APPLICATION NOTE

Product Family: Solo Controllers

Number: AN-LC-011

Subject: Overview for setting up PID control and optionally ramp/soak on Solo Controllers

Date Issued: 6-24-2010

Revision: Original

OVERVIEW
If you are unclear on how to perform a specific step, then follow the step number to read more details for that step.

STEP 1: INTRODUCTION
PID control introduction. Quick Start Sections: 12-1, 12-2, or 12-3 for input selection.

STEP 2: DETERMINING YOUR PROCESS TYPE
Determine whether you need heating, cooling, heat/cool, or cool/heat control and whether your main control (OUTPUT 1) will be analog or discrete.

STEP 3: TIME PROPORTIONING CONTROL
If you're using discrete outputs for PID control, you will need to determine your time period for the output.

STEP 4: PID CONTROL SETUP
Set the controller for the type of PID control you will use in your process (heat, cool, heat/cool, cool/heat). Quick Start Sections: 13-2, 13-4, 13-6, or 13-8 to set up the loop type with PID control.

STEP 5: AUTOTUNE
Perform an autotune to teach the controller about your process. Quick Start Sections: 13-1.

STEP 6: RAMP/SOAK CONTROL
If you need to perform a sequence of setpoints to complete your process, set up a ramp/soak profile. Quick Start Section: 13-10.

STEP 1: INTRODUCTION

The Solo controller can be set up for two forms of automatic process/temperature control.

The first and easiest to set up and use is the ON/OFF control mode. This works like the thermostat in your house, where the output turns on if the temperature goes below (if you're heating) or above (if you're cooling) the thermostat setpoint (SP). This form of control is less accurate and provides a wider band of temperature drift around the setpoint (SP), but for some applications it provides a sufficient degree of control. If it doesn't provide the degree of control you need in your process, then the other form of automatic control is the PID control.

PID control uses a mathematical algorithm (formula) to try and simulate degrees of control of the output. By adjusting the output in smaller steps instead of just full on or full off, you can generally provide more accurate, smaller levels of change in the control output and therefore smaller changes in the process variable (PV) drift around the setpoint (SP).

In the Solo controller setting up the controller to perform PID control has a few more steps than setting one up for ON/OFF control. This overview will describe each step to make it simpler to use PID control in your application.

Regardless of which control mode you will eventually use, you must set up the input signal (process variable or PV) for the Solo first. The Quick Start Guide, which comes with the controller you order as well as being downloadable from our website, breaks the setup of the controller into various steps and will be used to direct this overview. Section 12 of the Quick Start Guide breaks the input (process variable or PV) into various sections: Thermocouple or RTD, Voltage Input, or Current Input. Use the appropriate section to set up your input and verify you are reading a valid signal.

STEP 2: DETERMINING YOUR PROCESS TYPE

Once the input is working correctly, you have to focus on the control signals you will be using in your application.

There are many different types of devices that can be controlled by the Solo, depending upon which output type you need and select. The discrete outputs on the Solo, the relay output or voltage pulse outputs are designed to control things that can only be turned ON or OFF. Such devices as relays, or contactors, or even direct power connections to heaters or similar devices can be controlled with the relay or voltage pulse outputs of the Solo. The relay output allows the Solo to control a voltage and current ON and OFF directly from the Solo output. The voltage pulse signal is designed to switch a DC input solid state relay ON and OFF, which can be used to control devices without the need for moving mechanical parts. Some devices, like variable frequency drives can provide a greater degree of control by accepting a 0-10V or 4-20mA analog signal to represent 0-100% power. With these types of devices, the analog outputs available on output 1 of the Solo (0-10V or 4-20mA) can provide more precise control. Which output signal you select for your Solo controller is determined by

what type of device you will be controlling with the Solo.

The Solo refers to everything as a temperature reference, but it is really a process controller, so it can just as easily control flow, or level, or speed, or any other process that will work within the Solo response and control rates. In your application, the way to determine whether you want to do heating or cooling in the Solo's terminology is to determine which way the input (process variable or PV) signal changes when a defined direction of the output is changed. Specifically, if the output signal increases from full OFF towards full ON, or even if it just goes from OFF to ON, does the process variable (PV) signal increase (start going higher) or does the process variable (PV) signal decrease (start going lower)? If the process variable (PV) signal increases when the output value increases, then that's a heating control loop. If the process variable (PV) signal decreases when the output value increases, then that's a cooling control loop. If you are only doing a heating or cooling type application, the Solo will only allow you to use the first control output to do this control. That's why the available analog outputs are only available on output 1, the first control output. But there is another control option. In some cases, like extruder controls, you may need to do heating and cooling from the same controller for the same loop. The Solo can do heat/cool control for a single loop if your application has one control for the heating part and a different control for the cooling part. The first control output can be a discrete output (like a relay or voltage pulse) or it can be an analog output like a 0-10V or 4-20mA signal. This is determined by which model you buy. If your second control device can be controlled with a discrete output like a relay contact or voltage pulse then you can use the Solo to do heat/cool or cool/heat type loops as well. The important things to define for your application is:
1. Do you only need one output for your process? (Heating or Cooling)
2. Do you need two outputs for your process? (Heating/Cooling or Cooling/Heating)
3. If you only need one output what type of signal do you need to control the device? (Relay Contact, Voltage Pulse for Solid State Relay, 0-10V, 4-20mA)
4. If you need a second output what type of signal do you need to control that device? (Relay Contact, Voltage Pulse for Solid State Relay)

STEP 3: TIME PROPORTIONING CONTROL

The biggest difference between a discrete output (ON or OFF) and an analog output, when dealing with PID, is that the PID control value is going to be a percentage value that the controller calculates to cause the process variable (PV) to match the setpoint (SP) value. So if you have a discrete output, then you have to simulate a variable output with just ON or OFF. The most common method of doing this is called time proportioning control. Essentially, instead of varying the amount of output (which you can't do if it can only be OFF or ON), you vary the amount of time the output is on in a preset time limit, thereby simulating a percentage output over time. That's why the Solo adds one more parameter for PID if the output is discrete. If you're doing a heating loop, the time period for discrete output is called Heat Period, if you're doing a cooling loop, the time period is called Cool Period. If the period is for PID for the second output,

it's call Heat/Cool Period. In any of the cases, though, you enter the time, in seconds, that represent how long the output would stay on to create a 100% output. Once that value is established, the PID loop controls the output based on the time period. So if you select 10 seconds as your heat period, then every 10 seconds the PID looks at the % output the PID controller wants the output to be, multiplies that output value (0-100%) by the time period, and that's how long the output will be on for the next 10 seconds. So, for example, if the controller wants the output to be on at 40% output, the discrete output would be on for 4 seconds and off for 6 seconds, then it would look at the desired output again and start over for the next 10 seconds. While this isn't the same as a real analog output, it comes much closer than just the ON/OFF control that a standard thermostat can do and generally provides better control.

STEP 4: PID CONTROL SETUP

So with this information, you should be able to determine what type of output your Solo controller has (analog or discrete) and what type of PID control you want to perform (heat, cool, or heat/cool). You're ready to set up the control portion of the Solo. Section 13 of the Quick Start Guide covers all the different configurations of output control. It mixes the two methods, ON/OFF control and PID control, with heating, cooling, heat/cool, and cool/heat. Since we're discussing PID control specifically, notice that section 13-1 covers PID Control Setup. We'll be visiting this section once we've told the controller what type of control we're going to use, which will be PID and either heat, or cool, or heat/cool or cool/heat. The appropriate part of section 13 is where we set up the controller for our choices.

Once we've set the controller for PID control and the type of process (heating or cooling or both), the next step is to set up the PID Control Setup 13-1. If you look over 13-1, you'll notice that the first part of this section covers the different PID groups. This can be a powerful feature that allows for more precise PID tuning over a wide range of setpoint (SP) values, but for our purposes, you should leave the PID group to one of the standard settings (PID0, PID1, PID2, or PID3). Whichever group is selected will be the PID group we'll autotune and then use to run the controller in PID mode, or optionally in the ramp/soak mode.

STEP 5: AUTOTUNE

The autotune feature in the Solo controller is a method of trying to determine the values for the parameters the PID loop uses to control your specific process. It does this by controlling the output and measuring the changes the output produces in the process variable (PV) input signal. During autotune, the controller makes the output increase and decrease to cause the process variable (PV) to change above and below the setpoint (SP) several times and measures how the process variable (PV) changes. The measurements it makes are used in a formula to produce proportional (P), integral (I), and derivative (D) values (as well as a few other parameters), which should ideally be the correct values to control your process. Sometimes these values are less than ideal, however. In that case, the only other option is to manually adjust these parameters to

provide better control. Unfortunately, it is outside our ability to teach sufficient PID theory to tell someone how to tune a controller for a specific application. Manually tuning a controller for a specific application requires a level of experience in PID tuning and an understanding of the underlying factors that affect the process you're trying to control.

Depending upon the speed of your process, you may want to take extra steps before starting the autotune in order to reduce the amount of time required. The autotune LED on the face of the controller starts blinking as soon as you set autotune ON in the controller. It immediately tries to drive the output to the setpoint (SP) on the face plate. You should make sure this setpoint (SP) is at, or in the midrange of your normal operating process variable (PV) value. So if you normally operate your process at a setpoint (SP) of 250, then make sure that's the current setpoint (SP) before you turn on autotune. If you run your process at several different setpoints (SP) depending upon what product you're running, then choose a setpoint (SP) that's near the middle of your normal range. So if you normally operate your process at 150 to 200, then make the setpoint (SP) 175 before you begin autotuning. For most processes this will provide the best autotuning setup. You can provide more precise control by using multiple PID groups and autotuning each of up to four different groups with their own setpoint (SP) value, but this is a more advanced configuration and is beyond what's being discussed in this document. Call into our Technical Support Department to discuss this type of configuration. Once you start the autotune process, the controller must drive the output to make the process variable (PV) cross over the setpoint (SP) value. Since the tuning parameters out of the box are at default values, it may take the Solo controller a lot of time to get the process variable (PV) at or over the setpoint (SP). The autotune process must make the process variable (PV) cross over and under the setpoint (SP) several times before it can complete the measurements and finish the autotune process. To reduce the time the Solo needs to get the process variable (PV) over the setpoint (SP), you can place the Solo unit in MANUAL control before autotuning. Then set the manual output to 100% (or whatever value you are comfortable with in your process) and thereby drive the output to a constant level to make the process variable (PV) change more quickly. Of course, if your process is relatively fast or the difference between the startup and operating process variable (PV) is fairly small you may not need to do this. However, if you set the output control to manual, as soon as the process variable (PV) crosses the setpoint (SP) value, set the Solo back to PID control mode and the enable the autotune, as described in section 13-1 of the Quick Start Guide.

The autotune process will complete after it has measured the process variable (PV) response as it crosses over and under the setpoint (SP) several times and the AT LED will stop blinking. A successful autotune means the controller has adjusted the P, I, and D parameters (and a few others) to make the Solo more responsive in your process. The final test is to verify that changing the setpoint (SP) will cause the Solo to adjust the output and therefore the process variable (PV) to match the new setpoint (SP) as quickly as possible with a minimum of over/under shoot. If all you want to do is control your process at a specific setpoint (SP) you should be finished.

STEP 6: RAMP/SOAK CONTROL

The last option allows you to control your process with a profile of setpoints (SP) and times instead of just holding one setpoint (SP). If you want to control your process with a profile, this is typically called a ramp/soak profile, known as the PROGRAM mode in the Solo controller. Section 13-10 gives an example of the ramp/soak mode in the Quick Start Guide. The Solo controller has up to 8 different profiles or 'patterns', each of which can have up to 7 steps. If you need more than 7 steps, you can set a pattern to jump to a different pattern at the end of the current one, thereby connecting multiple patterns together to make larger ones.

The ramp/soak control mode only uses the PID control. It won't use ON/OFF control, so you must set up the PID control so that it's working satisfactorily as a PID mode controller before you will get satisfactory control from the ramp/soak mode.

Technical Assistance: If you have questions regarding this Application Note, please contact us at 770-844-4200 for further assistance.