



## BFI Applications Support Library

<b>Application Note</b>	<b>AN-BEI-H3-032</b>
<b>Title</b>	<b>PID Closed Loop Feedback Control Applications</b>
<b>Related Products</b>	<b>Beijer Frequency Inverter H3</b>
<b>Level</b> <b>2</b>	1 – Fundamental - No previous experience necessary 2 – Basic – Some Basic drives knowledge recommended 3 – Advanced – Some Basic drives knowledge required 4 – Expert – Good experience in topic of subject matter recommended

### Overview:

BFI-H3 has a built-in flexible PID controller that can be used for a variety of process control applications. Typical applications include pressure control, flow rate control, temperature control etc.

This document describes procedure for setting up the BFI-H3 in PID mode and how to calculate the parameter values.

### PID Overview

PID (Proportional, Integral & Differential) control is widely used in many applications. A PID system requires:

#### **Setpoint Signal (reference)**

This is the desired operating point of the system proportional to the feedback signal, e.g. a pressure level which the pump is required to maintain, e.g. 1.5 bar

#### **Feedback Signal**

This is the feedback signal proportional to the range of the feedback transducer, e.g. a pressure transducer has a range of 4-20mA for a 0-10 bar signal range.

The drive will continuously monitor the feedback signal and compare it to the setpoint, then adjust the output speed automatically to try to maintain the correct set-point level.

### Drive Configuration

The following section will explain how to configure the BFI-H3 in PID mode for a basic application. The configuration has been broken down into smaller steps set out in the sequence that they should be followed during commissioning.

The following steps assume that the BFI-H3 is in the default state – if parameters have been modified from their default state, this could affect the operation of the drive.

#### **Motor data**

The first step is to enter the motor nameplate data into the drive as follows:

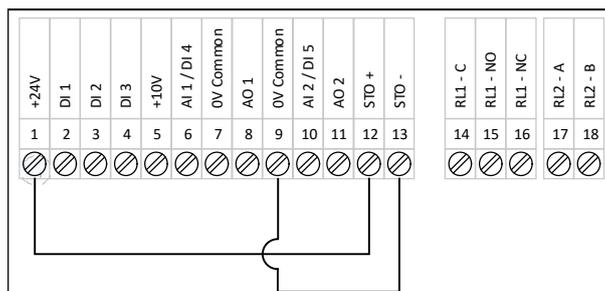
P1-07 = Motor Rated Voltage

P1-08 = Motor Rated Current

P1-09 = Motor Rated Frequency

#### **Auto-tune**

Once the motor data has been entered into the drive it is advisable to carry out an Auto-tune so that the motor stator resistance is measured. In order to carry out the auto-tune operation, there are minimum control terminal connections that must be made as shown below.



To enable the auto-tune, the extended parameters must be accessible which is achieved by setting P1-14 = 101  
 With the extended parameters now accessible, the auto-tune should be enabled by setting P4-02 = 1

**Please Note:** the motor must be stationary when carrying out the auto-tune

### Enabling and configuring the PID

The PID is enabled by setting:

P1-12 = 3

#### P3-01 PID Proportional Gain

In simple terms, the PID proportional gain parameter controls how great a variation in pump speed will be seen relative to a change in pressure. If the value used is too high, the pump will continuously change speed, and the pressure will be unstable. Typical on a pump system, the factory set value of 1 will provide good performance. If the pump speed is unstable, reduce the value.

#### P3-02 PID Integral Time Constant

The BFI-H3 monitors the change of feedback over time to determine the average pressure and how rapidly it is changing. This time filter helps to provide smooth operation. In most cases, the factory set value of 1 second provides good operation, however the value may need to be increased on systems where the feedback level changes relatively slowly.

#### P3-03 PID Differential Time Constant

The differential time constant is sometimes used in highly responsive PID systems to reduce overshoot by limiting the rate of change of the PID output. For general pumping and fan applications, this parameter should be left at its default value of 0.00s

#### P3-04 PID Operating Mode:

This parameter allows the user to select either direct or inverse PID control, as described below.

P3-04	Function	Typical Application	Explanation
0	Direct mode	Pump Pressure Control Compressor Pressure Control	An <b>INCREASE</b> in the motor speed should result in an <b>INCREASE</b> in the feedback signal, e.g. a pump rotates faster to create more pressure
1	Inverse mode	Condenser Fan Temperature Control	An <b>INCREASE</b> in the motor speed should result in a <b>DECREASE</b> in the feedback signal, e.g. a fan rotates faster to provide more cooling effect

#### P3-05 PID Reference (set-point) Source select:

The PID reference or set-point can be taken as either of the analogue inputs or simply by using a digital reference – this is selected by P3-05. A digital reference can be used in most applications but it is possible to use an analogue input if a variable reference is required. If a digital reference is selected, then the reference is set in parameter P3-06 as below. It is also possible to change PID reference by Modbus RTU, fieldbus or Ethernet.

#### P3-06 PID Digital Reference (set-point) value:

For a simple system with a fixed set-point, the value for P3-06 can be calculated from the transducer range.

e.g. if a system is required to hold a constant pressure of 1.5 bar, and uses a transducer for feedback with measurement range 0 - 10 bar, the value of P3-06 can be calculated as

$$\frac{1,5 \text{ bar} \times 100 \%}{10 \text{ bar}} = 15 \%$$

**P3-10 PID Feedback Source Select:**

The PID feedback can be selected from a variety of different sources:

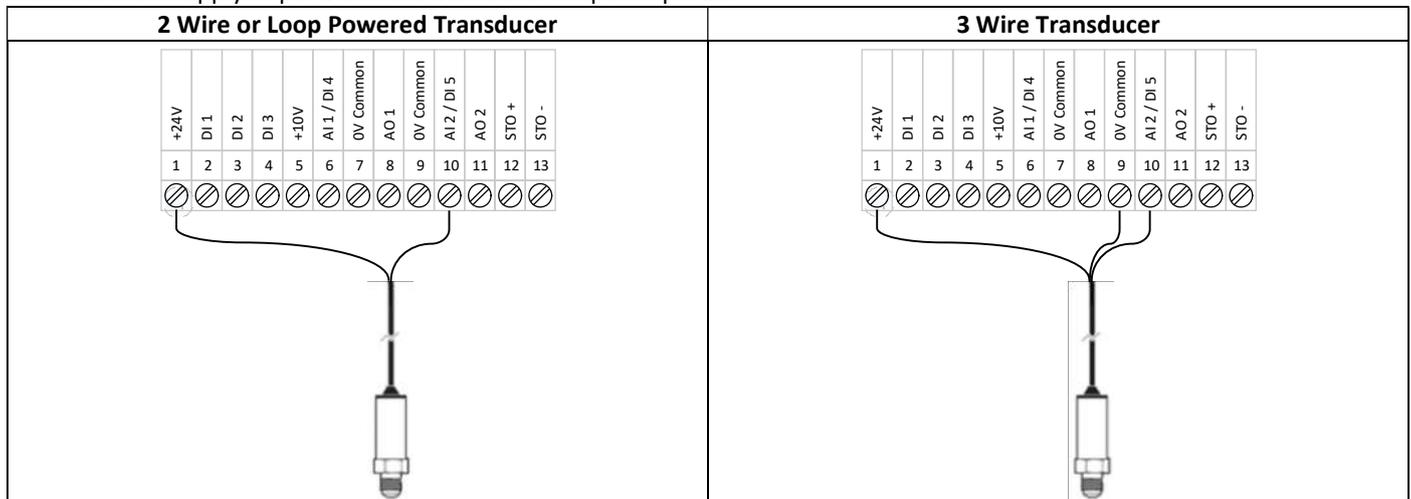
Value	Feedback Signal	Format of the feedback
0	Analogue Input 2 (T10)	0 – 100.0 % of P2-33 signal type selection
1	Analogue Input 1 (T6)	0 – 100.0 % of P2-30 signal type selection
2	Motor load current	0 – 100.0 % of P1-08 setting
3	DC Bus Voltage	0 – 1000 Volts = 0 – 100.0 %
4	Analogue Input 1 – Analogue Input 2 (Differential)	0 – 100.0 % of signal differential
5	Maximum (Analogue Input 1, Analogue Input 2)	0 – 100.0 % of largest analogue signal

By default the feedback signal is set to Analogue Input 2 on terminal 10

The format of the feedback signal can be configured by setting the format of the analogue input in use as required. Most feedback transducers use the 4-20 mA format.

**Feedback Transducers**

There are generally two types of transducers, and an example of how to connect each of these to the drive is shown below. When connecting a 2-wire feedback transducer (e.g. 4-20 mA type), check that the transducer is suitable for 24V operation, then connect the transducer supply to pin 1 and the transducer output to pin 10.

**P3-12 PID Feedback Value Display Scaling Factor:**

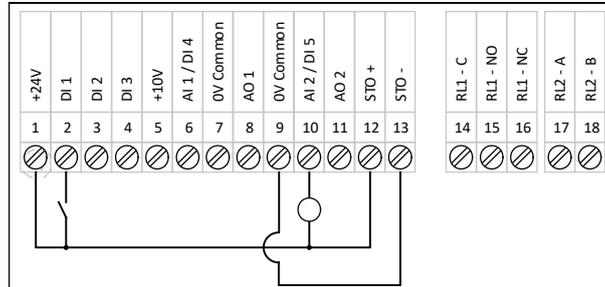
It is possible to apply a scaling factor to the PID Feedback so that the user can display the actual signal level on the drive as opposed to a percentage. If we consider our example of a transducer that reads 1-10 bar, we would want 100 % feedback to be displayed as 10 and not 100, this can be done using the scaling factor as follows:

$$P3 - 12 = \frac{10 \text{ bar}}{100 \%} = 15 \%$$

The scaled feedback is now visible on the drive display as one of the visible variables that can be switched between by pressing the navigate button. Please Note that on the OLED display, the units given to this parameter will remain as %.

## Preparing to run the motor

So far, the drive has been configured for the motor and auto-tuned, the basic PID parameters have been set and we are almost ready to start running the application to test the operation. The feedback sensor should also be connected to the drive and only one more control connection required to give the run enable for the drive (considering only the absolute minimum connections). The diagram below shows an example of the connections necessary (assuming a 2-wire transducer):



- T1 = User +24V
- T2 = Run enable signal (apply 24V to run)
- T9 = User 0V Common
- T10 = Analogue Input 2 (used for the feedback signal from the transducer)
- T12 = STO + (connect to +24V T1)
- T13 = STO – (connect to 0V common T9)

If the system is safe to run, we can close the switch on T2 (run enable) and check first to ensure that the motor rotates in the correct direction. If the motor runs in the reverse direction then stop the drive (open the switch on T2) and power down the drive and leave for 10 minutes before swapping any two of the three output motor phases (U, V & W). With the motor running in the correct direction and the drive running, the motor should start to speed up and in our example system, the pressure should start to increase up to the 1.5 bar set-point. This can be monitored on the drive display when looking at the PID Feedback Scaled Parameter.

If the load on the system drops, then the speed of the motor is also likely to reduce (assuming that direct operation has been selected) as the motor can achieve the required pressure set-point at lower speeds. Conversely, if the load increases then the motor speed should increase in an attempt to maintain the pressure set-point.

The response of the drive to any changes in the feedback can be altered by changing the PID Proportional Gain (P3-01) and the PID Integral Time Constant (P3-02) as explained on page 2 of this application note, taking care to make only small changes to reduce the risk of an unstable system.

## Configuring the Standby or Sleep mode

In some applications such as a pump booster set, it may be sensible to consider setting up a Standby or Sleep Threshold. This should only be attempted once the system is working satisfactorily. This function basically shuts down the drive if there is no demand on the system and then re-starts the drive when the pressure falls below a particular threshold. Below is a brief guide on how to set up the PID Standby/Sleep Mode and the PID Wake-Up Threshold.

To set-up the PID Sleep/Standby Mode it is best to run the pump in PID mode and to close a valve on high pressure side of the pump but the other side of the pressure transducer (the pressure transducer must be measuring any change in pressure caused by the pump). Under this condition, it should be possible to determine the no-flow speed for the pump. The standby threshold speed (P3-14) should be set slightly higher than this value. The PID Standby Mode Delay should also be set in P2-27 (20s should be about right but this can be modified if required).

It is also recommended to set the drive minimum frequency (P1-02) a few Hz below the PID Standby Speed Threshold (P3-14) to allow the drive to respond more quickly to a demand increase whilst in Standby Mode.

In order to determine the PID Error Wake Up Level, we need to consider at which pressure we should re-start the pump. If we have a set-point of 1.5 bar we may want to re-start the pump at 1.2 bar, this is calculated as below:

$$P3-13 = \frac{(\text{Set point} - \text{Wake up level})}{\text{Full scale Transducer} \times 100\%} = \frac{1,5 \text{ bar} - 1,2 \text{ bar}}{10 \text{ bar} \times 100\%} = 3,0 \%$$

## Additional Settings

In some applications such as a pump booster set, it sometimes helps to prevent the drive from going in and out of Standby/Sleep Mode frequently by configuring the Speed Hold Time on Disable parameter (P6-12). What this does is run the motor at the frequency defined in P2-08 for the time set in P6-12 before the drive goes into Standby/Sleep Mode.

This has the benefit of providing a slight pressure boost to the system before going into Standby/Sleep Mode and allows the drive to stay in Standby/Sleep Mode for longer periods.

**Please Note:** if this function is configured, the drive will ramp the motor up to the frequency set in P2-08 for the time set in P6-12 upon the removal of the run command.

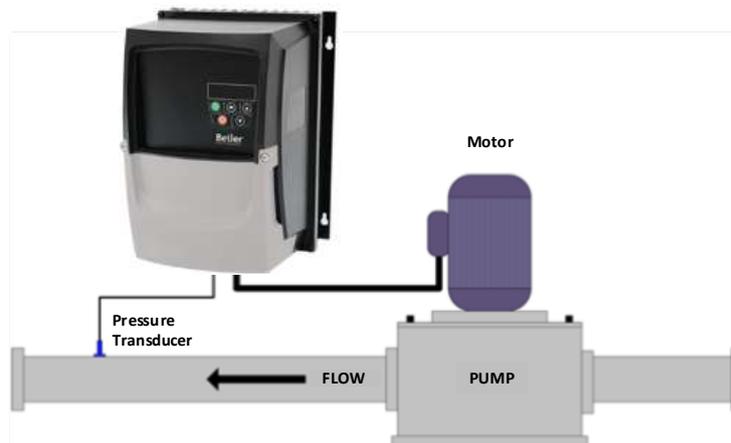
A similar function is available to provide a pressure boost on enable or when the drive wakes up from Standby/Sleep Mode. This is configured by setting the Speed Hold Time on Enable (P6-11). When configured (the time is set to greater than 0 s), the drive will run at the frequency set in P2-07 for a time set in P6-11 when the drive is first enabled or when the drive wakes up from the PID Standby/Sleep Mode.

To disable the Speed Hold Time on Enable, set P6-11 to 0 s (this is the default value).

To disable the Speed Hold Time on Disable, set P6-12 to 0 s (this is the default value).

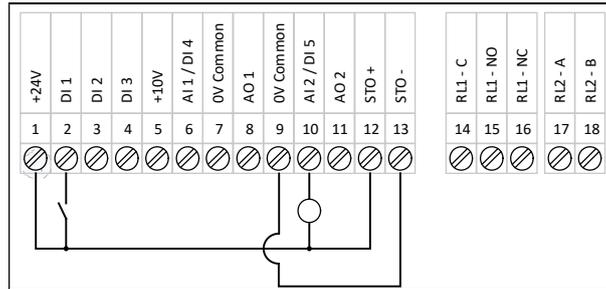
## Application Examples

### Pressure Control – Simple Fixed PID Setpoint



Par	Function	Example Setting	Explanation
P1-07	Motor Rated Voltage	-	Enter the values from the motor nameplate, for best performance and to avoid damaging the motor.
P1-08	Motor Rated Current	-	
P1-09	Motor Rated Frequency	-	
P1-12	Primary Command Source	3	Enables PID Control
P1-14	Access Code	101	Allows Access to PI Parameters
P2-33	2 <sup>nd</sup> Analog Input Format	4-20 mA	Set to match the transducer signal type
P3-01	PID Proportional Gain	0.5 – 2	System Dependant
P3-02	PID Integral Time Constant	1 – 5 seconds	System Dependant
P3-06	PID Digital Reference (Set-point)	40.0 %	System Dependant – set as per example overleaf
P3-12	PID Feedback Value Display Scaling	0.100	System Dependant – set as per example overleaf
P3-13	PID Error Wake Up Level	5.0 %	System Dependant – set as per example overleaf
P3-14	PID Standby Speed Threshold	24 Hz	System Dependant – set as per example overleaf
P2-27	PID Standby Mode Enable Delay	20 s	System Dependant – set as per example overleaf
P1-02	Minimum Frequency	20 Hz	System Dependant – set as per example overleaf
P6-12	Speed Hold Time on Disable	15 s	System Dependant – set as per example overleaf
P2-08	Pre-set Speed 8 (used for P6-12)	45 Hz	System Dependant – set as per example overleaf
P6-11	Speed Hold Time on Enable	15 s	System Dependant – set as per example overleaf
P2-07	Pre-set Speed 7 (used for P6-11)	40 Hz	System Dependant – set as per example overleaf

## Connections



## Example Application

Consider a pumping application.

Feedback Transducer = 0 – 10 bar

Pressure Target level = 4 bar

Enter Standby after 20 seconds if the pressure is maintained with no flow

Restart the pump if the pressure falls below 3.5 bar

In this case, we can calculate the values for parameters as follows:

$$P3-06 \text{ Set-point} = \frac{4 \text{ bar}}{10 \text{ bar} \times 100\%} = 40.0 \%$$

The simplest method to determine the minimum speed to use for Standby Mode is to slowly close the outlet flow valve from the pump after the pressure transducer. The pump should then maintain pressure on the closed system, and the no flow speed can be determined by looking at the output frequency or motor speed on the drive display. The standby threshold speed (P3-14) should be set slightly higher than this value.

The PID Standby Mode Delay should also be set in P2-27 (20 s should be about right but this can be modified if required).

It is also recommended to set the drive minimum frequency (P1-02) a few Hz below the PID Standby Speed Threshold (P3-14) to allow the drive to respond more quickly to a demand increase whilst in Standby Mode.

In order to determine the PID Error Wake Up Level, we need to consider at which pressure we should re-start the pump. If we have a set-point of 4.0 bar we may want to re-start the pump at 3.5 bar, this is calculated as below:

$$P3-13 = \frac{(\text{Set point} - \text{Wake up level})}{\text{Full scale Transducer} \times 100\%} = \frac{4.0 \text{ ba} - 3.5 \text{ ba}}{10 \text{ bar} \times 100\%} = 5.0 \%$$

## Appendix:

Revision History			
Version	Comments	Author	Date
1.00	Document Creation	JSG	13/03/18