SELECTRONIX, INC.
WOODINVILLE, WA

SUPERSTEP SERIES 4000

SEQUENCING STEP

CONTROLLERS

INSTALLATION & OPERATING

ADDENDUM

PROPORTIONAL OPTIMIZED PROGRESSIVE SEQUENCING (POPS)

for Proportional Gas Valve

And

PROGRESSIVE PROGRESSIVE SEQUENCING (PPS)

"LEAD/LAG" CONTROL

for Staged-Electric Boilers

Rev. 05/25/17

Contents

1 Introduction

This addendum describes the Selectronix "Lead/Lag" control for both gas and electric boilers using various configurations of SLC4000 controllers. The "Lead/Lag" control improves on the traditional Lead/Lag control in that there is no longer a dedicated Lead or Lag unit, as the utilization of the burners, in a gas boiler, or the elements in an electric boiler are continually being sequenced as the demand varies. This method accomplishes the goal of Lead/Lag control in that it assures that all the components are utilized in an equal fashion. After a no demand state, the next step to activate when the demand returns is the following step after the last step on. This is true progressive sequencing of the "Lead" unit. For POPS, the next step to come on will always start at the 1st step of the next boiler in sequence, ensuring full modulating range of the new Lead boiler.

There are various control configurations for different configurations:

1) **Proportional Optimized Progressive Sequencing (POPS) "Lead/Lag" Control is for controlling *up to 4 boilers* equipped with proportional fuel valves.** The POPS control is a derivative of the electric boiler step controls, and operates in a similar fashion by progressively sequencing to successive boilers upon demand change. The proportional demand is distributed among the available boilers in the same fashion as standard step controls, with an important difference. The flame control output is optimized such that fractional valve settings are combined into a single unit, maximizing burn efficiency. The "Lead/Lag" concept is replaced by control that continually and equally balances the operation across all available boilers!
    - An **SLC4000-1** is installed in each boiler and is connected in a daisy-chain fashion by SLC4020 cascading cables.
    - A Burner Enable relay output is energized on the master as well as each expander (slave) unit, whenever an output signal is active on that particular controller.
    - When demand goes to 0, an optimizing feature advances the sequence such when the demand returns, the next step to come on will be the 1st step of the next boiler in sequence. This ensures that the new Lead boiler has the full modulating range available.

2) The **Progressive Sequencing (PS) "Lead/Lag" for boilers operated in "Full On/Full Off"** mode **may be used for *up to 33 boilers***. A single boiler operates as a proportional "trim" unit.
    - An **SLC4000-8-01** controller is used for up to 9 boilers.
        - If a boiler is to operate as a trim unit, it must be equipped with a proportional fuel control.
    - Up to 3 additional **SLC4000** units may be cascaded to control up to 33 boilers.

3) **The Progressive Sequencing (PS) "Lead/Lag" for electric boilers utilizes a separate SLC4000 unit for each boiler, for control of *up to 4 boilers***. The "Lead" unit is configured as the master, while the remaining boilers are configured as expansion units. Continuous "Lead/Lag" control is accomplished by spreading the wear continually across all relays and contactors. After a "no demand" condition occurs, the next stage to operate is the one following the last stage that was turned off, for true progressive sequencing. An SLC4000 equipped with a vernier output may be used if an SCR is desired for a trim capability.
    - An SLC4000 controller is required for each of the boilers, up to 4. The controller is set for the desired stages of the individual boiler.
    - An SLC4000-4-01 or SLC4000-8-01 is required as the master unit, if a 0-10V dc controlled SCR power unit is desired.

The Selectronix "Lead/Lag" control is fully compatible with the Selectronix Building Management Interface Controls. See SLC4075, Touch Screen Gateway and SLC4060 Process Gateway for further information.

2 POPS "Lead/Lag" Control for Oil or Gas Boilers

The **Proportional Optimized Progressive Sequencing (POPS) "Lead/Lag"** Control uses a modified 8 step sequencer in each of up to 4 boilers, the **SLC4000-1**. This board sequences as if there were 7 relays installed. As the demand changes, "steps" are added or subtracted in a progressive sequence in a first on/first off order. A 0-10V dc output is produced in proportion to the number of active "steps" for a 14.2% resolution. The output of each of the boards is ***optimized so that it favors a 50% or higher signal***, thus maximizing the overall burner efficiency! The setup is very easy, as the only *required* non-default DIP switch settings are for the input signal on the master and the addresses on the expander units.
Each SLC4000-1 is connected to another in a daisy-chain fashion by cascading cables. The communication uses the RS485 protocol so that the boilers may be separated up to a theoretical 4000 cable feet, from the first to the last boiler. The proportional demand is distributed among the available boilers in the same fashion as standard step controls, with an important difference. The "Lead/Lag" concept is replaced by a control that continually, optimally, and equally balances the operation across all available boilers. Local/Remote control is optionally available by providing a switch from the SLC4000-1 output to a local signal.

The POPS Lead/Lag operates pretty much like the standard sequencer with multiple slave units. The difference is that each unit produces an analog voltage equal to the proportion of stages on. For example, if 6 steps are in, the output is 8.6 volts.
The optimization occurs when 2 units have only a few steps on. Say there are 3 SLC4000-1 units. The first has 7, 2nd has 7 and the 3rd has 4 on. The corresponding output is 10v, 10v and 5.7v. Now say the demand drops so stages start coming off the 1st unit, where it would normally stop at 3 steps on. Now the first unit has 3, 2nd unit has 7, and last unit has 4 steps on. The master will sequence the units until the first unit has 0 and the 2nd and 3rd units have 7 steps on. The resultant voltage output is 0v, 10v, and 10v. POPS versions prior to 5.0/7.0 have a slightly earlier state at which it performed the optimization. See Section 10 for the POPS optimizing control states.

- The first 7 LEDS show the exact fraction of the 10v signal, as well as DS10 that varies proportionately in brightness.
- The 8th LED is the Burner Enable signal and is ON, whenever there is an active proportional output on this particular controller. This output is available on the master as well as the expansion units.
- An optimizing feature for burner control after the demand has gone to 0, is that the next boiler in sequence starts with the 1st step. This ensures that the new Lead boiler has the full modulating range.
- ***Special feature***: ***By adding an additional SLC4000-1 as the master controller, each of the slave units may be powered off individually without affecting the operation of the remaining slave units. The master automatically adjusts for remaining online slave units.***
    - ***If our Building Management Interface is used with an optional Classic Lead Lag (CLL) enabled POPS unit, individual boiler enable/disable is available for all boilers, while allowing the native POPS algorithm.***

2.1 Required Control Components

An SLC4000-1 is required for each boiler. One boiler is designated as the master, and the remaining are configured as expanders with unique addresses. An SLC4020-x cascading cable is used to connect the units. All SLC4000s must be a POPS unit or a standard SLC4000 with the relays in-service set to 7.

2.2 Voltage Driver Output

- SLC4000-1 provides a 0-10V dc proportional output at TB7 (+) and TB8, signal common (-).
- Potentiometer RV2 is delivered fully counterclockwise for normal 0-10V dc output, when all steps are on. The output may be adjusted using RV2 so full output is achieved before all the steps are on.

3 PS "On/Off Lead/Lag" Control for Oil or Gas Boilers

Up to **33 boilers** may be controlled using the Progressive Sequencing (PS) "On/Off Lead/Lag" control with an optional proportional control of a single boiler. The PS method of "Lead/Lag" control uses a standard **SLC4000-x** sequencer to control the boilers. The progressive sequencing results in a continually rotating and balanced usage of the boilers without having to set timers or other programmed settings, resulting in intuitive setup and operation. Use an **SLC4000-x-1** for systems with a single proportional burner control.

3.1 Required Control Units

Each boiler is connected to a relay output which is used to enable burner in the "high flame" mode. The required number of relays is equal to the number of boilers to be controlled. Use any combination of **SLC4000-4** or **SLC4000-8** units, as required, to provide a separate relay for each boiler. Add an interposing relay for each SLC4000 pilot relay output in order to provide a dry contact pair for each burner control. To control a boiler with a proportional burner control, use an **SLC4000-8-01**, **SLC4000-8-03**, **SLC4000-4-01** or **SLC40004-03** as the master controller. These units have a 0-10V dc output which is used to control the proportional flame controller. Set the master controller to use 7 relays, and use the alternate function relay #8 as the burner enable for the proportional control. The -03 suffix is for a unit that also is configured for a 4-20ma load limit input.

3.2 Control Unit Separation

Use cascading cables SLC4020-x to connect the various SLC4000 units. The communication between units is via RS485 and thus the control units may be separated by a theoretic distance of up to 4000'. Note that as distances increase, it may be necessary to add terminating resistors at both ends of the network. Use SLC4029, RS485 terminating adapter if required.

4 PPS "Lead/Lag" Control for Electric Boilers

4.1 Multi-Step Control With or Without Vernier Output

Standard **SLC4000-4 or SLC4000-8** are used to control a "Lead/Lag boiler array of up to **4 boilers** which have less than or equal to 8 steps per boiler. Each "Lead/Lag" boiler is equipped with an individual SLC4000-4 or -8, which are cascaded together. As demand varies, relays are activated in a first-on-first-off manner across all connected boilers, spreading the wear evenly over all the elements. There are no timers or other tasks required to ensure that the goal of equal wear is achieved.
If a vernier output is desired to control an SCR power unit, then use an **SLC4000-4-01 or SLC4000-8-01** as the master unit.

4.2 Boilers with Extended Sequencer Chains or a SCR-only Loads

Use an **SLC4000-1** with firmware version V4.30+ configured for PPS mode by setting DIP switch SW2-6 ON. This makes the unit the same as the former **SLC4000-1-01 PPS (Proportional Progressive Sequencing)** unit.
This configuration is used to control a "Lead/Lag" boiler array of up to 4 staged electric boilers which may have up to ***32 elements per boiler.*** Each boiler is equipped with an Extended Sequencer Chain OR an SCR-only load. An Extended Sequencer Chain is an additional SLC4000 master with or without expansion units. The extended sequencer SLC4000 master is driven by the proportional output of the PPS unit. The control is the same as **POPS** without the flame optimizing feature, which is unnecessary with electric loads. Up to 4 **SLC4000-1** units may be cascaded to control up to **4 boilers**. With firmware V4.30+ the analog output of the PPS unit provides ***full range analog output*** for the unit at the head of the sequencing.

Tip: ***If the master PPS is not used to control a boiler, any of the remaining boilers may be taken off line at any time. The system automatically reconfigures to control the remaining online boilers. This configuration, however limits the maximum boilers to 3.***

5 SLC4000-1 Settings and Features

5.1 Unit Configuration – DIP Switch Settings

5.1.1 Master

See the SLC4000 Installation and Operating Manual to configure the DIP switch settings for signal input, sequencing mode, operational mode, On and Off delay. Set SW1-7 and SW1-8 to off for the master.

5.1.2 Expansion Units

The only applicable DIP switches are SW1-7 and SW1-8 which configure the unit's address.

5.1.3 Relays In-Service

The quantity of relays in-service is internally set to 7 for both master and expansion units. The number of phantom steps is 7 for a 14% proportional output resolution.
For multiple boiler systems where individual boilers are to be disabled, add an additional SLC4000-1 as a zero-output master. This master mode is set by SW2-8 to On. With this configuration, the master unit is only used to control the expansion units and has no output. The benefit of this configuration is that power to any of the expansion units may be turned off, and the system will be automatically reconfigured using the remaining units to eliminate the inactive stages.
If our Building Management Interface is used with an optional Classic Lead Lag (CLL) enabled POPS unit, individual boiler enable/disable is available for all boilers, while allowing the native POPS algorithm

5.2 Burner Enable, Relay #8

Relay #8 is the Burner Enable relay, and is activated anytime there is 1 or more phantom steps activated on the individual board. This relay is provided on the master as well as all expansion units.

5.3 POPS output

With firmware version V4.30+, POPS mode is set by SW2-8 OFF. The voltage driver output from an **SLC4000-1** is proportional to the number of phantom steps on. The POPS algorithm combines a fractional number of steps by sequencing the steps until they are combined onto a single unit. The voltage output with V4.30 is full analog resolution for a single unit, or for the head unit for a multiple unit system.

5.4 PPS output

With firmware version V4.30+, PPS mode is set by SW2-6 ON, which is equivalent to the former SLC4000-1-01. PPS output is the same as the POPS output without the flame optimizing feature. This unit is used for "Lead/Lag" control of an array of up to 4 boilers, where each boiler requires more than 8 steps each. The proportional output is used to drive an ***Extended Sequencer Chain*** comprised of standard SLC4000-x sequencers. For boiler arrays with less than 8 steps per boiler, use the standard SLC4000-x.

5.5 Dynamic Reconfiguration

Should one of the boilers controlled by an expansion unit experience a lockout, the master reconfigures the system automatically, such that there are no discontinuities with the other expansion units.

5.6 Proportional Output Trim Potentiometer, RV2

The voltage driver output from an SLC4000-x-01 is adjustable by potentiometer RV2. For a 0-10V output proportional to the quantity of active steps, turn RV2 to the full counterclockwise position. The potentiometer provides for up to a 2X gain, so that the full output may be trimmed to achieve full output with less than the maximum steps activated.

5.7 PS "Full On/Full Off" with a Single Proportional output

This mode uses the standard SLC4000-x using the relay outputs as the "Full On/Full Off" outputs. The single proportional output is from the vernier (voltage driver) output on the master unit. It provides the trim level between the next sequential boiler, on either increasing or decreasing demand.

5.8 "Lead/Lag" Controller Selection Guide

Type	Control Algorithm	Control	Max Boilers SLC4000-1 POPS Mode	Max Boilers SLC4000-1 PPS Mode	Max Boilers SLC4000-4 or SLC4000-8	SLC4000-4-01 SLC4000-4-03 SLC4000-8-01 SLC4000-8-03
Oil or Gas	POPS	Proportional with Burner Enable	Up to 4 *1 #8 relay is burner enable for the proportional output	Up to 4 *1 #8 relay is boiler enable		
Oil or Gas	PS	On/Off using Burner Enable			Up to 32	
Electric	PS	Multi-step proportional each boiler			Up to 4 with each boiler with 8 steps or less	
	PS	Multi-step All On/All Off with proportional				Up to 33
Electric	PPS	Extended sequencer chain or SCR only		Up to 4 with each boiler with 32 steps or less	Extended Sequencer Chain is driven with proportional output of SLC4000-1 PPS mode	

*1 Up to 3, if master is not used to control a boiler. This configuration enables any expansion unit to be taken off-line without affecting the operation of the remaining boilers.

6 Remote LED Panel

SLC4000-1 is compatible with SLC2170-08 and will show the proportional signal using 8 LEDS.

7 Local/Remote Control

Local control of the burner is achieved by providing an external DPDT switch between the voltage driver output and the burner control.

8 Building Management Interface

The Selectronix "Lead/Lag" control is fully compatible with the Selectronix Building Management Interface Controls. See SLC4075, Touch Screen Gateway and SLC4060 Process Gateway for further information.

8.1 Scheduled "Lead/Lag" Sequencing

Should the user desire to sequence the controller on a scheduled basis, in addition to the normal demand-based sequencing, the remote load limit feature may be engaged momentarily. This will cause a number of "steps" to be removed from the tail, which were the first ones energized. When the load limit is returned to the original setting, the same quantity-of-steps are progressively added to the head end of the energized steps. This control might be used for systems which have little change in demand and the user wishes to sequence at a minimum frequency. Our Building Management Interface combined with a Classic Lead Lag SLC4000, allows timed Lead unit change, as well as individual enable/disable of any of the boilers, including the master. ***Classic Lead Lag provides various profiles for the output, as well as the ability to use the POPS algorithm!***

8.2 Important SLCnet Wiring Consideration for Limit Controls

SLCnet is the communication link between the Touchscreen Gateway (TSGW), the Process Gateway (PGW), and the SLC4000 (S4K) master. These units must remain powered during a control limit event for inter-unit communication. Source the SLC4000 RLYCOM terminal from the limit string to ensure that all loads are disconnected during the limit event.
If the TSGW has been configured to report the limit condition and to switch the AUX/BMS switch to the AUX, position, ensure that any control connected to the S4K command input terminals source a zero command. Any connected auxiliary control should be sourced from the limit string. If there is no auxiliary controller, the S4K terminals may be left open if the configuration switches are set to 4-20ma, 0-10V, or 2-10V.

9 UL Recognized Component

SLC4000 controllers are a UL Recognized Component for both US and Canada. File Number E124742.

10 Version 5.00/7.00 POPS Optimizing States

- **Mod** is the remainder after dividing the quantity of relays ON by 7.
- **Tail** is the First relay to be turned off, when using progressive sequencing
- **Head** is the last relay turned off, when using progressive sequencing.
- **Seq?** is whether the steps will be automatically sequenced when the system is quiescent

Mod	Tail S4K	Head S4K	Seq?		Mod	Tail S4K	Head S4K	Seq?		Mod	Tail S4K	Head S4K	Seq?
0	6	1	Y		**3**	6	4	N		**6**	5	1	N
	5	2	Y			5	5	N			4	2	N
	4	3	N			4	6	N			3	3	Y
	3	4	Y			3	7	N			2	4	Y
	2	5	Y			2	1	Y			1	5	Y
	1	6	Y			1	2	Y			0	6	N
	0	7	N			0	3	N					
1	6	2	Y		**4**	6	5	N					
	5	3	N			5	6	N					
	4	4	N			4	7	N					
	3	5	N			3	1	Y					
	2	6	N			2	2	Y					
	1	7	N			1	3	Y					
	0	1	N			0	4	N					
2	6	3	N		**5**	6	6	N					
	5	4	N			5	7	N					
	4	5	N			4	1	Y					
	3	6	N			3	2	Y					
	2	7	N			2	3	Y					
	1	1	Y			1	4	Y					
	0	2	N			0	5	N					