The GPD 51/G5, with this factory-installed FLASH software, has the capability to "trim" a speed reference with a PID (Proportional, Integral, Differential) control algorithm. This software provides the capability to set a speed reference, then add or subtract from that speed reference according to a feedback device; dancer, position transducer, pressure transducer, etc.

This document supplements Technical Manual TM 4515 and describes the effect of this software on the parameters in the G5 drive.

Specifications:
- Part No: GPD515C-ZZZZ-CS012 [1]
- Available for All GPD515/G5 drives
- 3 Different PID Modes:
    PID output only
    PID + Line Speed
    PID + Line Speed w/ accel/decel timer
- Digital or Analog Setpoint
- Inverted PID Output Available
- Integral Reset Available
- Integral Hold Available
- Control Modes: Open Loop Vector, Flux Vector & V//f
- Serial Communications: Modbus RTU, RS-232 (RS485 w/option card)
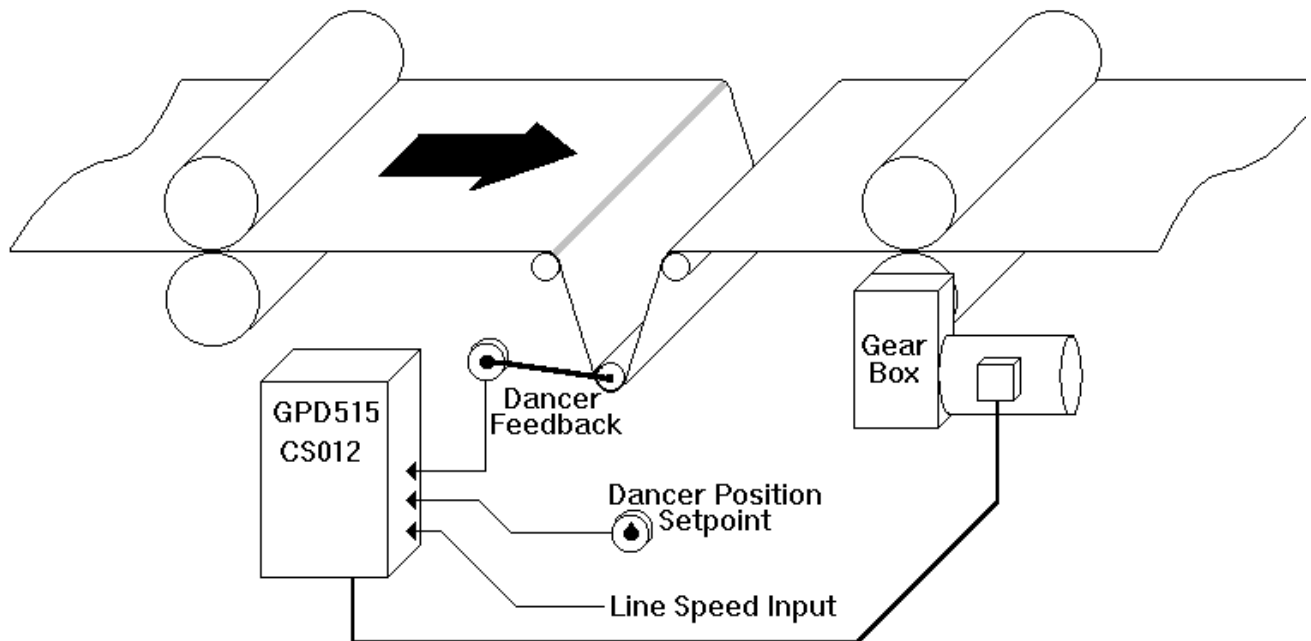
[1] ZZZZ refers to the base Model Number of the drive in which the software is installed.

PID For Trim Control   This section _replaces_ section 5.36 [2]

The Proportional, Integral and Derivative control function provides closed-loop control, or regulation of a system process variable (dancer position, pressure, temperature, etc.). This regulation is accomplished by comparing a feedback signal to a setpoint reference, which results in an error signal. The PID control algorithm then performs calculations, based upon the PID parameter settings (**b5-01** thru **b5-12**), on this error signal. The result of the PID algorithm is then used as the new speed reference, or to trim the existing speed reference.

5.36A. b5-01 : PID Selection

Factory Setting: **0**
Range: 0, 1, 2, 3

Using this parameter, PID control can be enabled, and the type of PID control can be selected.

Setting	Description
0	PID Disabled
1	PID Enabled (Output Only) - PID output becomes the output frequency
2	PID Enabled (Output + Reference) - PID output "trims" the frequency reference
3	PID Enabled (Output + Reference, with accel / decel timer) - PID output "trims" the frequency reference

- If **b5-01** is set to **0**, no PID function will occur.
- If **b5-01** is set to **1**, the frequency reference the drive will use will come from the PID control only.
- If **b5-01** is set to **2**, the frequency reference the drive will use will be the actual frequency reference (Terminal 13 or d1-01 thru d1-09) plus the output of the PID control. This mode could be used to perform a line speed w/dancer trim function.
- If **b5-01** is set to **3**, the frequency reference the drive will use will be the actual frequency reference (Terminal 13 or d1-01 thru d1-09) plus the output of the PID control. In addition, the accel/decel ramps will change to the settings in **C1-07 & C1-08** after the time specified in **b5-08**. See description of b5-08 for more details.

5.36B. Line Speed / Frequency Reference Selection

Refer to Section 5.25 - _Local/Remote and Reference Selection_[2] in order to select the line speed.   NOTE: in Section 5.25, the "Auto" speed reference is terminal 13. The "Manual" speed reference is terminal 16, and the "Memory Data" refers to speed reference parameters d1-01 thru d1-09.

5.36C. PID Setpoint Selection

b5-07: Position Offset

Factory Setting: **0.00**
Range: -10.00 to +10.00V

H3-05: Multi-function Analog Input 1
         Selection (Term. 16)

Factory Setting: **0**
Range: 0 - 21

H3-09: Multi-function Analog Input 2
         Selection (Term. 14)

Factory Setting: **1F**
Range: 0 - 21

Select the PID control Setpoint Reference from either the internal digital setting **b5-07**, or from an analog input (Terminal 16 or 14). Note: if both a digital and an analog setpoint reference are used simultaneously, the two will add together.

- Voltage signal (0 -10 VDC) Terminal 16: Set **H3-05** to data "20" and **H3-04** to data "0".
- Voltage signal (-10 to +10 VDC) Terminal 16: Set **H3-05** to data "20" and **H3-04** to data "1".
- Current signal (4 to 20 mA) Terminal 14: Set **H3-09** to data "20" and **H3-08** to data "2".
- Voltage signal [3](0 -10 VDC) Terminal 14: Set **H3-09** to data "20" and **H3-04** to data "0".
- Voltage signal [3](-10 to +10 VDC) Terminal 14: Set **H3-09** to data "20" and **H3-04** to data "1".

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5.36D. Feedback Signal Selection

H3-05: Multi-function Analog Input 1
　　　Selection (Term. 16)

Factory Setting: **0**
Range: 0 - 21

H3-09: Multi-function Analog Input 2
　　　Selection (Term. 14)

Factory Setting: **1F**
Range: 0 - 21

Select the PID control Feedback Signal from external Terminal 14 or 16.

- Voltage signal (0 -10 VDC) Terminal 16: Set **H3-05** to data "B" and **H3-04** to data "0".
- Voltage signal (-10 to +10 VDC) Terminal 16: Set **H3-05** to data "B" and **H3-04** to data "1".
- Current signal (4 to 20 mA) Terminal 14: Set **H3-09** to data "B" and **H3-08** to data "2".
- Voltage signal [3](0 -10 VDC) Terminal 14: Set **H3-09** to data "B" and **H3-04** to data "0".
- Voltage signal [3](-10 to +10 VDC) Terminal 14: Set **H3-09** to data "B" and **H3-04** to data "1".

[3] In order to utilize Terminal 14 as a voltage input, a wire jumper needs to be cut on the main control board. With the input power removed from the drive and the charge light out, use a small wire cutter to clip the wire labeled J1.
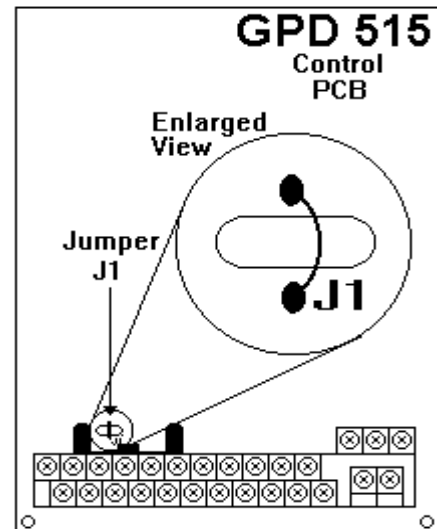
Jumper J1 Location

5.36E. PID Settings

b5-02: Proportional Gain

Factory Setting: **1.00**
Range: 0.00 - 25.00

Proportional gain is the value by which the error signal is multiplied to generate a new PID controller output.

b5-03: Integral Time

Factory Setting: **1.0**
Range: 0.0 - 360.0 seconds

This parameter determines how fast the PID controller will seek to eliminate any steady-state error. The smaller the setting, the faster the error will be eliminated. To eliminate the integral function entirely, set this parameter to 0.0 seconds.

b5-04: Integral Limit

Factory Setting: **100**
Range: 0.0 - 100.0

This parameter will limit the effect that the integrator can have. It works whether the PID controller output is positive or negative. It can also be used to prevent integrator "wind-up".

b5-05: Differential Time

Factory Setting: **0.00**
Range: 0.00-10.00 seconds

Differential time can be adjusted to increase system response to fast load or reference changes, and to reduce overshoot upon startup.   To eliminate the differential function entirely, set this parameter to 0.00 seconds.

b5-06: PID Output Limit

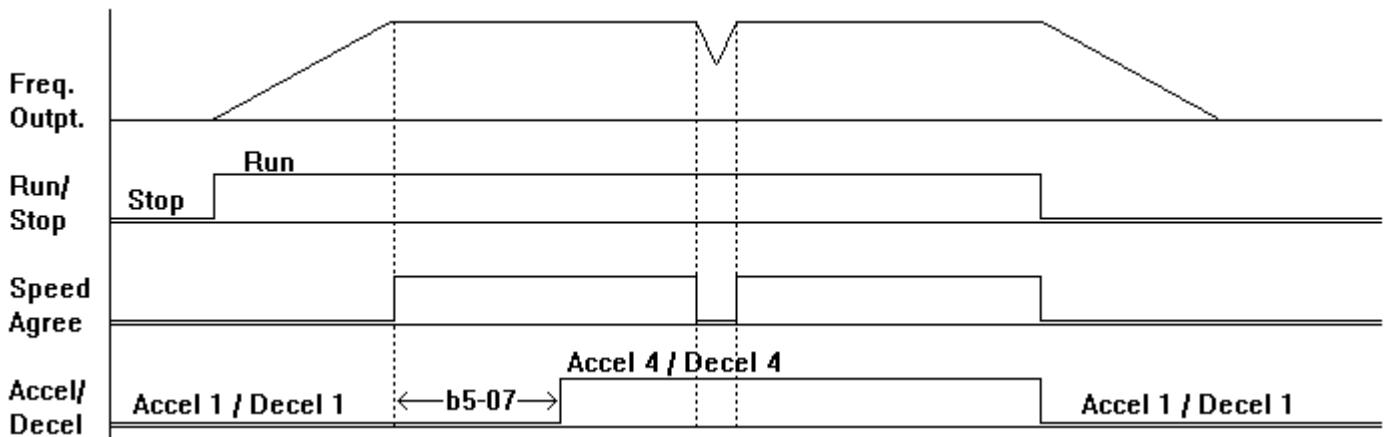| Factory Setting: **100.00** |
|---|
| Range: 0.00 - 100.00 |

This parameter can be used to set the maximum effect the PID controller will have on the system. This works whether the PID controller output is positive or negative. NOTE: When the PID output limit is reached, the integrator will hold and not increase in value until the PID output is less than the PID output limit.

b5-08: Accel/Decel Switching Delay

Factory Setting: **0.00**
Range: 0.00-10.00 seconds

This parameter sets the amount of time after achieving set speed when the accel/decel ramps will switch between their present settings and Accel/Decel 4 (**C1-07 & C1-08**). When a stop command is given, the Accel/Decel ramps will revert to Accel 1 / Decel 1. This feature is only effective when **b5-01 = 3**.

Timing Chart of Output + Reference, With accel / decel timer (b5-01 =3)

b5-09: PID Output Select

Factory Setting: **0**
Range: 0, 1

This parameter determines whether the output of the PID controller will be added to or subtracted from the frequency reference (only when **b5-01 = 2 or 3**).

Setting	Description
0 Not Inverted	The output of the PID controller will be added to the frequency reference. This would be used when the output voltage or current of the feedback device increases with motor speed.
1 Inverted	The output of the PID controller will be subtracted from the frequency reference. This would used when the output voltage or current of the feedback device decreases with motor speed.

b5-10: PID Position High

Factory Setting: 1**0.00**
Range: -10.00 - +10.00V

b5-11: PID Position Low

Factory Setting: **0.00**
Range: -10.00 - +10.00V

b5-12: PID Hysteresis

Factory Setting: **0.10**
Range: 0.00 - 1.00V

H2-01: Multi-function Output (Term. 9 & 10)
H2-02: Multi-function Output (Term. 25-27)
H2-03: Multi-function Output (Term. 26-27)

Data **40**: High Position
or
Data **41**: Low Position

Parameters **b5-10, b5-11**, and **b5-12** are used in conjunction with one or two multi-function outputs. With these a Multi-function Output can be activated when the feedback signal goes above a certain level (**b5-10**), or drops below a certain level (**b5-11**). Parameter **b5-12** determines at what point the Multi-function Output will de-energize.

EXAMPLE OF POSITION HIGH AND POSITION LOW OUTPUTS

B5-10 = 8.00V (PID Position High)   H2-02 = 40 (High Position)
B5-11 = 2.00V (PID Position Low)   H2-03 = 41 (Low Position)
B5-12 = 1.0V (PID Hystersis)
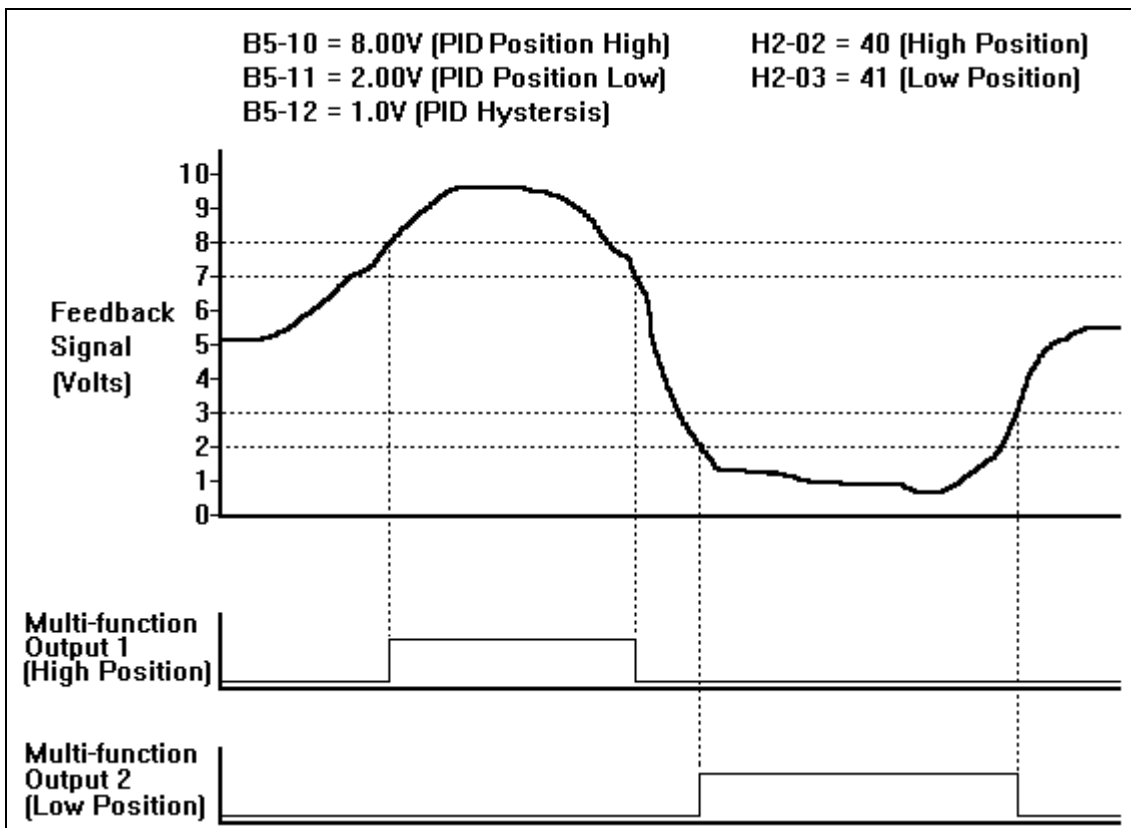
5.36F. H1-01 thru H1-06 : Multi-function Input Terminals

Data **19**: PID Control Disable
A multi-function Input Terminal can be used to disable PID control. When this terminal is activated and **b5-01 = 2 or 3**, the frequency reference (Terminal 13 or Multi-step speed) is not modified in any way by the PID Controller . When this terminal is activated and **b5-01 = 1**, the frequency reference goes to zero.

Data **30**: PID Integral Reset
A Multi-function Input Terminal can be used to reset the integrator's value to zero.

Data **80**: Integral Hold
A Multi-function Input Terminal can be used to hold the integrator's output value. When the contact is closed (on the Multi-Function Input Terminal), whatever value the integrator is outputting will remain the same until the contact is opened.

Data **81**: Positive Integral Hold
A Multi-function Input Terminal can be used to keep the integrator's value from increasing, yet allow it to decrease.

Data **82**: Negative Integral Hold
A Multi-function Input Terminal can be used to keep the integrator's value from decreasing, yet allow it to increase.

The PID parameters are all interactive, and will need to be adjusted until the control loop is properly tuned, i.e. stable with minimal steady-state error. A general procedure for tuning these parameters is as follows:

1. Adjust Proportional Gain until continuous oscillations in the Controlled Variable are at a minimum.

2. The addition of Integral Time will cause the steady-state error to approach zero. The time should be adjusted so that this minimal error is attained as fast as possible, without making the system oscillate.

3. If necessary, adjust derivative time to reduce overshoot during startup. The drive's accel and decel rate times can also be used for this purpose.

This Table Replaces A Portion Of Table A1-2[2]

Parameter Number	Function Name	Description	Incre-ment	Setting Range	Factory Setting	Access Level [3]				Modbus Address
						0	1	2	3	
b5-01	PID Control Mode Selection	0 : Disabled 1 : PID Output Only 2 : PID + Reference 3 : Accel / Decel Time Change	1	0 - 3	0	A	A	A	A	194H
b5-02	PID Proportional Gain		0.01	0.00 - 25.00	1.00	A	A	A	A	195H
b5-03	PID Integral Time		0.1 sec	0.0 - 360.0	1.0	A	A	A	A	196H
b5-04	PID Integral Limit		0.1%	0.0 - 100.0	100.0	A	A	A	A	197H
b5-05	PID Differential Time		0.01 sec	0.00 - 10.00	0.00	A	A	A	A	198H
b5-06	PID Output Limit		0.01 %	0.00 - 100.00	100.00	A	A	A	A	199H
b5-07	PID Position Offset		0.01 V	-10.00 - 10.00	0.00	A	A	A	A	19AH
b5-08	Accel/Decel Switching Delay		0.01 sec	0.00 - 10.00	0.00	A	A	A	A	19BH
b5-09	PID Output Select	0 : Not Inverted 1 : Inverted	1	0 - 1	0	A	A	A	A	589H
b5-10	PID Position High		0.01 V	-10.00 - 10.00	10.00	A	A	A	A	587H
b5-11	PID Position Low		0.01 V	-10.00 - 10.00	0.00	A	A	A	A	588H
b5-12	PID Hysteresis		0.01 V	0.00 - 1.00	0.10	A	A	A	A	586H

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[3]Capability to view and set specific parameters is dependent upon the Access Level (**A1-01**) and Control Method **(A1-02);** 0 = V/f, 1 = V/f w/PG, 2 = Open Loop Vector, 3 = Flux Vector) the drive is programmed for. Each column represents the Access Level for a given Control Method: 0 = Operation only; Q = Quick-start; B - Basic; A = Advanced; - = not available.

Additions to Table A1-10 (Appendix 1)[2]

Parameter Number	Monitor Item	Description	Display Unit	Analog Monitor Output Level	Access Level[3]				Modbus Address
					0	1	2	3	
U1-36	Feedback Monitor	Feedback Level	0.01 V	10V / 10V feedback signal	A	A	A	A	0E1H
U1-37	PID Error	Difference between setpoint and feedback	0.01%	10V / max. output freq. (**E1-04**)	A	A	A	A	0E2H
U1-38	PID Output	Output of the PID control algorithm before its added into the main frequency reference	0.01%	10V / max. output freq. (**E1-04**)	A	A	A	A	0E3H
U1-39	Proportional Value	Output value of just the proportional portion of the PID algorithm	0.01%	10V / max. output freq. (**E1-04**)	A	A	A	A	0E4H
U1-40	Integral Value	Output value of just the integral portion of the PID algorithm	0.01%	10V / max. output freq. (**E1-04**)	A	A	A	A	0E5H
U1-41	Derivative Value	Output value of just the derivative portion of the PID algorithm	0.01%	10V / max. output freq. (**E1-04**)	A	A	A	A	0E6H
U1-42	PID Setpoint	Actual PID setpoint (Analog value + **b5-07**)	0.01V	10V / 10V setpoint	A	A	A	A	0E7H

Addition to Table 5-2 Multi-Function Input Terminal Data Settings (Section 5.32)[2]

Parameters H1-01 thru H1-06 and terminals 3 thru 8.

Data	Function	Description	Availability			
			0	1	2	3
30	PID Integral Reset	Closed = Reset integrator to zero **See Paragraph 5.36F**	X	X	X	X
80	Integral Hold	Closed = Hold integrator at its present level **See Paragraph 5.36F**	X	X	X	X
81	Positive Integral Hold	Closed = Will allow integrator level to decrease, but not increase. **See Paragraph 5.36F**	X	X	X	X
82	Negative Integral Hold	Closed = Will allow integrator level to increase, but not decrease. **See Paragraph 5.36F**	X	X	X	X

Addition to Table 5-3 Multi-Function Output Terminal Data Settings (Section 5.33)[2]

Parameters H2-01 thru H2-03 and terminals 9, 10, 25, 26 & 27   Plus DO-02C option card F5-01 & F5-02.

Data	Condition	Signal Level	Availability			
			0	1	2	3
40	High Position	Closed When PID Feedback is above High position **b5-10**	X	X	X	X
41	Low Position	Closed When PID Feedback is below Low position **b5-11**	X	X	X	X

Addition to Section 5.30   Multi-Function Analog Input Terminal Data Settings[2]

Parameters H3-05 & H3-09 and terminals 16 & 14.

Data	Function	Description	Availability			
			0	1	2	3
20	PID Setpoint	Provides a setpoint signal for use with PID control.	X	X	X	X
21	PID Feed-back Analog Input Bias	Mathematically adds to the feedback signal when using PID control.	X	X	X	X

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Startup Procedure (*typical installation - PID + Line Speed Reference*):

1. Follow the appropriate startup procedure in Section 2.2 of the GPD515 Technical Manual TM4515 (2.2a for Open Loop Vector, 2.2b for Flux Vector, 2.2c for V/f, or 2.2d for V/f with PG Feedback).

2. Calibrate the line speed signal. (using terminal 13 as a 0-10V input)
    2a. Determine the required drive output frequency for maximum line speed.
        Frequency = Motor RPM* Motor Poles / 120
      NOTE: if this option is being applied as a winder with dancer control, use the motor speed when the winder is at its smallest diameter (core).
    2b. Determine the maximum amount of positive trim required as a percentage of line speed.
    2c. Set **E1-04**(maximum output frequency) to the value determined by the following formula:
        $$\text{E1-04} = \text{Frequency}_{(@ \text{ max line speed})} + \text{Frequency}_{(@ \text{ max line speed})} * \frac{\text{Max. Trim(\%)}}{100}$$
        NOTE: If the value of **E1-04** is less than 60Hz, use 60 instead of the calculated value.
    2d. Determine what the line speed signal voltage will be when the line is running at the maximum speed.
    2e. Input the voltage determined in step 2d into terminal 13 and adjust parameter **H3-02**(terminal 13 gain) until the line speed is correct (while running the drive). NOTE: in order for the drive to respond to the line speed, the REF light on the digital operator needs to be illuminated. The LOCAL/REMOTE switch will turn this light on and off.
    2f. Stop the drive.

3. Program multi-function analog input 1 (terminal 16) to be PID feedback. The feedback signal can be either $\pm$10V or 0-10V:
    $\pm$10V: set **H3-04=1** and set **H3-05=b** (NOTE: a $\pm$15VDC power supply is available on terminals 15 & 33)
    0-10V: set **H3-04=0** and set **H3-05=b** (NOTE: a 15VDC power supply is available at terminals 15 & 17)

4. Program the drive to accept a PID setpoint. The setpoint for the PID loop can come from one of two places, either a digitally entered value (**b5-07**) or an analog value. If a digital value is desired, set the appropriate voltage value into **b5-07**. If an analog value is desired, program multi-function analog input 2 (terminal 14) to be a PID setpoint:
    $\pm$10V: clip jumper J1(see Section 5.36D), set **H3-08=1** and set **H3-09=20**
    0-10V: clip jumper J1(see Section 5.36D), set **H3-08=0** and set **H3-09=20**
    4-20mA: set **H3-08=2** and set **H3-09=20**

5. Determine and set PID output polarity.
    Program **b5-09 = 0** if an increase in feedback voltage level results in a decrease of motor speed.
    Program **b5-09 = 1** if an increase in feedback voltage level results in an increase of motor speed.

6. Set the appropriate PID mode.
    Program **b5-01** = **2**. When this is programmed, the drive will output a frequency proportional to the algebraic sum of the line speed signal and the PID algorithm output.

7. Verify all analog signals while the drive is stopped.
    7a. Bring up **U1-01** on the digital operator and verify that the line speed signal working and correct.
    7b. Bring up **U1-36** on the digital operator and verify that the feedback voltage is working and correct.
    7c. If an analog PID setpoint is being used, bring up **U1-42** on the digital operator and verify correct operation.

8. Determine and set the appropriate PID setpoint.
    8a. With the drive stopped, bring up **U1-36** on the digital operator and then position the feedback device where it would be while the machine was operating normally. Note the value of **U1-36**.
    8b. If a digital PID setpoint is being used, set the value recorded during step 8a into parameter **b5-07**. If an analog PID setpoint is being used, bring up **U1-42** on the digital operator and adjust the setpoint until **U1-42** matches the value of **U1-36** recorded during step 8a.

9. Set the maximum amount of trim the PID can output. Program this value into parameter **b5-06** (set as a percentage of the maximum output frequency **E1-04**) .
    NOTE: for most applications, the integral limit (**b5-04**) needs to be set equal to or less than the setting of **b5-06** to avoid "wind up" of the PID algorithm.

10. (Optional Step) Test operation of the system prior to running product through the machine.
    10a. Be sure the DRIVE light on the digital operator is on. To turn the DRIVE light on, press MENU, then DATA/ENTER.
    10b. Be sure the reference is set to remote by verifying that the REMOTE REF light is illuminated. If it is not illuminated, press the LOCAL/REMOTE key and/or set **b1-01** = 1 (terminals)
    10c. Start the machine and the drive, then monitor the output frequency **U1-02** while moving the feedback device. As the feedback device is moved, the output frequency of the drive should increase and decrease the amount specified in step 9.

11. Run the machine while loaded and adjust the PID parameters to achieve the correct response.
    11.a Adjust the gain **b5-02**. Increase = faster response (too much will result in instability). Decrease = slower response (not enough will result in poor reaction to step changes or impact loads).
    11.b Adjust the PID I time **b5-03**. Decrease = faster response (too low results in instability). Increase = slower response (too high and recovery from step changes or impact loads will be slow).
    11.c Adjust the PID D time **b5-05** only if very rapid changes are expected in the system process. Normally this setting is left at the factory of zero in order to maintain system stability.
    11.d Repeat this procedure at different (expected) line speeds in order to find optimum settings)

Verifying Installed Software Number

For the PID for trim control software option, the software number is 12051. The software version installed in the drive can be verified by either reading it off of the control board, or calling it up on the digital operator.

In order to read the software number off of the control board, take the cover off of the drive and look for the white sticker on the main control board. This sticker is just to the right of connector 2CN. On it is the version of the control board, then a dash, then the software number (see Figure 1). The "S" before the number can be disregarded.

Software Number Location

In order to view the software number from the digital operator, bring up drive parameter U1-14 (FLASH ID). This is done by powering up the drive and using the following key sequence:

(13 times)

PID With Trim Block Diagram

FREQUENCY REFERENCE
LINE SPEED

Terminal 13

d1-01
d1-02
d1-03
d1-04
d1-05
d1-06
d1-07
d1-08
Jog (d1-09)

Line Speed Reference Selection

PID Control Mode Selection
b5-01

0,2,3

1

On-Delay Timer
b5-08
(When b5-01 = 3)

0

1,2,3

Accel / Decel & S-Curve Selection

Accel X / Decel X
Accel 4 / Decel 4

PID Disable
Multi-function Input Terminal
Data = 19

Frequency Reference

U1-38

PID Output Select
b5-09

×1
×-1

Analog Setpoint
Multi-function Analog Input
Data = 20

Signal Level Selection

Gain / Bias

Digital Setpoint Position Offset
b5-07

U1-36

I N P U T
O P T I O N
S E T
P I D

Feedback
Multi-function Analog Input
Data = b

Signal Level Selection

Gain / Bias

±11V Limit

U1-37

U1-42

Feedback Bias
Multi-function Analog Input
Data = 21

Signal Level Selection

Gain / Bias

F E E D B A C K

b5-02
P Gain

U1-39

b5-05
D Time

b5-03
I Time

b5-04

Integral Limit

U1-41

U1-40

Integral Hold When In PID Limit

b5-06

PID Limit

U1-XX

Parameters inside of ovals indicate monitoring parameters

b5-10
Position High

b5-11
Position Low

b5-12

b5-12
Hysteresis

Multi-function Output = 40 Position High

Multi-function Output = 41 Position Low