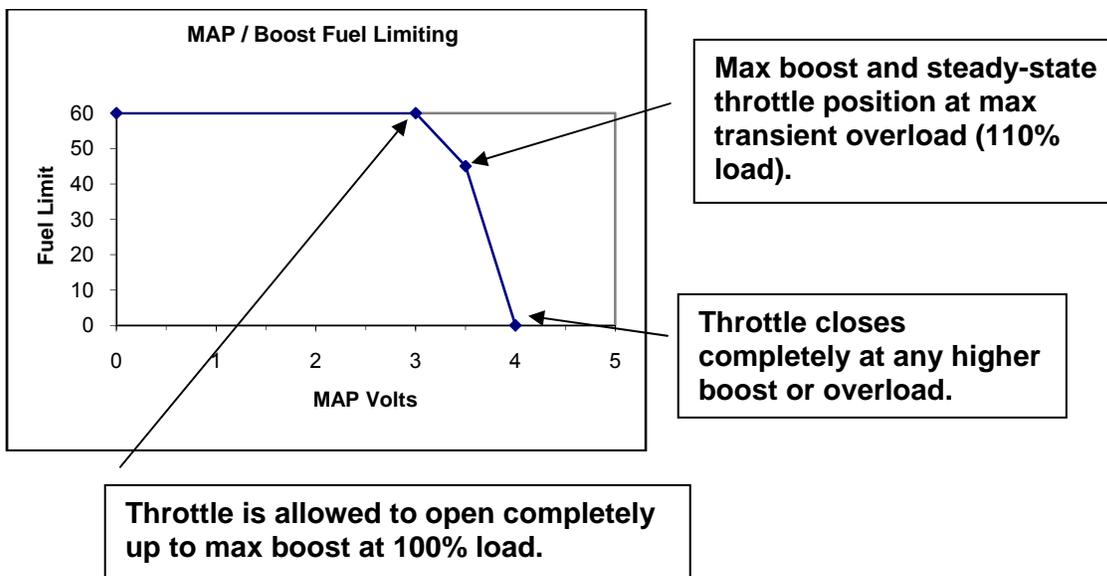
Figure 2-3. MAP/Boost Fuel Limiting

ACTUATOR CONTROL FUNCTIONS
Actuator Control—This function calculates the difference between the desired position and the actual measured actuator position, and adjusts the actuator torque as a result. Proportional, derivative, and integral parameters are referenced by this function. This is the position control loop.

Actuator Gate—When the governor state is 'powerup,' this function overrides the output of the Actuator Control function and prevents the actuator from developing any torque. When the governor state is 'start' or 'run,' this function passes the torque command of the Actuator Control function directly to the actuator. When the governor state is 'error' this function overrides the output of the Actuator Control function and drives the actuator to minimum fuel, which is dependent on the direction setting in the configuration. These gates control the start fuel limit and fault conditions.

LOGIC AND SUPPORT FUNCTIONS
Overspeed Error—The LCS control has an overspeed function that can be set by the OEM to shut down the engine at a speed that is typically 110% of rated speed. When the control senses this speed, it will drive the throttle to minimum position, turn on the relay contact output (if enabled), and the software will store a fault bit in EEPROM (if fault storage is enabled). Cycling power to the LCS will restore normal operation, but the fault bit will remain in non-volatile memory until reset.

⚠**WARNING**	**The LCS control should never be used as the primary overspeed protection device.**

Related configuration file parameters: overspeed, EE fault storage, relay control, overspeed thresh

Failsafe Error—To protect the engine against overspeed upon loss of the speed input signal, the control will drive the actuator to minimum throttle anytime the control senses a missing speed input for a programmable amount of time not to exceed 0.5 second. The relay contact output will also be turned on (if enabled) and the software will store a fault bit in EEPROM (if fault storage is enabled). Cycling power to the LCS will restore normal operation, but the fault bit will remain in non-volatile memory until reset.

Related configuration file parameters: Failsafe, Failsafe timeout period, EE fault storage, relay control

Configuration Error—The Configuration Error function is permanently enabled to check for the presence or absence of a configuration file in the control during power-up. If a configuration error is detected, software sets the configuration error flag, activating the relay output and rendering the control inoperable until the power is cycled.

Relay Control—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 fuel shutoff solenoids. It has an internal protection diode, so it is not necessary to provide one externally. This output is normally floating with a very weak resistor to an internal +5V, but when an error condition occurs (overspeed, configuration, failsafe), this output sinks up to 250 mA to ground.

There are two conditions that will prevent this output from operating. The first is if battery positive is accidentally connected to it, and the second is if it is shorted to ground. If this output is intended to drive a fault light, these conditions will not be obvious.

Fault Storage—Enabling this bit turns on the EE Fault Storage function when the governor state is 'error'. When the governor state transitions to 'error,' the source of the error (configuration, overspeed, or failsafe) is stored as a set bit in the control fault register of the LCS's EEPROM.

Governor State—This function sets an internal state variable to one of four values (powerup, start, run, or error) based on the current engine speed and error function data. When power is first applied to the governor, its state is 'powerup.' As the engine is cranking and its speed exceeds the start speed threshold, the state of the governor changes to 'start'. When the engine speed exceeds the run speed threshold, the state of the governor changes to 'run'. If any of the speed error functions (overspeed, failsafe) are enabled, and they detect a speed error, then the state of the governor transitions to 'error' and remains there until power to the control is cycled. This function is required for all speed governor applications; it is not required for positioner applications.

Password Protection—This feature allows an OEM to password protect the configuration files. This prevents unauthorized dealers or competitors from reading configuration, dynamics, or fault information from the OEM's controls. In general the OEM should only use one security key for all LCS applications; otherwise multiple copies of service tools and security key files will be required. If you choose to put a value in this parameter, then you will also have to generate companion encrypted security key file using the software tools and distribute this key file with the dealer service tools.

If an OEM decides to put a value into the OEM SECURITY KEY field, and downloads that configuration file into a control, the OEM must supply an encrypted security key file called ACCESS.KEY when giving the OEM dealer network a copy of the dealer service tools. If a dealer tries to work with an LCS control and does not have a ACCESS.KEY file, the tool will not permit access to the control's data.

Related configuration file parameters: OEM Security Key, Make Key function

Manual 26135 **LCS ITB / LC-50**

Chapter 3.
Installation

Mechanical Installation

Locate the LCS control a distance from sources of extreme radiant heat, such as exhaust manifolds or turbochargers. The operating temperature range of the control is –40 to +85 °C (–40 to +185 °F). In spark-ignited applications, make sure the LCS is located away from the ignition coil, and that harness wires are not routed next to the spark plug wires.

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.

The 25, 30, and 36 mm throttles mount with 5 mm fasteners in a 43 mm square bolt pattern. The 43 and 50 mm throttles use 6 mm mounting screws in a 57 mm square pattern.

The LCS actuator has a rotation of 0–60 degrees. To get full blade rotation on the ITB, a mechanical linkage exists inside the ITB that converts 0 to 60 degrees actuator rotation to 3 to 85 degrees blade position.

The LC-50 mixer can be mounted in any of three orientations of the ITB to allow convenient fuel system connections. The LCS ITB and LC-50 are intended to be used with gaseous fuels from low quality pipeline natural gas to HD-5 LPG. The quality of this range of fuel varies from a lower heating value of 850 BTU/SCF (34.0 MJ/m³) to 2325 BTU/SCF (93.0 MJ/m³), and the specific gravity varies from 0.55 to 1.56 relative to air. When using a Woodward supplied ZPR, fuel pressure should be 0.25 psi (7" water column) (1.7 kPa [178 mm water column]) to 1 psi (28" water column) (6.9 kPa [711 mm water column]). Pressure supply range is 4–14" water for the R500Z, and 4–28" water for the R600Z.

The LC-50 mixer has two inlet sizes for air filter attachment. The smaller throttles (25, 30, and 36 mm) have a 2.0-inch (50.8 mm) inlet. The larger throttles (43 and 50 mm) have a 2.5 inch (63.5 mm) inlet.

We recommend installing all components of the gas system, such as air filter, main adjustment screw, and throttle valve in a symmetric way to minimize possibility of unequal mixture distribution.

Curved pipes should not be installed closer to the venturi than 3D (where D is the diameter of the venturi at the air inlet side).

Woodward recommends that you install a compensation line between the ZPR and the air inlet to maintain consistent air/fuel ratio throughout the life of the system. If a compensation line is not installed, the air/fuel ratio will be affected by the changing restriction of the air cleaner as it accumulates dirt.

Woodward **19**

If the Maxitrol ZPR is obtained from Woodward, the following installation instructions apply. If another brand of ZPR is used, consult that manufacturer for installation guidelines. The ZPR should be mounted with the spring tower up. If it is not, the weight of the diaphragm and spring can offset the pressure setting. The ZPR should be mounted as close to the MAS as possible to prevent pressure drop across excessively long pipe lengths. This pressure drop and associated system lag can cause stability and response issues with the mixer air/fuel ratio control.

On a turbo-charged engine, the mixer should be located before the turbo compressor. This will yield very high mixture homogeneity as well as allowing the use of a standard ZPR and the ability to use low-pressure gas. To increase safety, some engine manufacturers have mounted flame arrestors between the inlet manifold and the cylinder head, ensuring that a backfire does not lead to an explosion in the inlet manifold, aftercooler, etc., which are filled with ignitable mixture.

The initial settings for the MAS and ZPR are indicated in the table below. These settings should provide the ability to consistently start and run at an approximately stoichiometric air/fuel ratio. The procedure for adjusting these settings for optimum air/fuel ratio will be described in the air/fuel ratio tuning section (Chapter 4). The main adjustment screw (MAS) settings are measured from the MAS valve body (not the jam nut) to the exterior end of the MAS screw. The zero-pressure regulator settings are measured from the top of the spring adjustment screw to the top of the spring tower.

For dual-fuel configurations, the standard NG fuel set up should have a tee added between the ZPR and MAS. The side-leg of the tee should then have the MAS and ZPR for the LP fuel. The initial settings for dual-fuel NG and LP are the same as the single-fuel settings below. The final air/fuel ratio adjustments should be done on NG first, then LP, using the procedure in Chapter 4 for each fuel.

MAS and ZPR Initial Settings

ITB Size	Natural Gas	Propane
50 mm	**Screw Setting Position (mm)**	
MAS	19	16
ZPR	16	14
43 mm		
MAS	17	15
ZPR	16	14
36 mm		
MAS	11	9.5
ZPR	14	14
30 mm		
MAS	11	9
ZPR	14	14
25 mm		
MAS	10	8
ZPR	14	14

Electrical Installation

A pinout of the LCS control, as viewed by looking into the control's connector feature, is shown in Figure 3-1. Typical connections to external devices are also shown.

The LCS has an operating voltage range of 8 to 16 Vdc with a nominal voltage of 13.5 V. The power supply is load dump and reverse polarity protected, and consumes 64 W maximum power at a peak current of 4 A (16 V) assuming 4 Ω stator resistance at 25 °C. The control system should be protected with a 6 A fuse in the voltage supply lines. Typical max average current is 1.8 A, or max 29 W at 16 V. The application should be configured to turn on power to the governor when the engine is first cranked. Power should be removed just before the engine is shut off so that the actuator loses torque and the return spring can move the throttle to a minimum fueling position.
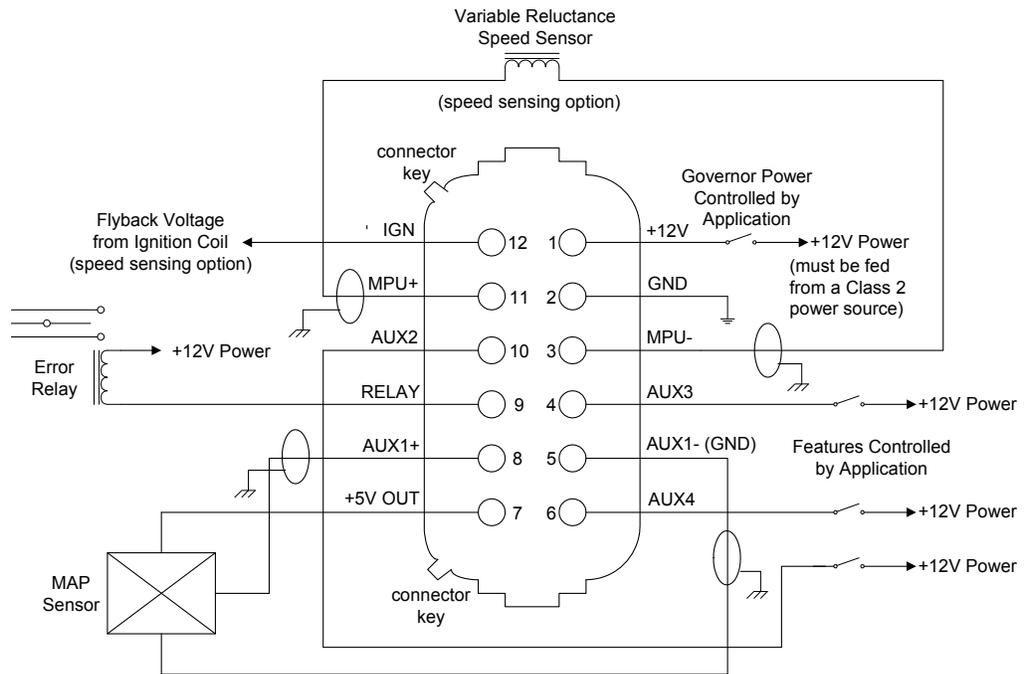
note: AUX1+ and AUX1- can also be used as a +/-3V load sharing input
note: AUX1+ can also be used as a digital input like AUX2, AUX3, and AUX4

Pinout as Viewed Looking Into LCS Control

Figure 3-1. Typical LCS Application Wiring

Several speed sensing options are supported. The LCS can sense speed from ignition coils, DIS modules, or variable reluctance magnetic pickups (MPU). When using the LCS with an ignition coil, attach the IGN input to the switched side of the coil's primary; typically this is the negative (–) terminal of the coil. Do not rely on the condenser connections to determine which side of the primary coil is the switched side—use a tachometer or frequency meter to check for engine speed.

When interfacing the LCS to a DIS module, connect the LCS control's MPU+ (pin 11) and MPU– (pin 3) input pins to the DIS module's signal and ground input pins. Be careful not to accidentally swap the connections; otherwise the engine will not start.

When using a variable reluctance magnetic pickup, make sure the gap between the pickup and the flywheel or gear teeth is sufficiently small so that the sensor output voltage meets or exceeds the voltage threshold curve shown in Figure 3-2 for the full range of engine speeds. The resistance of the MPU must be less than 900 Ω.
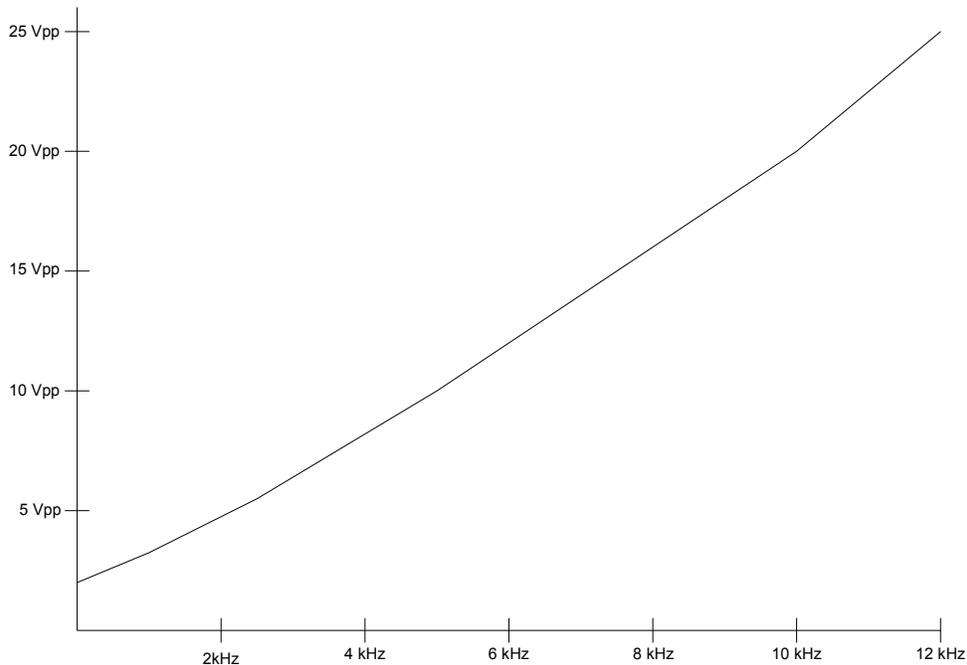
MPU Input Voltage (peak-to-peak) Requirement vs. Input Frequency

Figure 3-2. Voltage Threshold Curve

The relay output driver is activated any time the governor detects an error condition (overspeed, failsafe, or configuration error). The driver sinks up to 250 mA of current through an external device powered from +12 V. This driver is internally protected against inductive flyback.

The +5 Vdc Power Output is intended to power the pressure transducer used with the manifold air pressure-biased fuel limiter function. The maximum output current is 10 mA. If the external wire associated with this function is shorted to ground, the actuator will lose its power and the ITB return spring will close the throttle. If the short persists, the control's internal regulator may go into thermal shutdown but should not be permanently damaged. If the short is cleared, the 5 V supply will return after the regulator chip cools down. Use special care when routing wire to this pin. Use well-insulated wire, and be sure to grommet any holes in sheet metal through which it may be routed.

The LCS has three dedicated digital inputs (AUX2, AUX3, and AUX4) used to activate various features of the control. Shorting an input pin to +12 V activates it. Removing +12 V from an input pin or shorting the pin to ground deactivates the input. At least 4 volts must be present on an input pin in order to change its state from inactive to active. All discrete inputs will be the same voltage as the system power supply and will be active only while the input is in a high state. Greater than 4 Vdc is considered high, and less than 1 Vdc is considered low.

All connector pins are short-circuit protected to ground and power except pins 2, 3, and 5, which are not protected against shorts to battery positive. Installation of a fuse on the power ground wire to pin 2 would provide protection to these pins but does not mean one is not needed in the power connection. Pin one (B+) still needs protection against a short to ground.

A combination analog/digital input (AUX1) is available on the LCS. When AUX1 is configured as a digital input, it must be grounded (not opened) to deactivate, but otherwise the AUX1+ pin is treated the same way as AUX2, AUX3, and AUX4. When the pin is used as a discrete input, it will have minimum impedance of 10 kΩ, and when configured as an analog input, it would have minimum impedance of 100 kΩ. When AUX1 is configured as a ±3 V analog input, the LCS may be interfaced to other Woodward load sharing equipment through the AUX1+ and AUX1– inputs. When AUX1 is configured as a 5 V analog input, +5V OUT, AUX1+, and AUX1– may be used to sense manifold absolute pressure or bias engine speed with a potentiometer.

The following Deutsch connector components are recommended for harness designs:

	Recommended	**Optional**
Mating Connector	DT06-12SA-P012	DT06-12SA
Secondary Lock	W12S-P012	N/A
Sockets	0462-201-16141	0462-201-16141

Woodward part number 8928-396 is a kit that provides all the necessary Deutsch components.

Use 16 to 18 AWG (1 to 1.5 mm²) stranded copper wire with insulation that meets temperature requirements in the harness design. In the event a wire is not used for each of the 12 pins on the control, a Deutsch 114017 plug should be used in place of each missing wire to environmentally seal the connector from the elements. A wiring harness stress relief within 16 inches (406 mm) of the control's connector is recommended. The maximum recommended harness length is 20 feet (6 m). Dress the harness with wire loom to contain it in a single bundle. Use grommets when passing the harness through metal panels. Ground the MPU signal wire shielding at the control, but do not ground the MPU signal wire shielding at the MPU.

When using the ignition signal as the speed input, connect a two inch (51 mm) insulated 18 AWG (1 mm²) wire between pins 3 and 11 (MPU+ and MPU-) of the 12 pin Deutsch connector.

Also use twisted pair, shielded wires for the AUX1 input when configured for Isoch Load Sharing, 0–5 Vdc Remote Speed Setting, or MAP Fuel Limiting. Ground this shielding on the engine near the control.

Chapter 4.
Software Programming

This chapter covers the process of tuning, configuring, and servicing the control via the LCS Service Tool Software Suite. It is assumed that the control has already been installed on the engine.

The following hardware is required to work with the LCS control, regardless of whether an application is being developed by engineering, a configuration file is being downloaded in production, or the application is being serviced in the field:
- PC-compatible laptop or desktop computer* with at least one available serial communications port, and Windows 95/98/00/NT as the operating system.
- Programming/datalink harness (part number 02-0004-174) as shown in Figure 4-1.

NOTICE

***—There is a potential for serial port damage when communicating with the LCS 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 LCS 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.**
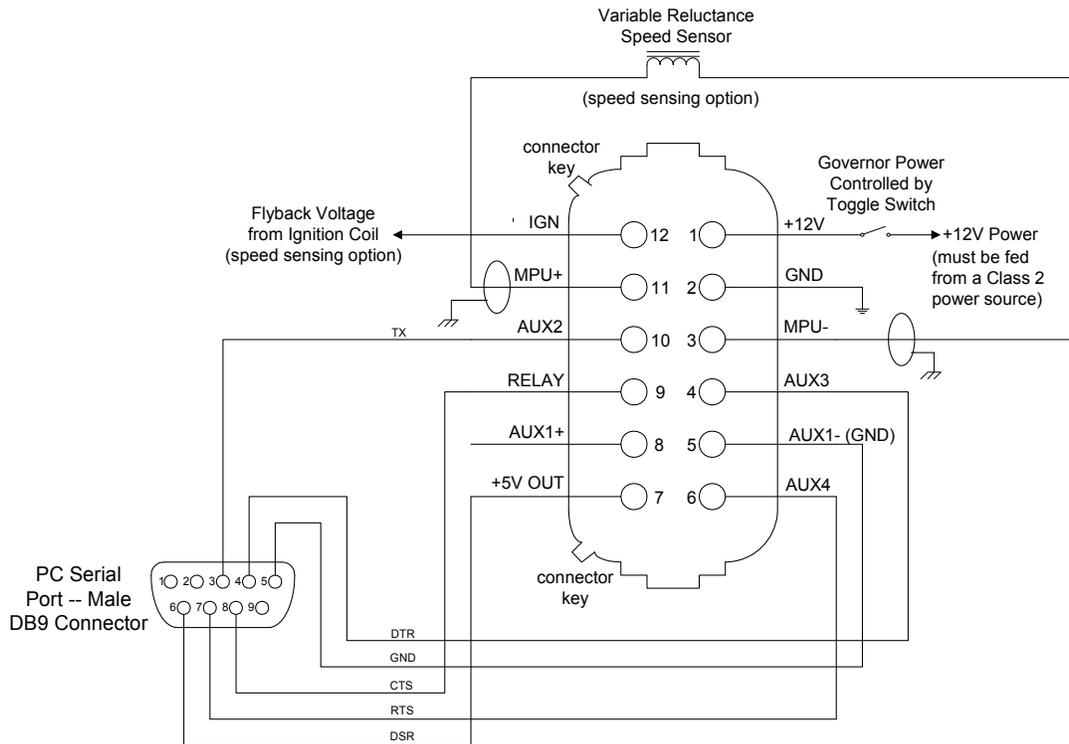
Pinouts Viewed Looking into Control Connector and Computer Connector

Figure 4-1. Typical Programming Datalink Harness Wiring

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

- Woodward part number 9927-1000, LCS Service Tools, Dealer Distribution
- Woodward part number 9927-1000, LCS Service Tools, OEM Distribution (license Woodward part number 8928-5002)

The dealer distribution is required to update control dynamics and read out fault codes. The OEM distribution is required to configure, tune, and secure the control; it also includes the utilities from the dealer distribution.

Software Installation

The software tool is available for download form Woodward's website:
     www.woodward.com/ic/software/software.cfm
Select the LCS Control from the pull-down menu. Then select GO. A new screen will appear with information about the product as well as installation instructions. To download the software, press the DOWNLOAD button.
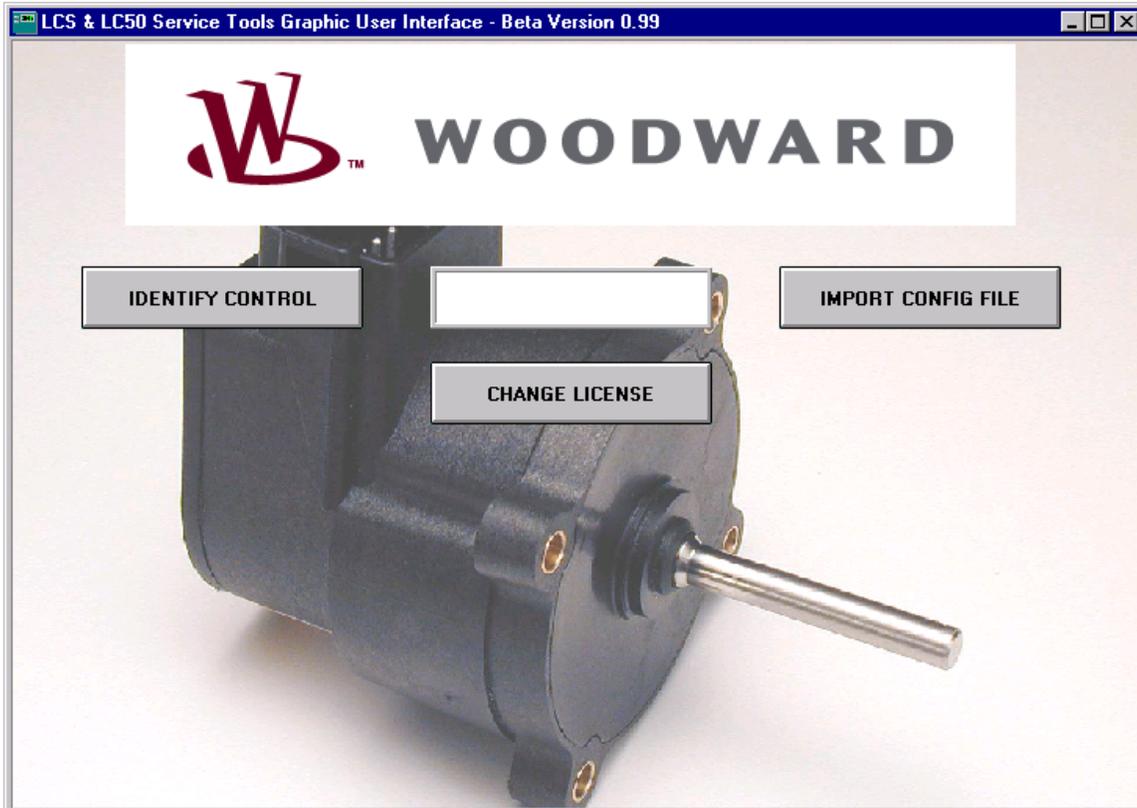
Before you can download, you will be prompted to log on to the Woodward site. If you have never downloaded Woodward software, you will have to complete a new registration.. Press this icon and fill out the information requested. If you have already registered, enter your e-mail address and press Login. The registration information is required so that we can alert you of updates to the software tools.

Once you have downloaded the software, double-click on the file (setupLCv1-0-A.exe) and follow the on-screen prompts. The defaults install is a dealer distribution in the default directory of LC-ctrl. To activate the OEM version, a license authorization must be obtained. This can be obtained from the same website.

You will need a serial number (obtained from your account manager) and a site code (obtained by pressing Change License) on the LC Control Software.

This is the first screen that appears when the GUI is initialized. To use the GUI Service tools, the user must have either an LCS with a supported firmware revision or the user must have access to a valid configuration file. This feature can also be used to identify the firmware revision of a particular configuration file.

The GUI supports several firmware revisions. The dialog box in the center of the screen will indicate "LCS B/C", "LCS D", "LC-50G", or "LC-50I" configuration format will be used. This manual covers the LC-50G and LC-50I versions. If your system comes up as B/C or D configuration format, contact Woodward for the appropriate manuals.

- **IDENTIFY CONTROL**—Identifies which version of firmware an LCS has. This requires that an LCS be connected to your laptop with a programming harness.
- **IMPORT CONFIG FILE**—Opens an existing config file. Select the desired file using the browser (config files use a *.lcs extension). Template files are available to get started.

Once a valid file or valid LCS has been identified, the screen below is displayed. The box in the center of the screen identifies which version of LCS is being used.

OEM Version of Main Screen

Dealer Version of Main Screen

CONFIGURATION Menu—Gives the user access to the configuration file handling options: edit config file, write to an LCS, read from an LCS, etc.

REAL-TIME TUNER Menu—Gives a user access to critical speed, dynamics, and position information for tuning. Both GAIN and Engine RPM can be monitored automatically by asserting the respective button. All data items must be read or written to by the GET and SET buttons, respectively.

SECURITY KEY Menu—Creates a security password and associated key to prevent other OEMs from viewing your *.lcs file.

FAULT CODES Menu—Fault codes can be viewed and reset from this menu.

DYNAMICS Menu—Provides access to a subset of the config file for dealers or field service.

Working with Configuration Files

This is the menu that is displayed when the CONFIGURATION Menu button is pressed. Six options are available. After the configuration file or LCS has been validated, its data is loaded into GUI's memory.
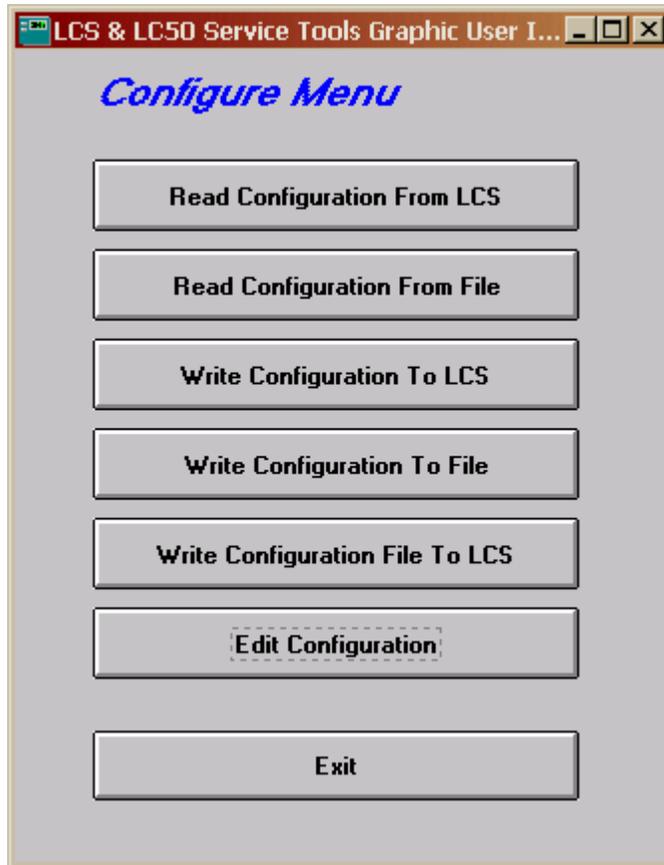
Read Configuration From LCS: Loads the config file from a LCS to the GUI. This requires that an LCS be connected to the computer through a programming harness. When you select this option, you will be asked to turn power on to the controller. Power is controlled by a toggle switch in the programming harness (see beginning of chapter for harness description).
Read Configuration From a File: Opens a Windows browser and allows the user to open an existing *.lcs file.
Write Configuration To LCS: Writes the active config file stored in the GUI to the LCS EEPROM. This requires an LCS be connected to the computer through a programming harness. When you select this option, you will be asked to turn power on to the controller. Power is controlled by a toggle switch in the programming harness (see beginning of chapter for harness description).
Write Configuration To File: Saves the active config file stored in the GUI to the location of your choosing.
Write Configuration File To LCS: Writes configuration file from hard drive or disk to the LCS.
Edit Configuration: Presents the LCS configuration file in a graphical format.
Exit: Returns to the main menu.

EDIT Configuration—Screen 1

On all screens numerical values can be entered by directly typing them in the field, or by pressing the up and down arrows to increase or decrease the value.

Features Configuration Menu—Generator Version

Features Configuration Menu—Industrial Version

This first screen allows the user to select the options to be enabled. See the Controller Features Description section of Chapter 2 for detailed explanations of each of the features.

The Free Form Text box allows the user to have a unique description for each configuration file. This text is stored in non-volatile EEPROM for future identification.

The OEM Security Key box is where the password is entered, if desired.

A feature is enabled or disabled by selecting ON or OFF from the pull down menu next to that feature.

For features that can be programmed to come in on a choice of multiple pins, a status of each AUX input is displayed on the lower left of the screen. If the user tries to put two features on the same AUX input, the status area will indicate that with red text and the words CONFLICT Exists.

If a feature is not turned on, the associated parameters cannot be edited. For example, if Droop is not turned on, the dialog box underneath asking for a droop percentage, cannot be edited.

EDIT Configuration—Screen 2

When you press NEXT from the FEATURES CONFIGURATION Menu, the DYNAMICS Menu appears.

This is where the engine governing speed control gains are configured. If the LCS is being used as a positioner, no information is needed on this screen.

Dynamics Menu—Generator & Industrial Versions

If the LCS is being used as a governor, then the control dynamics, speed sensing, and speed settings will be entered on this screen.

Primary and alternate refer to the dual dynamics function. If the dual dynamics option was selected on the first screen, then values should be entered for both primary and alternate gains.

Speed 1 box on the left is the primary speed setting. If 50/60 Hz, idle/rated, or three-speed was selected, the pull-down menu at the top of the screen becomes accessible. This allows you to enter the speed settings and dynamics for the various functions.

Common gain, compensation, GPOS1, GPOS2, GPOS3 are common for all speed settings and both primary and alternate dynamics.

The graph on the bottom right will show a plot of the primary dynamics for the speed setting reflected in the speed select box.

The speed sensing mode is also defined here. If MPU is selected, an option drops down for number of flywheel teeth. If ignition is selected, drop down menus appear requesting inputs for number of cylinders and type of engine.

EDIT Configuration—Screen 3

The third screen in the configuration file editor is the positioner screen. The proportional, integral, and derivative terms control the response of the throttle blade. Typical values for throttle body applications are: proportional = 25 to 40, integral = 15 to 25, derivative = 0 to 30.

No load and full-load actuator positions are used by the droop function. If droop is not being used, no information is needed here.

Position Menu—Generator Version

Position Menu—Industrial Version

EDIT Configuration—Screen 4

The Fuel Parameters Menu is the fourth screen. This screen is where the fuel limiting parameters are entered. If start fuel limiting and boost fuel limiting are not being used, this screen can be skipped.

If start fuel limiting is being used, enter the actuator position limit on this screen. The RPM threshold is entered on the next screen.

If boost fuel limiting is being used, enter the parameters here. These points act as a three-point curve, with linear interpolation between points.
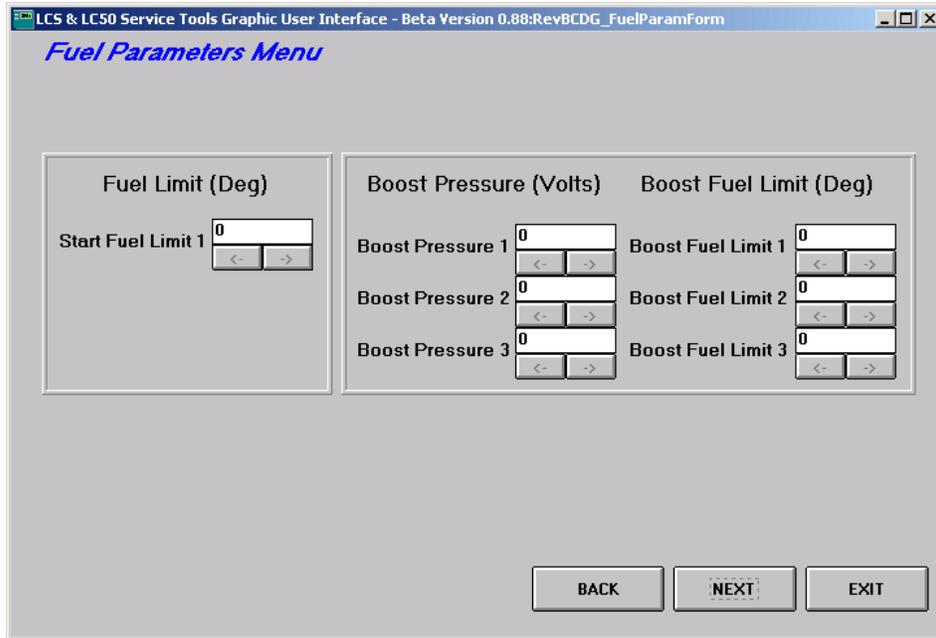
Fuel Parameters Menu—Generator Version
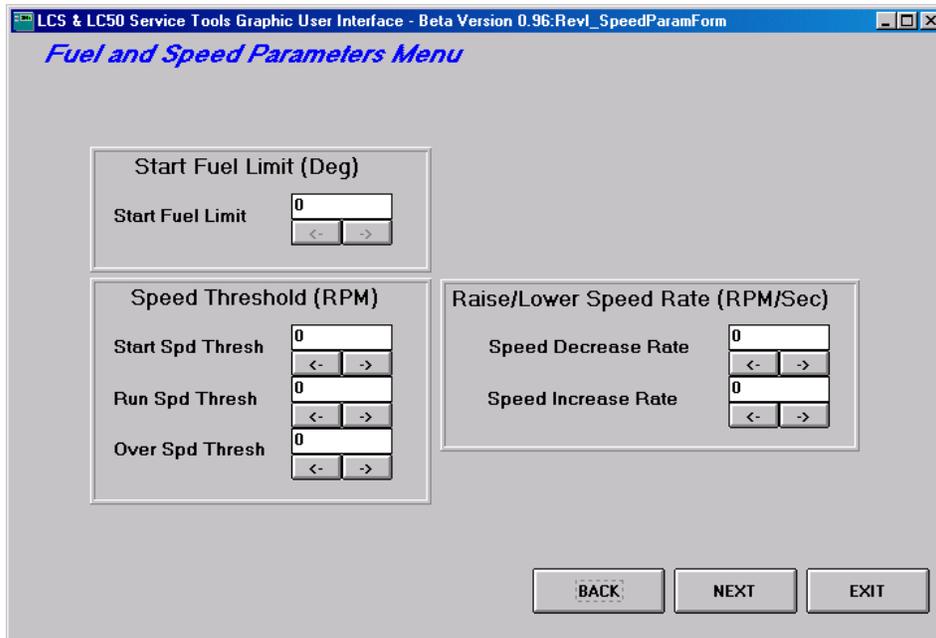
Fuel Parameters Menu—Industrial Version

EDIT Configuration—Screen 5

The fifth screen presents the Speed Parameters Menu. The start speed threshold, run speed threshold, and overspeed threshold are entered here.

If the raise/lower function has been enabled, enter the ramp rates in speed decrease rate and speed increase rate. The upper and lower limits for the raise/lower function are also entered here. The ramp rates are also used by the idle/rated function and the three-speed function. The speed will transition between the various set speeds at these rates.

Speed Parameters Menu—Generator Version

EDIT Configuration—Screen 6

This is the final screen in the EDIT Configuration Menu. This screen is where the auto gain parameters are entered. The GAIN DECREMENT and GAIN INCREMENT indicate how much the gain should be altered when the system is determined to be unstable. Minimum Gain and Maximum Gain are the limits for any changes in the gain. Steady State (rpm) and Transient (rpm) are the windows to determine instability. If the system is operating in a steady state mode, then if the RPM varies by more than this amount the gain will be decremented by the amount indicated in Gain Decrement. Likewise, during a transient event, if the RPM varies outside the transient RPM window, the control will increment gain.

Real-Time Tuner

The OEM utility REAL-TIME TUNER is designed to give application engineers the ability to tune an LCS control's actuator position control loop and engine speed control loop.

The program initializes the control for real-time communications while the main control loops are executing. Because the real-time tuning software uses AUX2, AUX3, AUX4, and the relay output to communicate, no auxiliary product features can be enabled. Use of this feature requires an LCS be connected to the computer through a programming harness. When you select this option, you will be asked to turn power on to the controller. Power is controlled by a toggle switch in the programming harness (see beginning of chapter for harness description).

Examples of how this tool is used are contained in the sections of this manual dealing with actuator tuning and engine tuning.
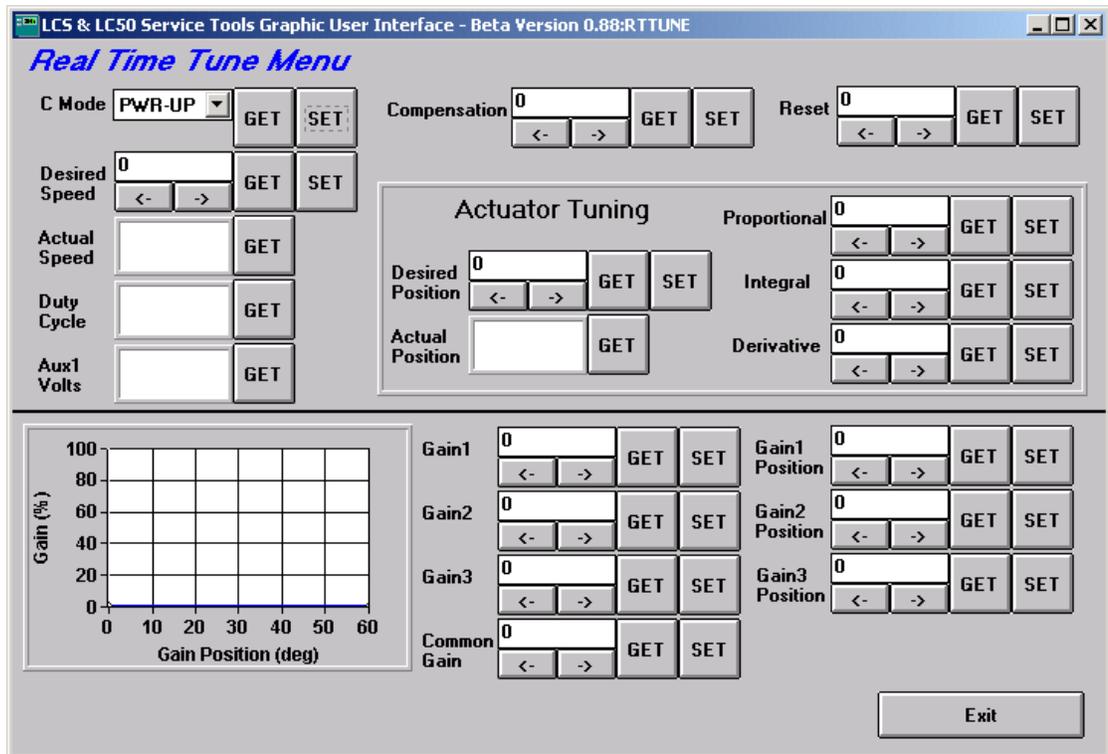
Working with Security Keys

If an OEM decides to make use of the password protection feature, this is where
the password is entered and the associated key is created. This screen is
accessed from the Main menu by pressing Security Key Menu. Enter the
password you would like to use in the text input box. Then press the Make Key
button. A file called "access.key" is created that must then be present in the
working directory any time you attempt to communicate with the LCS.

Viewing and Resetting Fault Codes

VIEW Fault Codes

To view the contents of a control's fault register, press the VIEW FAULT CODES
button located in the FAULT CODES Menu.

The program will display which of the error bits are set within the register
(configuration error, overspeed error, or failsafe error). A configuration error is the
result of not downloading a configuration file into a new control. Overspeed, and
failsafe errors all relate to issues with the MPU or connection to an ignition
system. The underspeed fault does not apply to the LC50 ITB versions of the
LCS.

RESET Fault Codes

To clear the contents of the control fault register, press the RESET FAULT
CODES button. The program will reset the state of all error bits.

Messages
In working with the LCS, the power must be cycled from time to time. The user
will be prompted to turn power on or off. If the power is not cycled in 10 seconds,
a message will appear which allows a retry or the cancellation of the current
activity.

Dynamics Menu

This is the menu displayed after pressing Dynamics menu. It allows access to a
subset of the entire configuration file. Dealers or field service personnel can
access all of the dynamics associated with the controller including: primary and
alternate reset, gain 1, gain 2, gain 3, and compensation for all speeds.

Read Dynamics From LCS—Loads the dynamics file from a LCS to the GUI.
This requires that an LCS be connected to the computer through a programming
harness. When you select this option, you will be asked to turn power on to the
controller. Power is controlled by a toggle switch in the programming harness.
Read Dynamics From File—Opens a Windows browser and allows the user to
open an existing *.dyn file
Write Dynamics To LCS—Writes the active dynamics file stored in the GUI to
the LCS controller. This requires that an LCS be connected to the computer
through a programming harness. When you select this option, you will be asked
to turn power on to the controller. Power is controlled by a toggle switch in the
programming harness.
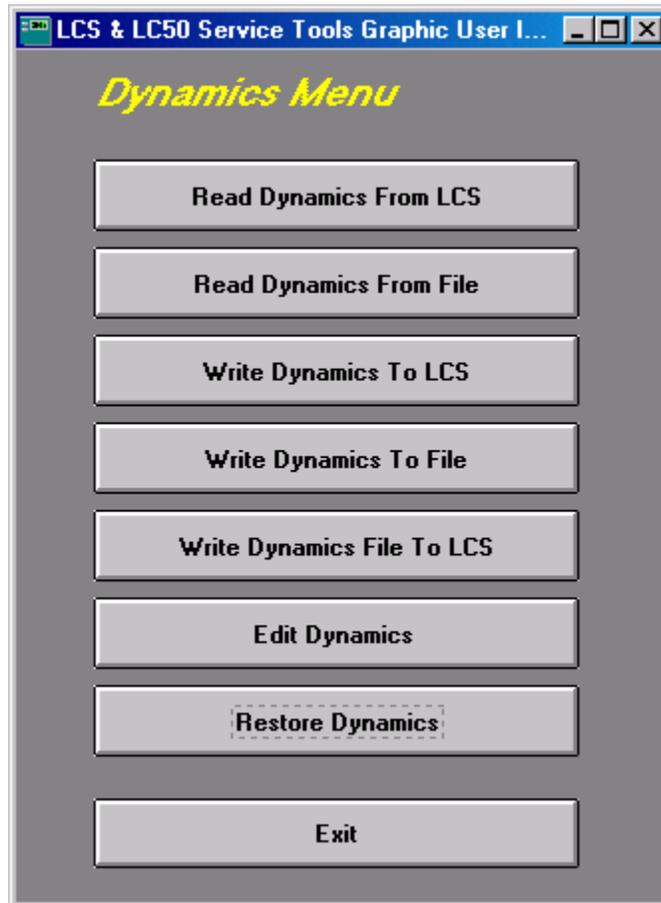
Write Dynamics To File—Saves the active dynamics file stored in the GUI to the location of your choosing.
Write Dynamics File To LCS—Writes a dynamics file from the hard drive or disk to the LCS.
Edit Dynamics—Presents the LCS dynamics file in a graphical format for editing.
Restore Dynamics—Restores the original OEM settings. If a user writes dynamics changes to the LCS and decides that they are not effective, pressing restore will copy the original settings from backup memory area on the controller.
Exit

When Edit Dynamics is pressed, the following screen is displayed.
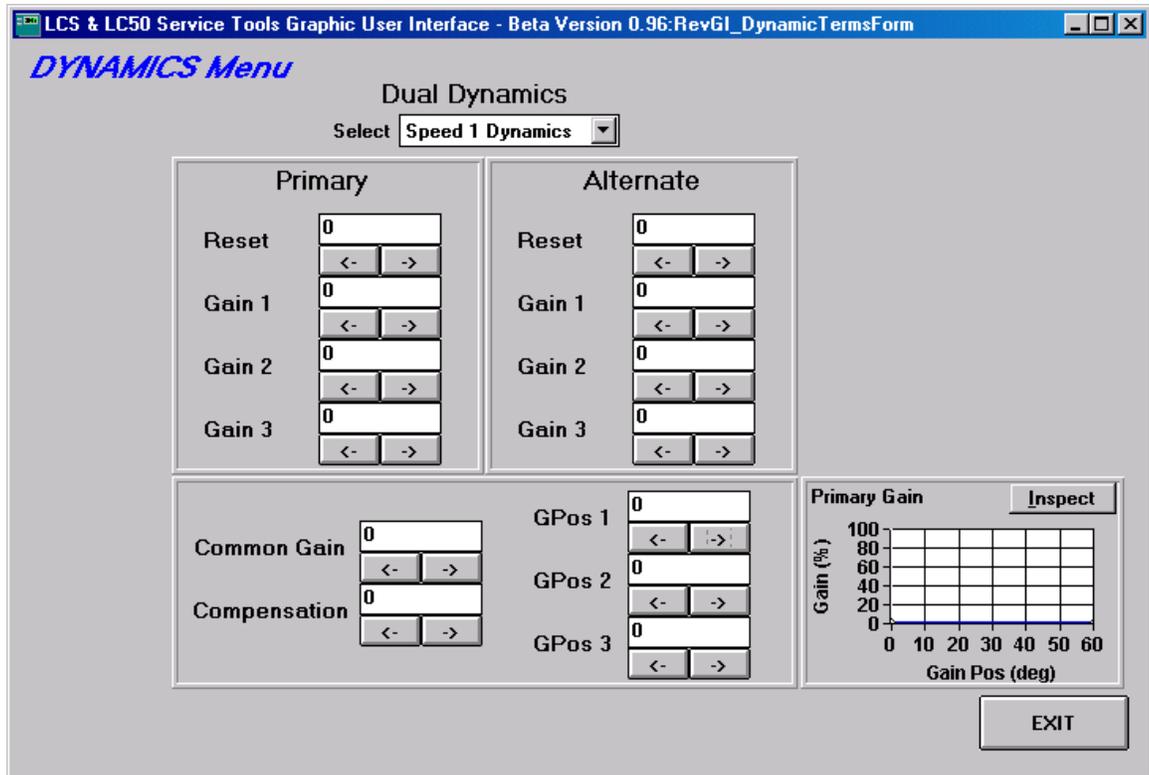
Controller Tuning

Before continuing, the OEM should already have in mind which speed setting, speed biasing, speed sensing, alternate dynamics, fuel limiting, and support logic features should be enabled. For more information on the features available, see the Features Description section of Chapter 2.

Initial File Construction

An initial configuration file must be created for every application. This file can either be created from scratch or an existing file can be modified. The steps below outline how to create the initial file.

1. Start the GUI program by selecting it from the Windows Start Programs menu.
2. Select IMPORT CONFIG FILE.
3. An existing config file can be used if the application is similar to one already developed. If this is the case, choose Config files from the file type drop down and then select the appropriate file from the Windows browser. If this is a new application, a template file can be opened. Select Template files from the drop down menu and then select the template that matches your version of LCS controller.

4. Select the file by double-clicking on it, or single-clicking and then pressing OPEN.
5. Once the file is opened, you are returned to the MAIN Menu.
6. To edit the configuration file, press the CONFIGURATION Menu button.
7. Then press the EDIT Configuration button.
8. You are taken to the first screen of the Configuration Menu. In this screen select the features you have determined you would like enabled.
9. If inputs are selected on the AUX pins, the bottom left of the screen indicates which inputs are associated with the AUX inputs. If a conflict exists, the text will turn red. Make sure that all inputs are coming in on a unique Aux input before continuing.

AUX Input Assignment Conflict Designation

10. For initial tuning, the AUTO-GAIN feature should be turned off.

11. When all the features are selected press NEXT.

Initial Speed Governor Feature Settings

Initial Positioner Settings

12. The next screen asks for dynamics information. If this is a new application, reset, compensation, and gain can all be set to the values shown initially. A common gain setting of 20 will give steady speed control for initial start-up and air/fuel ratio tuning. The controller may not respond will to large transients however. If this is for a positioner application, the values on this screen will be ignored.
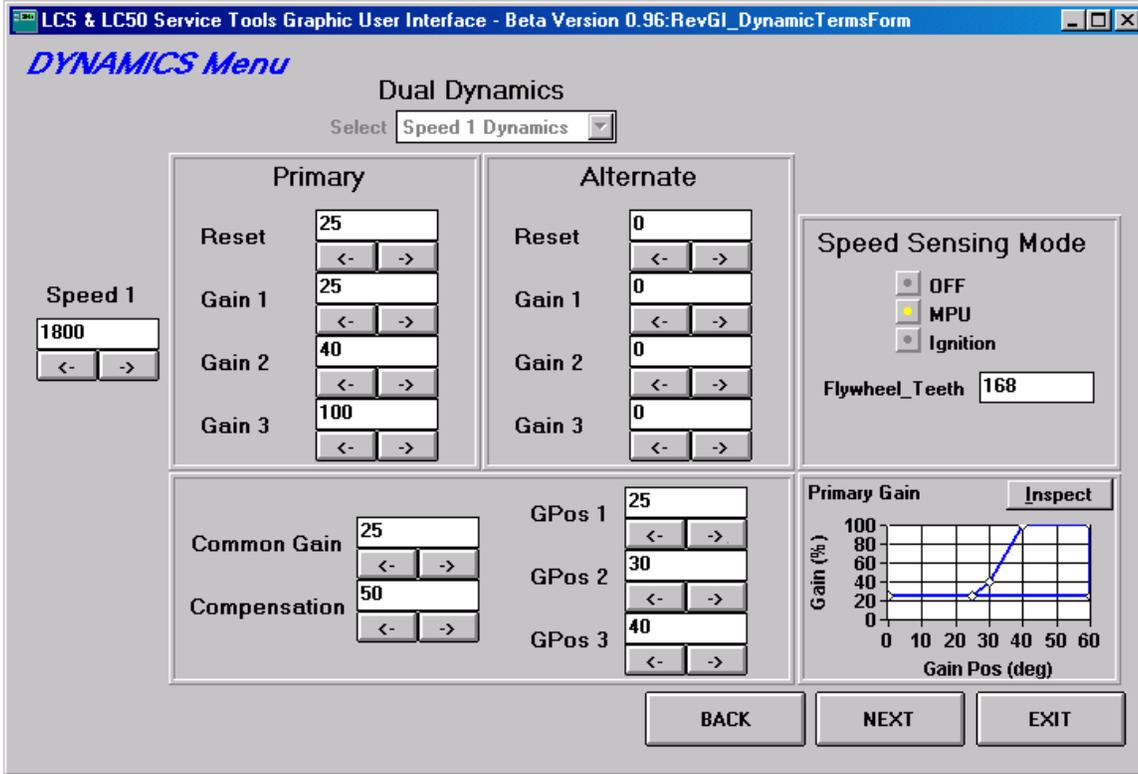
Initial Dynamics Settings for Speed Governor Applications

13. The appropriate speed setting should be entered on this screen.
14. The speed sensing mode is also entered here.
15. After entering these values, press NEXT.

16. The POSITION Menu is displayed. Appropriate initial values for the PID terms are: proportional = 35, integral = 10, derivative = 0.
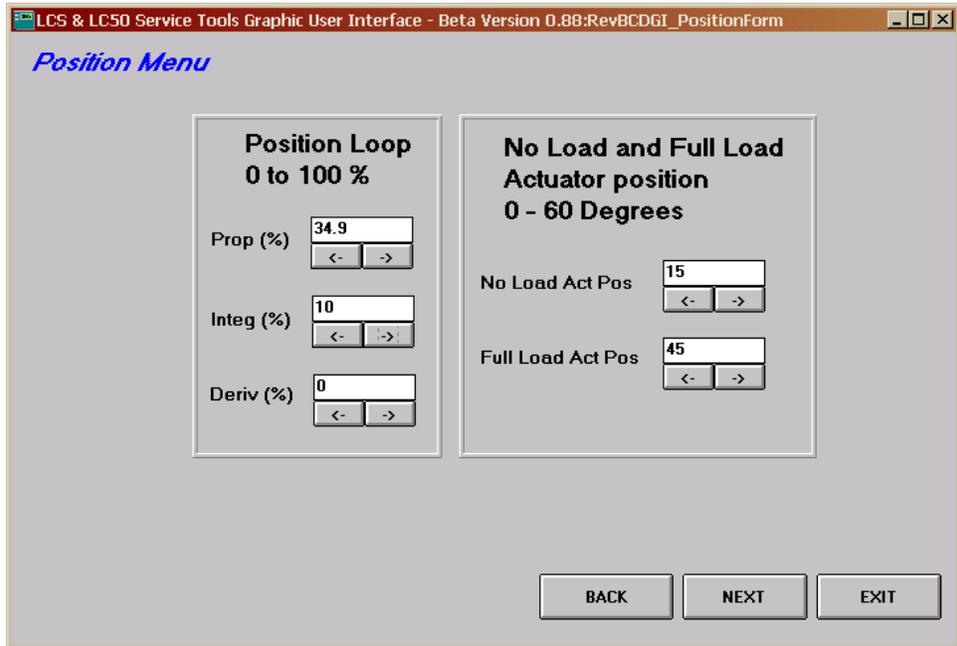
Typical Speed Governor and Positioner Values

17. If droop is being used, full-load and no-load actuator positions will need to be determined and entered here. (This can be after initial tuning.) Typical values are approximately 15° at no load and 50° at full load.
18. Press NEXT.
19. The FUEL PARAMETERS Menus is displayed. Enter any desired values here. The start fuel limit will help to avoid over-speed on start-up. Typical values are 20° to 30°. Boost fuel limit function is discussed in Chapter 2.
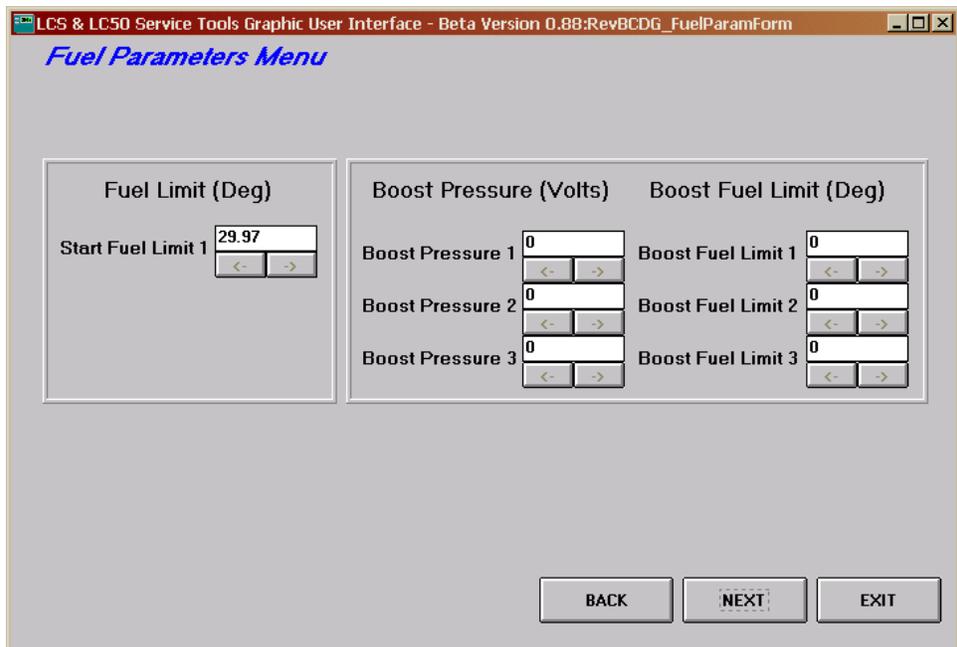
20. Press NEXT.
21. The SPEED PARAMETERS Menus is displayed. Enter start speed threshold, run speed threshold, and overspeed threshold here. Also enter any desired raise/lower values here.

22. Press NEXT.
23. The AUTO-GAIN parameters Menu is displayed. This feature should be turned off for initial tuning. So, these values should be zero.

24. Press EXIT.
25. You are returned to the Main Menu. Press Write Configuration To File to save your initial configuration file to a file. Press Write Configuration To LCS to write the file to the controller and begin tuning.

LC-50 Applications (Mixer Applications)

After the initial program is configured, the air/fuel ratio should be optimized before extensive engine speed governor tuning is done. Start with low gain values and step slowly through load changes until the air/fuel ratio is tuned.

Initial settings are described in the hardware installation section of the INSTALLATION chapter. These settings should get the gensets up and running for final adjustment with an oxygen sensor or exhaust analyzer.

> ⚠️ **WARNING** **Know in advance how to safely shut off the engine during normal and emergency stop conditions. Shutting off power to the governor does not always guarantee a controlled shutdown; it depends on the final application. Safety needs to be the overriding thought during this procedure.**

Air/Fuel Ratio Tuning

1. Insert an oxygen sensor or exhaust gas analyzer into the exhaust stream as directed by the manufacturer of the sensor or analyzer.
2. Ensure a configuration file has been downloaded into the LCS controller (See initial configuration file section.)
3. With LCS power off, press **Start Real Time Tuner Menu** and turn power on.
4. Start the engine.
5. If the engine overspeeds and shuts down, perform the following
   o Exit Real Time Tuner Menu
   o Remove power from the control.
   o Go to the EDIT Configuration Menu, then go to screen 4, and adjust the start fuel limit to a lower value.
   o Repeat steps 3 through 5.
6. Start the engine and allow it to warm up for about 15 minutes.
7. Apply 75% to 90% load to the engine. With initial, low gain values in the speed control loop, the load may need to be applied gradually to avoid under and overspeed conditions.
8. Adjust the MAS to achieve the desired air/fuel ratio. Figures below show characteristic response of oxygen sensors and exhaust gas. Clockwise rotation of the MAS will cause the air/fuel ratio to become more lean. Counter-clockwise rotation will cause the air / fuel ratio to become more rich.
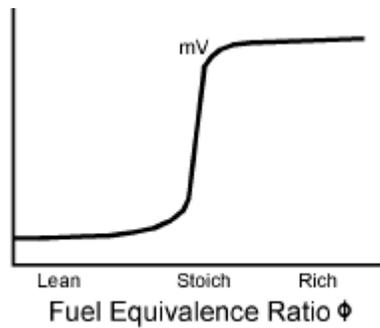
Figure 4-2. Zirconia Oxygen Sensor Response
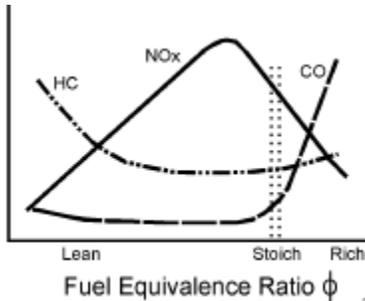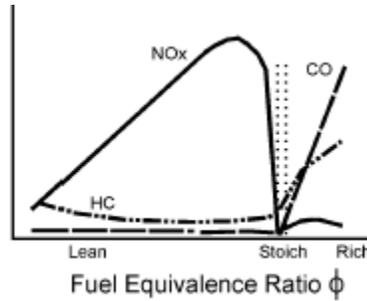
Figure 4-3. Pre-Catalyst Emissions   Figure 4-4. Post-Catalyst Emissions

9. The ZPR should then be adjusted at no-load. Clockwise rotation of the screw will cause the mixture to become richer, counter-clockwise rotation will cause the mixture to become leaner. When the cover is removed from the ZPR, extra air leakage is introduced into the system. So, a final setting cannot be determined until the ZPR spring tower is covered.
10. One or two more iterations at full load for the MAS and no load for the ZPR should provide the correct air/fuel ratio over the entire operating range.

Speed Governor Applications

⚠️ **WARNING**	**Know in advance how to safely shut off the engine during normal and emergency stop conditions. Shutting off power to the governor does not always guarantee a controlled shutdown; it depends on the final application. Safety needs to be the overriding thought during this procedure.**

Speed governor applications require that the speed control loop be tuned for load transients and steady-state stability. Use this procedure to derive the values of the speed control coefficients (reset, gain, and compensation) for a fixed engine speed. The speed control coefficients are described below:

GAIN determines how fast the control responds to an error in speed when the speed reference is changed or a load disturbance occurs. A value too high will result in sustained, fast oscillations in speed. A value too small will result in poor control performance and possibly slower oscillations.

RESET prevents slow hunting at steady state and controls damping when speed error returns to zero after a speed disturbance. A value too high will result in large, low frequency oscillations in engine speed. The actuator will tend to "bang" from stop-to-stop. A value slightly too high is indicated by an over-damped condition, or the speed error returning too slowly to zero. A value slightly too low is indicated by an under-damped condition, or the speed value overshooting the reference and returning, possibly with several damped oscillations. A value too low will result in slow, low amplitude hunting of speed about the speed reference.

COMPENSATION term compensate for actuator lag. It adjusts the rate of change in actuator output when a load disturbance occurs. A value too low will result in slow and under-damped control. A value too high will result in excessive high frequency actuator movement.

Because the dynamics of an engine depends on its speed of operation, some of this tuning process must be repeated more than once. This procedure assumes the following:
*   The LCS ITB or LC-50 is already installed on the application.
*   A programming harness is connected between the LCS, computer, power source, and speed pickup.
*   The OEM distribution of the service tools is already installed on the computer.
*   The air/fuel ratio tuning has been done. Therefore, a valid configuration file is in the LCS.
*   The generator is connected to a load bank with strip-chart recording capability.

1. With LCS power off, press Real Time Tuner Menu and turn power on.
2. Start the engine.
3. If the actuator is rapidly oscillating (> 5 Hz) around a position and the engine is making barking/chattering noises, lower the proportional term by 5% decrements until the oscillation stops. (Use the P-Term slider and SET button.)
4. If the actuator is limit cycling (~2 Hz) and the engine speed is oscillating along with it, lower the common gain term by 5% decrements until the limit cycling stabilizes. (Use the Common gain box and SET button.)
5. If the actuator is slowly hunting (< 0.5 Hz) and the engine speed is slowly hunting with it, increase the reset term by 5% increments until the hunt is minimized. Increasing the reset term too much will cause the actuator to start limit cycling. When the switchover from hunting to limit cycling occurs, reduce the reset term to eliminate the limit cycling.
6. If no good compromise can be found between hunting and limit cycling while adjusting the reset term, lower the gain term by 5% and repeat the adjustments on the reset term. Repeat lowering the gain if the reset adjustments fail to yield a stable engine.

7. Assuming the engine speed is fairly stable at this point, disturb the load on the engine (or the speed setting) slightly, and observe how the engine speed recovers. If the recovery has some ringing (oscillations with decreasing amplitude) to it, reduce the gain term and increase the reset term. Repeat the tap test until the recovery looks and sounds critically damped.
8. Attach a chart recorder to the engine to monitor its speed versus time.
9. Load and unload the engine in varying amounts. Observe the engine speed response on the chart recorder. Based on the shape of the response to changing load, change the reset and gain settings in one of three combinations as shown in Figure 4-5.

Observed Transient Load Responses During Load Acceptance
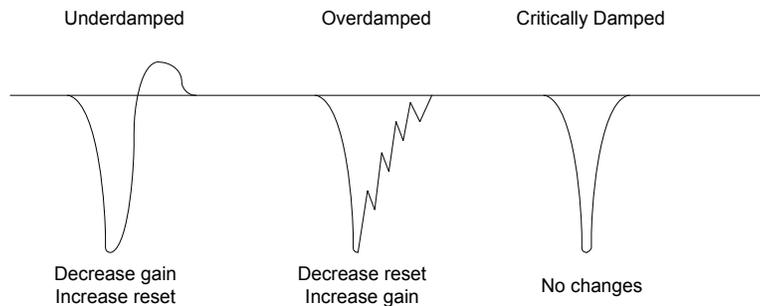
Figure 4-5. Recommended Control Setting Changes

10. The goal is to obtain the tightest possible critically damped response to load transients, at least initially. The gain term affects how quickly the governor reacts to a speed difference between the set point and the actual speed. The reset term affects the damping (or anticipation) of the governor. In general, the highest gain and lowest reset that still has good steady-state load stability will give the best transient response to large load changes.
11. When the governor and engine have been tuned optimally. Press EXIT. The following screen will appear. Press Yes and the changes will be saved to the current configuration parameters. The changes are not resident in the LCS at this time. As soon as you cycle power to the unit, the changes are erased from the controller's memory. To permanently change them, go to the Configuration Menu and Write Config File To LCS. It is also a good idea at this time to Write Config File To File, so that you have a record of the changes.

12. If the final application uses more than one engine speed or more than one fuel, tuning values should be obtained with these settings.
13. Press the Real Time Tuner Menu selection. Set a different engine speed by entering the value next to DESIRED SPEED, and press SET. Repeat the tuning process as outlined in steps 9 through 11. Or run the engine with the different fuel.
14. When optimal tuning is achieved, manually write down the reset and gain values. Common gain and compensation are common to all speed settings and dynamics so they should be optimized for all settings. DO NOT ACCEPT THE TRANSFER CHANGES TO CONFIGURATION option when you exit the real time tuner. This option will overwrite the values you established for the primary fuel and speed setting 1. You will need to manually enter these values in the appropriate places on SCREEN 2 of the EDIT Configuration Menu.
15. If the final application uses droop, run the engine at no-load and full-load conditions. Note the shaft position at both load conditions using the GET APOS (actuator actual position) button.
16. Shut down the engine safely.
17. Remove power from the control.
18. Exit the REAL-TIME TUNER menu.

Application Development Testing

The actuator tuning and engine tuning exercises outlined earlier in this manual yield control loop settings that are optimized for a specific instance of a fuel system, engine, and load. Due to fuel system tolerances, changing fuel quality, engine-to-engine output power variations, load changes, environmental changes, and long-term mechanical wear, it is NOT recommended that an initial configuration file be put into production without some sort of application development testing.

The LCS has been engineered to provide highly repeatable performance from unit to unit; therefore, a configuration file must be robust enough to account for all of the possible variations in an engine's power output. A recommended, but not comprehensive, list of tests might include:

- Cold start, warm start, and hot start tests
- Sea-level and high-altitude tests
- Fuel quality variation tests
- Engine break-in tests
- Long-term (endurance) tests
- Multiple engine application tests

The intention of such testing is to identify scenarios where the governor goes unstable due to changes in the application. An actuator might rapidly oscillate after some long-term wear testing due to the friction changes. In certain environmental, fuel quality, or engine break-in tests the engine may actually develop more or less power than during the tuning exercises, in which case the governor may become unstable. In all cases of high-frequency instability, the appropriate control coefficient must be reduced. This action must also be balanced against basic performance requirement imposed on the application.

Chapter 5.
Troubleshooting

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 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.

Engine/Generator Troubleshooting

Problem	Possible Cause	Suggested Test/Correction
Engine does not start	Stuck throttle/frozen shaft	Move throttle by hand. Assess smoothness, friction, and return spring force.
	Power not applied to control	Disconnect starter motor solenoid. Disconnect harness from governor. Activate application. Test for +12 V between +12V pin and ground pin.
	+5V output shorted to ground	Disconnect starter motor solenoid. Activate application. Test for +5 V between +5V OUT pin and AUX1– pin.
	MPU gap too large	Remove and reinstall MPU per OEM's instructions. Rotate engine manually to check for interference.
	MPU signal connection open	Disconnect harness from governor. Activate application. Test for at least 1.5 Vrms between MPU+ pin and MPU– pin during cranking.
	Ignition signal connection open	Disconnect harness from governor. Activate application. Test for bouncing voltage between IGN pin and ground pin during cranking.

Problem	Possible Cause	Suggested Test/Correction
Engine does not start (cont.)	No configuration file or incorrect configuration file in controller	Disconnect harness from governor. Attach programming harness to computer. Read configuration file from controller and evaluate parameters for correction.
Engine starts, but shuts down on error	MPU gap too large	Remove and reinstall MPU per OEM's instructions. Rotate engine manually to check for interference.
	MPU signal intermittent	Disconnect harness from governor. Continuously check resistance between MPU+ pin and MPU– pin while inspecting harness and connectors during cranking.
	Ignition signal intermittent	Disconnect harness from governor. Continuously check continuity between IGN pin and ignition coil primary while inspecting harness and connectors during cranking.
Engine starts, runs, but is unstable	Dual dynamics AUX shorted or open	Disconnect starter motor solenoid. Activate application. Check for correct voltage level between dual dynamics AUX pin and ground pin for known application mode.
	Dynamics values not tuned	Follow engine governor tuning procedure.
	Air/fuel ratio not correct	If using LC-50 mixer, MAS, & ZPR, follow air/fuel ratio tuning guidelines in Chapter 4. Otherwise, follow fuel system manufacturer's guidelines.
Incorrect mode of operation (speed, speed bias function, dynamics)	AUX inputs shorted or open	Disconnect starter motor solenoid. Disconnect harness from governor. Activate application. Check for correct voltage level between AUX pin(s) under question and ground pin for known application modes.

Problem	Possible Cause	Suggested Test/Correction
Unable to develop full power	Non-indexed linkage slipped on shaft	Manually verify full travel of throttle plate.
	Shorted MAP sensor input	Disconnect starter motor solenoid. Activate application. Verify AUX1+ voltage matches expected voltage for known atmospheric conditions.
	Fault code set	Disconnect harness from governor. Attach programming harness. view status of fault codes. Take appropriate action for active faults.
Overspeed Error	Gains not set properly for transients	If overspeed occurs on transient, raise common gain to reduce overshoot.
	Start Fuel Limit not set properly	Lower rpm run threshold or lower start fuel position.
	Speed sensing error	Follow instructions for MPU or ignition signal intermittent under Failsafe Error.
Failsafe Error	MPU signal intermittent	Disconnect harness from governor. Continuously check resistance between MPU+ pin and MPU– pin while inspecting harness and connectors during cranking.
	Ignition signal intermittent	Disconnect harness from governor. Continuously check continuity between IGN pin and ignition coil primary while inspecting harness and connectors during cranking.
	Engine running at extremely low speed	Increase failsafe timeout period.
Configuration Error	No configuration file written to controller.	Disconnect harness from governor. Attach programming harness to governor. Write appropriate configuration file to controller using the software tools.

Programming Troubleshooting

Problem	Possible Cause	Suggested Test/Correction
Error message: Missing ACCESS.KEY file	Configuration file has OEM security key written to it	Make an access key with the software tools.
Error message: The configuration data is the wrong format. Try converting the data to the current LCS Firmware Rev	Configuration file not same version as actuator	Obtain proper configuration file.
Error message: Timed Out!	No power to actuator	Check connections and retry.
Error message: Unable to establish link. Exit real time tuner?	No power to actuator	Check connections and retry.

Chapter 6.
Service Options

Product Service Options

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

- Consult the troubleshooting guide in the manual.
- Contact the manufacturer or packager of your system.
- Contact the Woodward Full Service Distributor serving your area.
- Contact Woodward technical assistance (see "How to Contact Woodward" later in this chapter) and discuss your problem. In many cases, your problem can be resolved over the phone. If not, you can select which course of action to pursue based on the available services listed in this chapter.

OEM and 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 **Recognized Turbine Retrofitter (RTR)** is an independent company that does both steam and gas turbine control retrofits and upgrades globally, and can provide the full line of Woodward systems and components for the retrofits and overhauls, long term service contracts, emergency repairs, etc.

A current list of Woodward Business Partners is available at **www.woodward.com/support**.

Woodward Factory Servicing Options

The following factory options for servicing Woodward products are available through your local Full-Service Distributor or the OEM or Packager of the equipment system, based on the standard Woodward Product and Service Warranty (5-01-1205) that is in effect at the time the product is originally shipped from Woodward or a service is performed:

- 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 is a flat-rate program and includes the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205).

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.

Charges for the Replacement/Exchange service are based on a flat rate plus shipping expenses. You are invoiced the flat rate replacement/exchange charge plus a core charge at the time the replacement unit is shipped. If the core (field unit) is returned within 60 days, a credit for the core charge will be issued.

Flat Rate Repair: Flat Rate Repair is available for the majority of standard 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. All repair work carries the standard Woodward service warranty (Woodward Product and Service Warranty 5-01-1205) on replaced parts and labor.

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 and carry with it the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205). 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 offers various Engineering Services for our products. For these services, you can contact us by telephone, by email, or through the Woodward website.
- 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. Emergency assistance is also available during non-business hours by phoning Woodward and stating the urgency of your problem.

Product Training is available as standard classes at many of our worldwide locations. We also offer customized classes, which can be tailored to your needs and can be held at one of our 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 many of our worldwide locations or 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 us via telephone, email us, or use our website and reference **www.woodward.com/support**, and then *Customer Support*.

How to Contact Woodward

For assistance, call one of the following Woodward facilities to obtain the address and phone number of the facility nearest your location where you will be able to get information and service.

Electrical Power Systems	Engine Systems	Turbine Systems
Facility -------------- Phone Number	**Facility -------------- Phone Number**	**Facility -------------- Phone Number**
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:	
Kempen --- +49 (0) 21 52 14 51		
Stuttgart -----+49 (711) 78954-0	Stuttgart -----+49 (711) 78954-0	
India -------------- +91 (129) 4097100	India -------------- +91 (129) 4097100	India -------------- +91 (129) 4097100
Japan -------------+81 (43) 213-2191	Japan -------------+81 (43) 213-2191	Japan -------------+81 (43) 213-2191
Korea--------------+82 (51) 636-7080	Korea--------------+82 (51) 636-7080	Korea--------------+82 (51) 636-7080
	The Netherlands -+31 (23) 5661111	The Netherlands -+31 (23) 5661111
Poland -------------- +48 12 618 92 00		
United States-----+1 (970) 482-5811	United States-----+1 (970) 482-5811	United States-----+1 (970) 482-5811

You can also contact the Woodward Customer Service Department or consult our worldwide directory on Woodward's website (**www.woodward.com/support**) for the name of your nearest Woodward distributor or service facility.

Technical Assistance

If you need to telephone for technical assistance, you will need to provide the following information. Please write it down here before phoning:

General
Your Name_____

Site Location_____

Phone Number_____

Fax Number_____

Prime Mover Information
Engine/Turbine Model Number_____

Manufacturer_____

Number of Cylinders (if applicable)_____

Type of Fuel (gas, gaseous, steam, etc)_____

Rating_____

Application_____

Control/Governor Information
Please list all Woodward governors, actuators, and electronic controls in your system:

Woodward Part Number and Revision Letter

_____

Control Description or Governor Type

_____

Serial Number _____

Woodward Part Number and Revision Letter

_____

Control Description or Governor Type

_____

Serial Number _____

Woodward Part Number and Revision Letter

_____

Control Description or Governor Type

_____

Serial Number _____

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/fuel ratio
Isoch	isochronous
CLI	command line interface
DIS	distributorless ignition system
EEPROM	electrically-erasable programmable read-only memory
EMC	electro-magnetic compatibility
GUI	graphic user interface
ITB	integrated throttle body
LC-50	Woodward system that incorporates LCS with an ITB and mixer
LCS	Woodward electronic engine governor that contains both a rotary actuator and a controller circuit board
MAP	manifold air pressure
MAS	main adjustment screw
MPU	magnetic pick up
OEM	original equipment manufacturer
stoichiometric	chemically balanced air/fuel ratio
ZPR	zero pressure regulator

Appendix B.
Configuration File

The GUI Tool presents the configuration files in a graphical format for editing and saving. This tool also creates a text file version of the configuration file that can be viewed and edited with any text editor. If there is ever any need to review the files in this form, this appendix presents the format. Consult the features description section for a more thorough review of the following parameters. This Appendix is intended only to be a decoder for the text version of the configuration file.

A configuration file contains 60 parameter entries spread across three major groupings—documentation/security, feature enable bits, and feature parameters. All parameter entries use the following format:
;
; parameter number:
; parameter name:
; comment:
; lower bound:
; upper bound:
;
actual value

Each line starting with a semicolon is considered a comment, and is ignored during a download. Parameter number relates a parameter's location in the file to a known memory address inside the control. Never change the order of parameters within a file—incorrect data may be downloaded into the control as a result. Parameter name is a mnemonic name given to a parameter so it is easier to identify. Parameter names typically reflect the name stored inside the control itself. A comment field is included with all parameters; this field of information helps explain the meaning of a parameter's value. Lower bound and upper bound are limits placed on a parameter's value. If the actual value of a parameter falls outside the lower or upper limits, then the file will not be downloadable into the control. Lines that do not start with a semicolon, and contain either a numeric or single-quoted ('xxx') string, are considered actual parameter values.

Generator Version Format (LC-50G)

Documentation and security parameters include:
- **Parameter #0: oem_free_form_text**: The OEM may use this parameter to record a configuration part number and revision level up to 20 characters in length. If the parameter is not used, the parameter value must still contain a set of single quotes ('').
- **Parameter #1: oem_security_key**: The OEM may use this parameter to key his controls to his distribution of dealer service tools.. If the OEM decides to not key his configuration files, then this parameter must still contain a set of single quotes ('').

Feature enable parameters include:
- **Parameter #2: hardware_configuration_register**: This parameter is used to select the direction of actuator rotation, configure AUX1 for analog or digital operation, and assign functions to alternate AUX input pins if necessary. The value of hardware_configuration_register is the sum of the bit values for each enabled option, as listed below:
    - **Bit 7** (value=128): rsvd, Reserved; setting this bit either way has no effect on the controller's operation.
    - **Bit 6** (value=64): A1anlg: when enabled, makes Aux 1 an analog
    - **Bit 5** (value=32): A1-5v: If AUX1 is an analog input and this bit is enabled, AUX1 is a 0–5 V input instead of a ±3 V input
    - **Bit 4** (value=16): 5060A1: If the 50/60 Hz select function is enabled, and this bit is enabled, then the selection function is based on the state of AUX1 instead of AUX4 when power is first applied to the governor.
    - **Bit 3** (value=8): isdpA2: If either the isoch/droop function or the aux bias/droop function is enabled, and this bit is enabled, then droop will be selected based on the polarity programmed into bit 1, and on the state of AUX2 instead of AUX4 when power is first applied to the governor.
    - **Bit 2** (value=4): ddA3: If the dual dynamics function is enabled, and this bit is enabled, then the function is based on the state of AUX3 instead of AUX4.
    - **Bit 1** (value=2): dpolLOW: If either the isosch/droop function or the aux bias/droop function is enabled, and this bit is enabled, then droop will be selected whenever the appropriate AUX input is left open or grounded. If this bit is not enabled, then droop will be selected whenever the AUX input is shorted to +12 V.
    - **Bit 0** (value=1): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
- **Parameter #3: feature_enable1**: This parameter is one of three used to turn on different functions within the control. Refer to Figure 1-1, the system block diagram, to see the relationship between bits, function names, and where they are within the control loop. The value of feature_enable1 is the sum of the bit values for each enabled option, as listed below:
    - **Bit 7** (value=128): cmode: Enabling this bit turns on the Governor State function. This function is required for all speed governor applications; it is not required for positioner applications.
    - **Bit 6** (value=64): ovspd: Enabling this bit turns on the Overspeed Error protection function when the governor state is 'run'.
    - **Bit 5** (value=32): fsafe: Enabling this bit turns on the Failsafe Error protection function when the governor state is 'run'.
    - **Bit 4** (value=16): rsvd, Reserved; setting this bit either way has no effect on the controller's operation.
    - **Bit 3** (value=8): relay: Enabling this bit turns on the Relay Control function when the governor state is 'error'.
    - **Bit 2** (value=4): fltst: Enabling this bit turns on the EE Fault Storage function when the governor state is 'error'.
    - **Bit 1** (value=2): actgt: Enabling this bit turns on the Actuator Gate function.

> o **Bit 0** (value=1): servo: Enabling this bit turns on the Position Control function. The Position Control function essentially overrides the Governor State function and translates a 0–5 V input into a desired position for the Actuator Control function.

IMPORTANT	The Configuration Error function does not have a bit in any feature_enable byte; it is permanently enabled to check for the presence or absence of a configuration file in the control during power up.

Parameter #4: feature_enable2: This parameter is one of three used to turn on different functions within the control. Refer to Figure 1-1, the system block diagram, to see the relationship between bits, function names, and where they are within the control loop. The value of feature_enable2 is the sum of the bit values for each enabled option, as listed below:

> o **Bit 7** (value=128): hzsel: Enabling this bit turns on the 50/60 Hz Select function when power is first applied to the governor.
> o **Bit 6** (value=64): idlrt: Enabling this bit turns on the Idle/Rated Select function.
> o **Bit 5** (value=32): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
> o **Bit 4** (value=16): rslwr: Enabling this bit turns on the Raise/Lower Adjust function .
> o **Bit 3** (value=8): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
> o **Bit 2** (value=4): droop: Enabling this bit turns on the Droop function.
> o **Bit 1** (value=2): auxbs: Enabling this bit turns on the Aux Bias function.
> o **Bit 0** (value=1): isodp: Enabling this bit turns on the Isoch/Droop Select function when power is first applied to the governor.

IMPORTANT	The Single Speed function does not have a bit in any feature_enable byte; it is the default speed setting function if none of the other speed setting functions are selected.
	The Isochronous function does not have a bit in any feature_enable byte; it is the default speed biasing function if none of the other speed biasing functions are selected.

Parameter #5: feature_enable3: This parameter is one of three used to turn on different functions within the control. Refer to Figure 1-1, the system block diagram, to see the relationship between bits, function names, and where they are within the control loop. The value of feature_enable3 is the sum of the bit values for each enabled option, as listed below:

- o **Bit 7** (value=128): bsdrp: Enabling this bit turns on the Aux Bias/Droop Select function when power is first applied to the governor.
- o **Bit 6** (value=64): duald: Enabling this bit turns on the Dual Dynamics function.
- o **Bit 5** (value=32): spgov: Enabling this bit turns on the Speed Control function.
- o **Bit 4** (value=16): adapt: This enables the auto-gain algorithm.
- o **Bit 3** (value=8): sfuel: Enabling this bit turns on the Start Fuel Limiter.
- o **Bit 2** (value=4): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
- o **Bit 1** (value=2): bfuel: Enabling this bit turns on the Boost Fuel Limiter function.
- o **Bit 0** (value=1): actrl: Enabling this bit turns on the Actuator Control function.

Parameter #6: speed_sensing_mode: This parameter is used to turn on different speed sensing functions within the control. Refer to Figure 1-1, the system block diagram, to see the relationship between bits, function names, and where they are within the control loop. The value of speed_sensing_mode is the sum of the bit values for each enabled option, as listed below:

- o **Bit 7** (value=128): ignition: Enabling this bit turns on the Ignition Speed Sensing function.
- o **Bit 6** (value=64): 2-stroke: Enabling this bit tells the Ignition Speed Sensing function that the ignition pulses present on pin 12 (IGN) are from a 2-stroke engine. Disabling this bit tells the ignition speed sensing function that the pulses are coming from a 4-stroke engine.
- o **Bit 5** (value=32): mpu: Enabling this bit turns on the MPU Speed Sensing function.
- o **Bits 2–0** (values 0-6): #cylinders: This set of bits specifies the number of cylinders for the Ignition Speed Sensing function.

Feature parameters include:

Parameter #7: failsafe_timeout_period: Specifies a timeout period for the Failsafe Error function between 0 and 512 milliseconds. Typical timeout value is 128 milliseconds.

Parameter #8: droop_percentage: Specifies the percentage reduction in engine speed for the Droop function when the actuator position equals full_load_actuator_position. Typical value is 10%.

Parameter #9: biasing_percentage: Specifies the percentage reduction/increase in engine speed for the Aux Bias function when the input voltage on AUX1 is –3 V, +3 V, 0 V, or 5 V. Typical value is 7%.

Parameter #10: start_fuel_limit: Specifies the maximum permitted shaft position when the Start Fuel Limiter function is enabled and the governor state is 'start1.' Typical value is same as full_load_actuator_position.

Parameter #11, #12, and #13: boost_pressure_volt1, boost_pressure_volt2, and boost_pressure_volt3: Specifies the x-points on the Boost Fuel Limiter curve.

Parameter #14, #15, and #16: boost_fuel_limit1, boost_fuel_limit2, boost_fuel_limit3: Specifies the y-points on the Boost Fuel Limiter curve.

Parameter #17: start_speed_threshold: Specifies the speed at which the Governor State changes from 'powerup' to 'start1.' Typical value is 64 rpm to detect engine cranking.

Parameter #18: run_speed_threshold: Specifies the speed at which the Governor State changes from 'start2' to 'run.' Typical value is 90% of the lowest speed_reference.

Parameter #19: overspeed_threshold: Specifies the speed threshold for changing the Governor State from 'run' to 'error' via the Overspeed Error function. Typical value is 10% to 20% above the highest speed_reference.

Parameter #20: reset1,: Primary set of dynamics for speed_reference1. Reset helps stabilize the engine/governor loop. Typical initial value is: reset=25%.

Parameter #21, #22, #23, gain11, gain12, gain13: Primary set of dynamics for speed_reference1. Gain affects engine load transient response and frequency of engine hunting. These are the y-points for the three point gain curve. The x-points are parameters #38, 39, 40.

Parameter #24: alternate_reset1,: Secondary set of dynamics for speed_reference1. Reset helps stabilize the engine/governor loop. Typical initial value is: reset=25%.

Parameter #25, #26, #27, alternate_gain11, alternate_gain12, alternate_gain13: Primary set of dynamics for speed_reference1.

Parameter #28: reset2, : Primary set of dynamics for speed_reference2.

Parameter #29, #30, #31, gain21, gain22, gain23: Primary set of dynamics for speed_reference2. These are the y-points for the three point gain curve. The x-points are parameters #38, 39, 40.

Parameter #32: alternate_reset2: Secondary set of dynamics for speed_reference2.

Parameter #33, #34, and #35: alternate_gain21, alternate_gain22, and alternate_gain23: Alternate set of dynamics for speed_reference2.

Parameter #36: compensation: Dynamic term common to all speed settings and **dynamics.**

Parameter #37: common_gain: Common to all speed settings and dynamics.

Parameter #38, #39, #40: gain_position1, gain_position2, gain_position3: Y-points for the three point gain curve. Common for all speed settings and all dynamics.

Parameter #41: gain_decrement: Used by auto-gain algorithm to decrement the gain by a predefined amount.

Parameter #42: gain_increment: Used by auto-gain algorithm to increase the gain by a predefined amount.

Parameter #43: min_gain: Used by auto-gain algorithm as lower limit.

Parameter #44: max_gain: Used by auto-gain algorithm to upper limit.

Parameter #45: rated_to_idle_delay: Specifies the amount of time to delay before ramping from rated speed (speed_reference2) to idle speed (speed_reference1) for the Idle/Rated Select function.

Parameter #46: speed_adjust_lower_limit: Specifies the lowest desired speed possible with the Raise/Lower Adjust function.

Parameter #47: speed_adjust_upper_limit: Specifies the highest desired speed possible with the Raise/Lower Adjust function.

Parameter #48, #49, and #50: proportional, derivative, and integral: Control coefficients for the Actuator Control function.

Parameter #51: events_per_engine_rev: Specifies the number of flywheel or gear teeth that pass the face of a MPU for one revolution of the engine's crankshaft.
Parameter #52, #53: speed_reference1, speed_reference2: Specifies the desired engine speeds depending on the enabled speed select function. Speed_reference1 is the default speed setting.
Parameter #54: steady_state: Used by auto-gain algorithm
Parameter #55: transient: Used by auto-gain algorithm.
Parameter #56, #57: speed_decrease_rate, speed_increase_rate: Specifies the ramping rates for the Raise/Lower Adjust function.
Parameter #58, #59: no_load_actuator_position, full_load_actuator_position: Specifies the 0% engine load and 100% engine load actuator positions for the Droop function.

Industrial Version Format (LC-50I)

An industrial configuration file contains 58 parameter entries.

Documentation and security parameters include:
- **Parameter #0: oem_free_form_text**: The OEM may use this parameter to record a configuration part number and revision level up to 20 characters in length. If the parameter is not used, the parameter value must still contain a set of single quotes ('').
- **Parameter #1: oem_security_key**: The OEM may use this parameter to key his controls to his distribution of dealer service tools.. If the OEM decides to not key his configuration files, then this parameter must still contain a set of single quotes ('').

Feature enable parameters include:
- **Parameter #2: hardware_configuration_register**: This parameter is used to select the direction of actuator rotation, configure AUX1 for analog or digital operation, and assign functions to alternate AUX input pins if necessary. The value of hardware_configuration_register is the sum of the bit values for each enabled option, as listed below:
  - o **Bit 7** (value=128): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
  - o **Bit 6** (value=64): A1anlg: If enabled, AUX1 is an analog input instead of a digital input.
  - o **Bit 5** (value=32): A1-5v: If AUX1 is an analog input and this bit is enabled, AUX1 is a 0–5 V input instead of a ±3 V input
  - o **Bit 4** (value=16): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
  - o **Bit 3** (value=8): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
  - o **Bit 2** (value=4): ddA3: If the dual dynamics function is enabled, and this bit is enabled, then the function is based on the state of AUX3 instead of AUX4.
  - o **Bit 1** (value=2): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.

- o **Bit 0** (value=1): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
- **Parameter #3: feature_enable1**: This parameter is one of three used to turn on different functions within the control. Refer to Figure 1-1, the system block diagram, to see the relationship between bits, function names, and where they are within the control loop. The value of feature_enable1 is the sum of the bit values for each enabled option, as listed below:
  - o **Bit 7** (value=128): cmode: Enabling this bit turns on the Governor State function. This function is required for all speed governor applications; it is not required for positioner applications.
  - o **Bit 6** (value=64): ovspd: Enabling this bit turns on the Overspeed Error protection function when the governor state is 'run'.
  - o **Bit 5** (value=32): fsafe: Enabling this bit turns on the Failsafe Error protection function when the governor state is 'run'.
  - o **Bit 4** (value=16): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
  - o **Bit 3** (value=8): relay: Enabling this bit turns on the Relay Control function when the governor state is 'error'.
  - o **Bit 2** (value=4): fltst: Enabling this bit turns on the EE Fault Storage function when the governor state is 'error'.
  - o **Bit 1** (value=2): actgt: Enabling this bit turns on the Actuator Gate function.
  - o **Bit 0** (value=1): servo: Enabling this bit turns on the Position Control function. The Position Control function essentially overrides the Governor State function and translates a 0–5 V input into a desired position for the Actuator Control function.

IMPORTANT | **The Configuration Error function does not have a bit in any feature_enable byte; it is permanently enabled to check for the presence or absence of a configuration file in the control during power up.**

- **Parameter #4: feature_enable2**: This parameter is one of three used to turn on different functions within the control. Refer to Figure 1-1, the system block diagram, to see the relationship between bits, function names, and where they are within the control loop. The value of feature_enable2 is the sum of the bit values for each enabled option, as listed below:
  - o **Bit 7** (value=128): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
  - o **Bit 6** (value=64): idlrt: Enabling this bit turns on the Idle/Rated Select function.
  - o **Bit 5** (value=32): 3-spd: Enabling this bit turns on the Three-Speed Select function.
  - o **Bit 4** (value=16): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
  - o **Bit 3** (value=8): rsvd: Reserved; this feature is not supported at this time. The bit should not be enabled.
  - o **Bit 2** (value=4): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.

- o **Bit 1** (value=2): auxbs: Enabling this bit turns on the Aux Bias function.
- o **Bit 0** (value=1): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.

IMPORTANT

The Single Speed function does not have a bit in any feature_enable byte; it is the default speed setting function if none of the other speed setting functions are selected.

The Isochronous function does not have a bit in any feature_enable byte; it is the default speed biasing function if none of the other speed biasing functions are selected.

- • **Parameter #5: feature_enable3**: This parameter is one of three used to turn on different functions within the control. Refer to Figure 1-1, the system block diagram, to see the relationship between bits, function names, and where they are within the control loop. The value of feature_enable3 is the sum of the bit values for each enabled option, as listed below:
    - o **Bit 7** (value=128): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
    - o **Bit 6** (value=64): duald: Enabling this bit turns on the Dual Dynamics function.
    - o **Bit 5** (value=32): spgov: Enabling this bit turns on the Speed Control function.
    - o **Bit 4** (value=16): adapt: This enable the auto-gain algorithm.
    - o **Bit 3** (value=8): sfuel: Enabling this bit turns on the Start Fuel Limiter.
    - o **Bit 2** (value=4): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
    - o **Bit 1** (value=2): rsvd: Reserved; setting this bit either way has no effect on the controller's operation.
    - o **Bit 0** (value=1): actrl: Enabling this bit turns on the Actuator Control function.
- • **Parameter #6: speed_sensing_mode**: This parameter is used to turn on different speed sensing functions within the control. Refer to Figure 1-1, the system block diagram, to see the relationship between bits, function names, and where they are within the control loop. The value of speed_sensing_mode is the sum of the bit values for each enabled option, as listed below:
    - o **Bit 7** (value=128): ignition: Enabling this bit turns on the Ignition Speed Sensing function.
    - o **Bit 6** (value=64): 2-stroke: Enabling this bit tells the Ignition Speed Sensing function that the ignition pulses present on pin 12 (IGN) are from a 2-stroke engine. Disabling this bit tells the ignition speed sensing function that the pulses are coming from a 4-stroke engine.
    - o **Bit 5** (value=32): mpu: Enabling this bit turns on the MPU Speed Sensing function.
    - o **Bits 2-0** (values 0-6): #cylinders: This set of bits specifies the number of cylinders for the Ignition Speed Sensing function.

Feature parameters include:

- **Parameter #7: failsafe_timeout_period**: Specifies a timeout period for the Failsafe Error function between 0 and 512 milliseconds. Typical timeout value is 128 milliseconds.
- **Parameter #8: biasing_percentage**: Specifies the percentage reduction/increase in engine speed for the Aux Bias function when the input voltage on AUX1 is –3 V, +3 V, 0 V, or 5 V. Typical value is 7%.
- **Parameter #9: start_fuel_limit**: Specifies the maximum permitted shaft position when the Start Fuel Limiter function is enabled and the governor state is 'start1.' Typical value is same as full_load_actuator_position.
- **Parameter #10: start_speed_threshold**: Specifies the speed at which the Governor State changes from 'powerup' to 'start1.' Typical value is 64 rpm to detect engine cranking.
- **Parameter #11: run_speed_threshold**: Specifies the speed at which the Governor State changes from 'start2' to 'run.' Typical value is 90% of the lowest speed_reference.
- **Parameter #12: overspeed_threshold**: Specifies the speed threshold for changing the Governor State from 'run' to 'error' via the Overspeed Error function. Typical value is 10% to 20% above the highest speed_reference.
- **Parameter #13: reset1**: Primary set of dynamics for speed_reference1. Reset helps stabilize the engine/governor loop. Typical initial value is: reset=25%.
- **Parameter #14, #15, #16, gain11, gain12, gain13**: Primary set of dynamics for speed_reference1. Gain affects engine load transient response and frequency of engine hunting. These are the y-points for the three point gain curve. The x-points are parameters #38, 39, 40.
- **Parameter #17: alternate_reset1**: Secondary set of dynamics for speed_reference1. Reset helps stabilize the engine/governor loop. Typical initial value is: reset=25%.
- **Parameter #18, #19, #20, alternate_gain11, alternate_gain12, alternate_gain13**: Primary set of dynamics for speed_reference1. Gain affects engine load transient response and frequency of engine hunting. These are the y-points for the three point gain curve. The x-points are parameters #38, 39, 40.
- **Parameter #21 : reset2**: Primary set of dynamics for speed_reference2. Reset helps stabilize the engine/governor loop. Typical initial value is: reset=25%.
- **Parameter #22, #23, #24, gain21, gain22, gain23**: Primary set of dynamics for speed_reference2. Gain affects engine load transient response and frequency of engine hunting. These are the y-points for the three point gain curve. The x-points are parameters #38, 39, 40.
- **Parameter #25: alternate_reset2**: Secondary set of dynamics for speed_reference2. Reset helps stabilize the engine/governor loop. Typical initial value is: reset=25%.
- **Parameter #26, #27, and #28: alternate_gain21, alternate_gain22, and alternate_gain23**: Alternate set of dynamics for speed_reference2. Gain affects engine load transient response and frequency of engine hunting.
- **Parameter #29: reset3**: Primary set of dynamics for speed_reference3. Reset helps stabilize the engine/governor loop. Typical initial value is: reset=25%.

- **Parameter #30, #31, and #32: gain31, gain32, and gain33**: Primaru set of dynamics for speed_reference3. Gain affects engine load transient response and frequency of engine hunting.
- **Parameter #33: alternate_reset3**: Secondary set of dynamics for speed_reference3. Reset helps stabilize the engine/governor loop. Typical initial value is: reset=25%.
- **Parameter #34, #35, and #36: alternate_gain31, alternate_gain32, and alternate_gain33**: Alternate set of dynamics for speed_reference3. Gain affects engine load transient response and frequency of engine hunting.
- **Parameter #37: compensation**: Compensation nulls out the lag effect of the actuator control loop. Typical initial value is: 50%.
- **Parameter #38: common_gain**:
- **Parameter #39, #40, #41: gain_position1, gain_position2, gain_position3**: Y-points for the three point gain curve. Common for all speed settings and all dynamics.
- **Parameter #42: gain_decrement**: Used by auto-gain algorithm to decrement the gain by a predefined amount.
- **Parameter #43: gain_increment**: Used by auto-gain algorithm to increase the gain by a predefined amount.
- **Parameter #44: min_gain**: Used by auto-gain algorithm as lower limit.
- **Parameter #45: max_gain**: Used by auto-gain algorithm to upper limit.
- **Parameter #46: rated_to_idle_delay**: Specifies the amount of time to delay before ramping from rated speed (speed_reference2) to idle speed (speed_reference1) for the Idle/Rated Select function.
- **Parameter #47, #48, and #49: proportional, derivative, and integral**: Control coefficients for the Actuator Control function.
- **Parameter #50: events_per_engine_rev**: Specifies the number of flywheel or gear teeth that pass the face of a MPU for one revolution of the engine's crankshaft.
- **Parameter #51: speed_reference1**: Specifies the desired engine speeds depending on the enabled speed select function. Speed_reference1 is the default speed setting.
- **Paramter #52: speed_reference2, speed_zone_1_to_2**: Secondary speed reference. Uses dynamics gain2x and alternate gain2x and reset 2
- **Parameter #53: speed_reference3, speed_zone_1_to_3**
- **Parameter #54: steady_state**: Used by auto-gain algorithm
- **Parameter #55: transient**: Used by auto-gain algorithm.
- **Parameter #56, #57: speed_decrease_rate, speed_increase_rate**: Specifies the ramping rates for the Raise/Lower Adjust function.

Appendix C.
Dynamics File Format

A dynamics file contains five parameter entries for the five available speed control gains. All parameter entries use the following format:

;
; parameter number:
; parameter name:
; comment:
; lower bound:
; upper bound:
;
actual value

Each line starting with a semicolon is considered a comment, and is ignored during a download. Parameter number relates a parameter's location in the file to a known memory address inside the control. Never change the order of parameters within a file—incorrect data may be downloaded into the control as a result. Parameter name is a mnemonic name given to a parameter so it is easier to identify. Parameter names typically reflect the name stored inside the control itself. A comment field is included with all parameters; this field of information helps explain the meaning of a parameter's value. Lower bound and upper bound are limits placed on a parameter's value. If the actual value of a parameter falls outside the lower or upper limits, then the file will not be downloadable into the control. Lines that do not start with a semicolon and contain a number are considered actual parameter values.

LCS Control Specifications

Specifications

Power Supply	12 V systems (8–16 Vdc) reverse polarity protection; must be fed from a Class 2 power source
Power Consumption	64 W maximum
Torque	0.34 N·m (0.25 lb-ft)
Mass/Weight	425 g (15 oz)

Control Characteristics

Speed Input and Range	Magnetic pickup, ignition coil input, or DIS input
MPU input	100 to 12 000 Hz
IGN input	1, 2, 3, 4, 5, 6, & 8 cylinder engines with rated speeds of 1200–4000 rpm
Engine Type	2-cycle or 4-cycle gasoline, diesel, or gaseous fuel
Target speed	Programmable
Actuator Torque	High-efficiency torque motor delivers 0.34 N·m (0.25 lb-ft) (standard model) over 60° travel range to operate fuel or air control

Steady State Speed Regulation	Fuel Type:	Gasoline	Diesel	Gaseous
	MPU Input:	±0.35%	±0.25%	±0.35%
	Ignition Input:	±0.50%	n/a	±0.50%

Functions/Auxiliary Inputs

Function Options	Isochronous speed (50 or 60 Hz), multiple speeds, two or three speed, droop, dual dynamics, adjustable max fuel stop, manifold air pressure-biased fuel limiter
Programmable	Through 12-pin Deutsch connector
Aux1 Options	Auxiliary load sharing, remote speed setting, MAP fuel limiting, 50/60 Hz select, isochronous load sharing/droop select
Aux2 Options	Lower speed, isochronous speed control/droop select, isochronous load sharing/droop select, idle/rated select, three speed select
Aux3 Options	Raise speed, dual dynamics select, three speed select
Aux4 Options	50/60 Hz select, isochronous speed control/droop select, isochronous load sharing/droop select, dual dynamics select, three speed select
Aux5 Options	Is permanently configured as an output to drive a relay

Environment

Ambient	
Operating Temperature	–40 to +85 °C (–40 to +185 °F)
Storage Temperature	–40 to +125 °C (–40 to +257 °F)
EMI/RFI	EN50081-1 (emissions)
	EN50082-2 (immunity)
Humidity	US MIL-STD 810E, Method 507.3, Procedure III
Salt Spray	US MIL-STD 810E, Method 509.3, Procedure I
Shock	US MIL-STD 810E, Method 516.4, Procedure I
Random Vibration	US MIL-STD 202F, Procedure 214A, Test Condition ID
Drop	SAE J1211, Paragraph 4.8.3 (modified)
Thermal Shock	SAE J1455, Paragraph 4.1.3.2
Dust	SAE J1455, Paragraph 4.7
Pressure Wash	A modified SAE J1455, Paragraph 4.5
Fluid Resistance	A modified SAE J1455, Paragraph 4.4
Inlet Pressure	Sealed shaft bearings: 2 bar (29 psi) gage
	Standard shaft bearings:0.068 bar (1 psi) gage

Compliance

UL/cUL	Listed (UL requires a Class 2 power source)
CE	Compliant
Other	89/392/EEC Machinery Directive
	Reliability and Quality Goals

The LCS 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.

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