

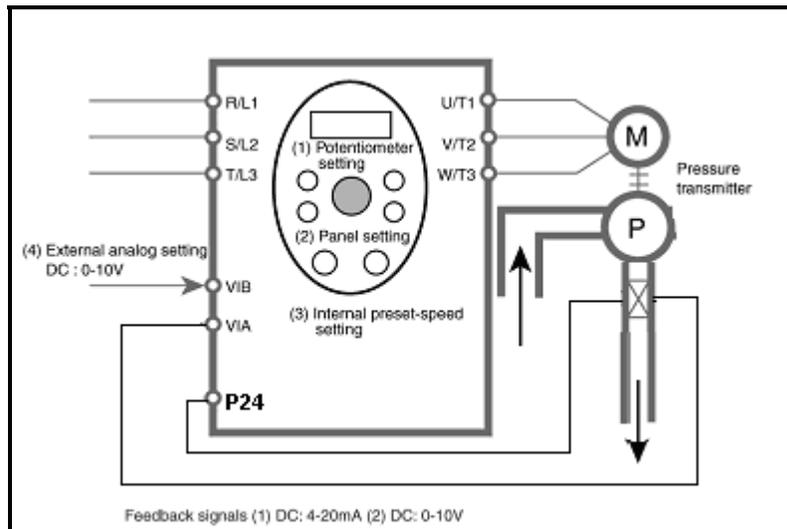
## **S11 APPLICATION GUIDELINE 6.3**

### ***PID Control***

#### **Introduction**

The PID program in the VF-S11 can be applied to a process control, to keep a temperature, flow, level, or pressure or other measured unit constant. This method is essential when critical processes must maintain a certain level (set-point). PID uses different variables: Proportional Gain, Integral Time, and Differential Time, to obtain precise regulation in a closed loop system. A closed loop control system is one where the measurement of a variable, (temperature, pressure, or, flow) of the process being controlled, is constantly being fed back to the controlling device (variable frequency drive) to ensure that the desired set-point is being maintained.

#### **Connections**



Note: Check your transducer's instruction manual for connection information specific to your transducer. The above diagram is typical for a two wire transducer.

The diagram above illustrates the wire connection options for receiving feedback signals and different methods of entering a set-point on the S11. Later in this guideline, these options will be discussed in greater detail. In this example, the VFD is used to adjust the speed of a pump motor to maintain a constant pressure at the output of the pump. As the valves on the output of the pump are opened, the pressure (process variable) decreases. This decrease is fed back to the variable frequency drive via the 4-20 mA feedback signal. The built-in PID of the VF-S11 compares this value to the set-point and speeds the motor up to increase the pressure to the desired level. As the valves close the drive will decrease the speed of the motor and pump. The program will have to be tuned for each system by adjusting proportional gain, integral gain, and differential gain for proper operation of this program.

## Programming

Note: When the **MODE** button is pressed the programmer will enter the first basic parameter **RUH**. Then the programmer will scroll up until the preferred parameter is found.

Parameter	Description	Default Value	New Value
<b>ACC</b>	Acceleration time 1	10.0 s	5.0 s
<b>DEC</b>	Deceleration time 1	10.0 s	5.0 s
<b>FH</b>	Maximum Frequency	80.0 Hz	60.0 Hz
<b>UL</b>	Upper Limit Frequency	50.0 (WP) 60.0 (WN, AN)	Drive dependent, typically 60Hz
<b>LL</b>	Lower Limit Frequency	0.0 Hz	10.0 Hz

The program above is standard for many HVAC applications. The lower limit frequency, acceleration, and deceleration rate settings may vary according to the system used. To enable the PID program the user must enter the extended parameter list which is described below.

Parameter	Description	Default	New Value
<b>F360</b>	PID Control	0	1
<b>F201</b>	VIA input point 1 setting	0 %	20 %
<b>F202</b>	VIA input point 1 frequency	0.0 Hz	0.0 Hz
<b>F203</b>	VIA input point 2 setting	100 %	100 %
<b>F204</b>	VIA input point 2 frequency	50.0 (WP) 60.0 (WN, AN)	Drive dependent, typically 60Hz

The above programming assumes a system in which an increase in the 4-20 mA feedback signal causes the drive to reduce its output frequency. If the system is such that increasing feedback should cause an increase in output frequency, the VIA terminal should be reversed by programming the following:

Parameter	Description	Default	New Value
<b>F201</b>	VIA input point 1 setting	0 %	100 %
<b>F202</b>	VIA input point 1 frequency	0.0 Hz	Drive dependent, typically 60Hz
<b>F203</b>	VIA input point 2 setting	100 %	20 %
<b>F204</b>	VIA input point 2 frequency	50.0 (WP) 60.0 (WN, AN)	0.0 Hz

The system may also be programmed to use a 0-10 V dc feedback signal instead of a 4-20 mA feedback signal. If the 0-10 Vdc feedback signal is preferred then use the following program:

Parameter	Description	Default	New Value
<i>F210</i>	VIB input point 1 setting	0 %	20 %
<i>F211</i>	VIB input point 1 frequency	0.0 Hz	0.0 Hz
<i>F212</i>	VIB input point 2 setting	100 %	100 %
<i>F213</i>	VIA input point 2 frequency	50.0 (WP) 60.0 (WN, AN)	Drive Dependent

## The Set-point

The set-point is the level at which the desired process variable is to be maintained (E.G. 75°C, 150PSI). This setting can be programmed using the *Frequency Setting Mode* parameter (*F<sub>NOd</sub>*). The S11 uses the ratio of the Frequency Command to the Maximum Output Frequency(*F<sub>H</sub>*) parameter to determine the feedback value it is trying to maintain (the set-point). Keep in mind that the frequency that is entered will rarely be seen as the output frequency. Once the S11 is put into PID mode, the only concern is that the drive maintains the set-point.

The set-point can be entered using a variety of methods. By using the S11s' built in potentiometer, the up/down arrows on the keypad, preset speed inputs, or an external analog signal. The most common method used to set the set-point will be discussed below.

### Methods for Setting the Set-point:

- 1) Set point via POTENTIOMETER on the keypad: Set parameter *F<sub>NOd</sub>* to a 0. Adjust the potentiometer on the front panel of the drive to the desired set-point.
- 2) Set point via and external analog signal (0-10 volt dc) input on **VIB** terminal: Set parameter *F<sub>NOd</sub>* to a 2. Adjust potentiometer to whatever setting it takes to generate the desired process variable value.
- 3) Set point via UP and DOWN arrows on the S11keypad: Set parameter *F<sub>NOd</sub>* to a 3. Adjust the set point with the up and down arrow keys to whatever value it takes to develop the desired set-point value. Note: This is the most commonly used method to adjust the set-point on the drive.
- 4) Set point via PRESET SPEED input on the S1 terminal: Set the *F<sub>NOd</sub>* parameter to either 1 or 2. Program the set-point frequency into parameter *Sr 1* to develop. Maintain a dry contact closure or wire jumper between the S1 and the CC terminals.

### How to find your set point in Local Mode (*F<sub>NOd</sub>* = 3):

You need to know what the range of your transducer is in order to solve for the set point in the drive. Here is a simple example:

**Transducer range:** 4 to 20mA

**Pressure range of transducer:** 0 to 5 inches of mercury

**Range of Drive:** 0 to 60Hz ( $FH = 60$  Hz)

**Desired set point:** 1.5 inches

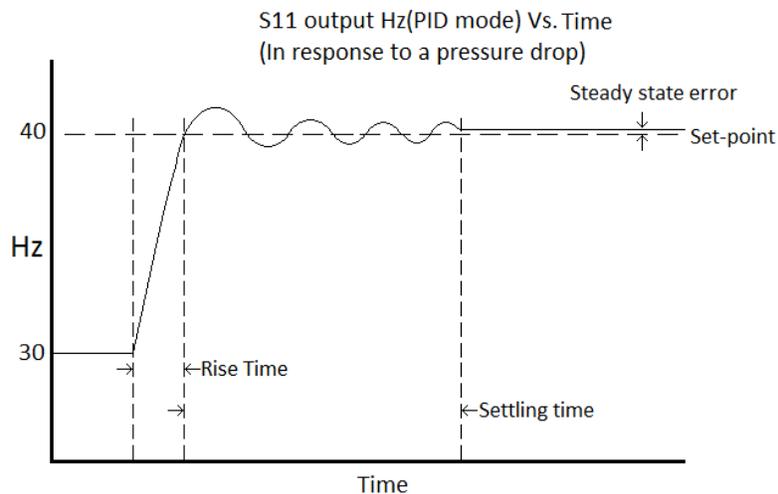
$$\text{Set point entered in the drive} = \frac{\text{desired\_setpoint\_pressure}}{(\text{pressureat20mA} - \text{pressureat4mA})} \times 60$$

$$= \frac{1.5\text{inches}}{5\text{inches} - 0\text{inches}} \times 60 = 18$$

So for this example you would enter 18Hz using the up and down arrow keys on the S11 keypad.

### Tuning the PID

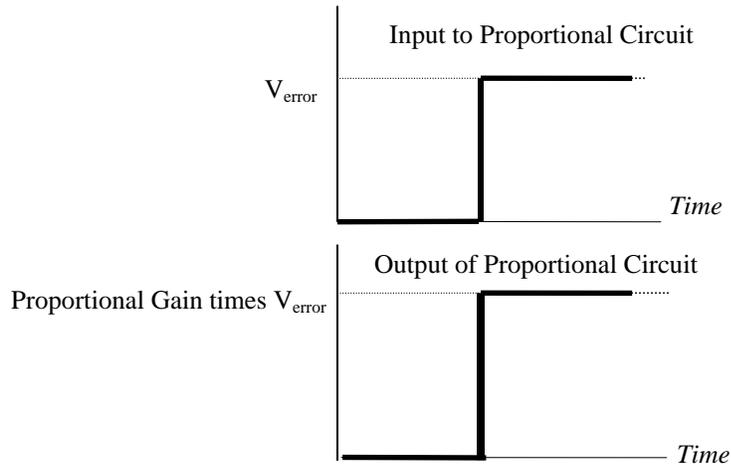
One problem with PID is that if the response to a change in the process variable is too quick, the drive can actually overshoot (put out a higher frequency than necessary), and in some cases, oscillations can occur. The object when tuning a PID loop is to minimize the rise and settling times.



The above figure illustrates what is meant by the rise and settling times. Suppose that an S11 is running at 30 Hz. At Time 0, all of the valves in the example system open. Suppose also that the drive now needs to speed up to 40 Hz to maintain the desired pressure. The rise time, is the time it takes to go from Time 0 (pressure change) to the needed Hz (for the first time). As seen in the above graph, there can be some oscillations that (hopefully) settle out after a time called the Settling Time. Remember that as the output frequency changes, so does the pressure. **THE USER MUST DECIDE WHAT ARE ACCEPTABLE RISE AND SETTLING TIMES.** The rise time, settling time, and overshoot are dependent on the system and can be adjusted by changing three of the parameters in the table programming above: Proportional Gain, Integral Time, and Differential Time.

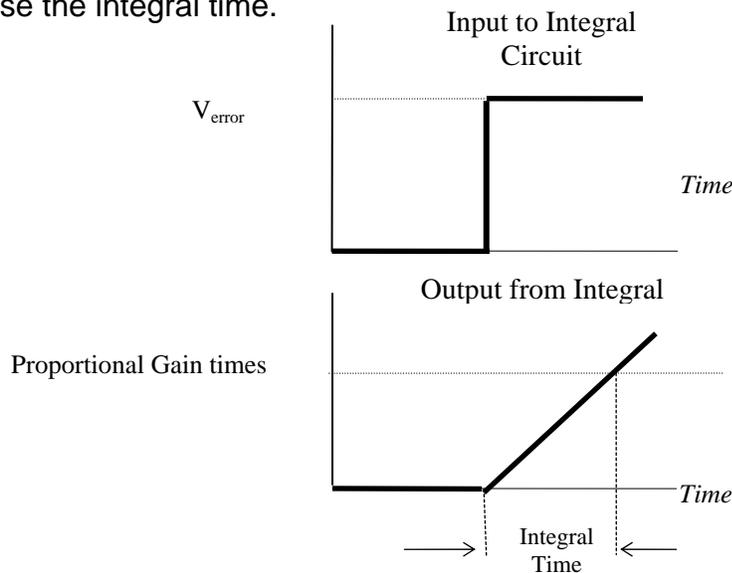
## PROPORTIONAL GAIN

Note that a PID with quickly-changing process variables has higher proportional gains than do their counterparts for slowly-changing process variables. The higher the proportional gain, the smaller the rise time will be. With increased proportional gain usually comes increased overshoot and increased chance of oscillation.



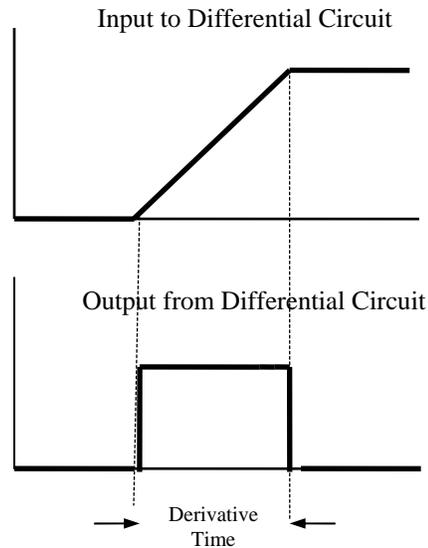
## INTEGRAL GAIN

Also known as reset, integral gain is not really a gain at all, but a time. The integral time (unit seconds per repeat) defines how long it takes the integral circuit output to go from zero to the level set by the output of the proportional circuit. The integral action is therefore influenced by the proportional action. The output of the integral circuit represents the area under the  $V_{error}$  vs. Time graph. In the below example, if  $V_{error}$  were to remain at the level shown, the output of the integral circuit would continue to increase linearly with time (integral output is proportional to area of the rectangle = Proportional gain times  $V_{error}$  times time). **The shorter the integral time, the stronger the effect of the integral action will be.** If you have a system that never quite gets to the set-point (there is steady-state error), decrease the integral time.



**DIFFERENTIAL GAIN**

Also known as anti-hunting gain or rate, differential gain is really not a gain, but a time. Differential gain is seldom used, but it helps to stop oscillations on slowly changing variables (temperature). Any high frequency changes in the system variable (including noise, if present) are picked up by the differential circuit and could lead to instability. **The longer the differential time, the stronger the differential action will be.**



**PID Notes**

1. Do not use VIA terminal and parameters for the set-point: FNOD, F207, and, F200. The VIA terminal is used for feedback signals.
2. By assigning F130, F131, or F132 respectively to 52 or 53, a signal can be sent from the inverter to indicate whether the amount of processing and the amount of feedback agree or reaches the appropriate value. Refer to page F-15 for more details or contact the Adjustable Speed Drives Department for more information.
3. Remember to perform voltage-setting adjustments as required when using external analog setting (VIA) or feedback input (VIA).
4. Program parameter F359 (PID control waiting time) to prevent the inverter from starting PID control before the control system becomes stable. Once a specific time is entered the inverter will ignore all feedback input signals and operate at the frequency determined by the amount of processing for the period of time specified in F359.

**Revision History:**

Rev.	Date	Written/Revised By	Approved By	Description
6.3	6/22/2011	Joshua Austin	Eric Houg	Formatting. Revised to incorporate document control requirements.