



# Optidrive Applications Support Library

<b>Application Note</b>	<b>AN-ODE-2-032</b>
<b>Title</b>	<b>PI Closed Loop Feedback Control Applications</b>
<b>Related Products</b>	<b>Optidrive E2</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

Optidrive E2 has a built-in flexible PI 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 the setup procedure for each of the operating modes available.

## PI Overview

PI (Proportional- & Integral) control is widely used in many applications. A PI 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 0-10 Bar for a 4-20mA 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 setpoint level.

## Configuration Parameters

### P-45 PI Setpoint (reference):

For a simple system with a fixed setpoint, the value for P-45 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 P-45 can be calculated as

$$\frac{1.5\text{Bar} \times 100\%}{10\text{Bar}} = 15\%$$

### P-41 PI Gain

In simple terms, the PI 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. Typically on a pump system, the factory set value of 1 will provide good performance. If the pump speed is unstable, reduce the value.

### P-42 PI Integral Time

The Optidrive 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.

**P-43 PI controller operating mode selection:**

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

P-43	Function	Typical Application	Explanation	Drive Firmware
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	=<V1.03
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	=<V1.03
2	Direct mode with scaling	As per 0	As per setting 0, however the display scaling function allows direct display of the feedback value, scaled using parameter P-40	>=V1.10
3	Inverse mode with scaling	As per 1	As per setting 1, however the display scaling function allows direct display of the feedback value, scaled using parameter P-40	>=V1.10

**P-46 PI feedback Select:**

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

Value	Feedback Signal	Format of the feedback	Drive Firmware
0	Analog Input 2 (T4)	0 – 100.0% of P-47 signal type selection	=<V1.03
1	Analog Input 1 (T6)	0 – 100.0% of P-16 signal type selection	=<V1.03
2	Motor load current	0 – 100.0% of P-08 setting	=<V1.03
3	DC Bus Voltage	0 – 1000 Volts = 0 – 100.0%	>=V1.10
4	Analog Input 1 – Analog Input 2 (Differential)	0 – 100.0% of signal differential	>=V1.10
5	Largest(Analog Input 1, Analog Input 2)	0 – 100.0% of largest analog signal	>=V1.10

By default the feedback signal is set to Analog Input 2 on terminal 4

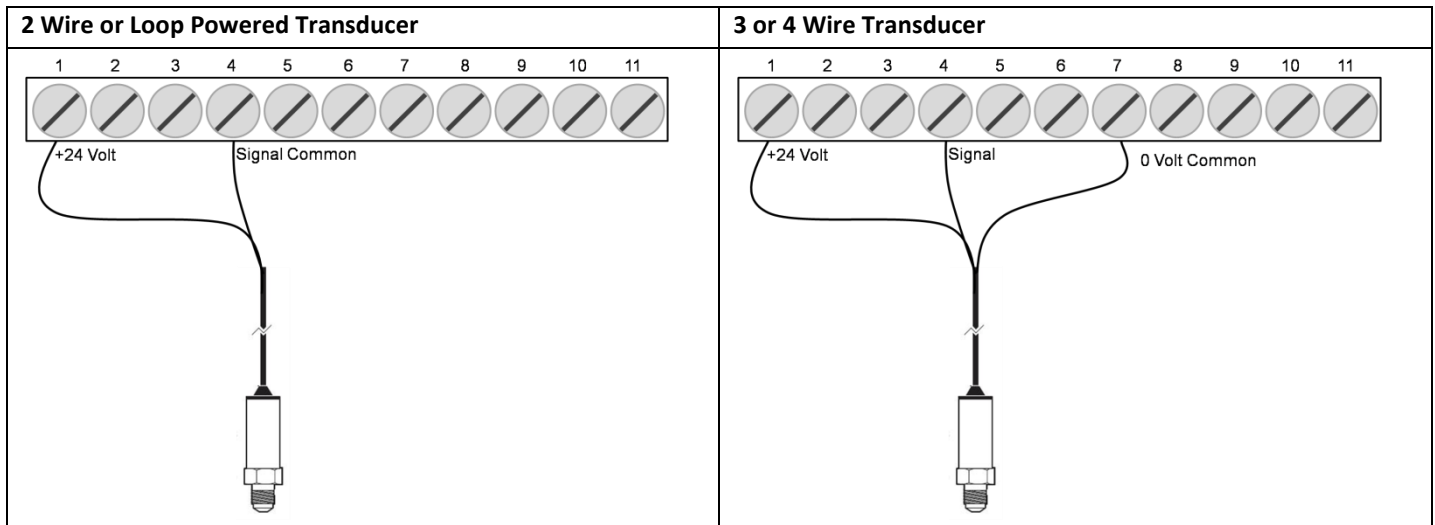
The format of the feedback signal can be configured by setting the format of the analog input in use as required. Most feedback transducers use the 4...20mA format.

If analog input 1 is selected as a feedback signal, digital input 3 (2<sup>nd</sup> analog input) can then be used as an external trip input which enables the user to connect a PTC motor thermistor for motor protection purposes and by setting P-15=3.

This external trip function is not available if 2<sup>nd</sup> analog input is selected as PI feedback input.

## 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...20mA type), check that the transducer is suitable for 24V operation, then connect the transducer supply to pin 1 and the transducer output to pin 4.



### P-44 PI reference select:

The PI controller reference can be given by an external analog input signal or by digital preset value depending on application requirements. This is set up using P44.

P-44	Description
0	PI control using the digital preset value for the reference input. The digital preset reference value is defined in Parameter P-45, this is proportional to 0 to 100% of the full range of the feedback value.
1	PI control using analog input 1 (T6) for the reference input.

### Note

The user has to adjust the PI control parameters (P-gain, I-gain) in P-41 and P-42 respectively to get the best control performance. The values will vary depending on system inertia and the time constant (rate of change) of the system being controlled.

### Standby Function

The Optidrive E2 has a built in Standby function, which allows the motor to automatically switch off completely when not required i.e. when the setpoint level is maintained without requiring further effort, such as a pump system where no flow is required, and the pressure will automatically maintain without further pump operation until there is flow demand.

#### Standby with Drive Firmware =<V1.03

For drive firmware versions up to and including 1.03, the drive enters standby mode when the speed reference on the drive remains at 0.0Hz for 20 seconds. After this time, the Optidrive will switch off the motor, and the display will show **Standby**.

For applications where a minimum operating frequency is required to protect the motor from overheating. The use of skip frequencies is possible to avoid operation below the minimum operating point frequency (typically between 20-30Hz).

#### Standby Function with skip frequencies

Parameter description:

Parameter	Function	Explanation
P-26	Skip frequency hysteresis band	Set P-09 before adjusting. Speed reference held at upper or lower skip frequency limit until input signal reaches the opposite skip frequency limit. Speed ramps through the skip frequency band at a rate set by P-03 and P-04.
P-27	Skip frequency	Set P-09 before adjusting. Skip frequency centre point

### Example Values

Minimum speed to be 24Hz then ramp down to 0Hz before entering **Standby** after 20 seconds

$$P-26 = 24\text{Hz}$$

$$P-27 = P-26 / 2 = 24\text{Hz} / 2 = 12\text{Hz}$$

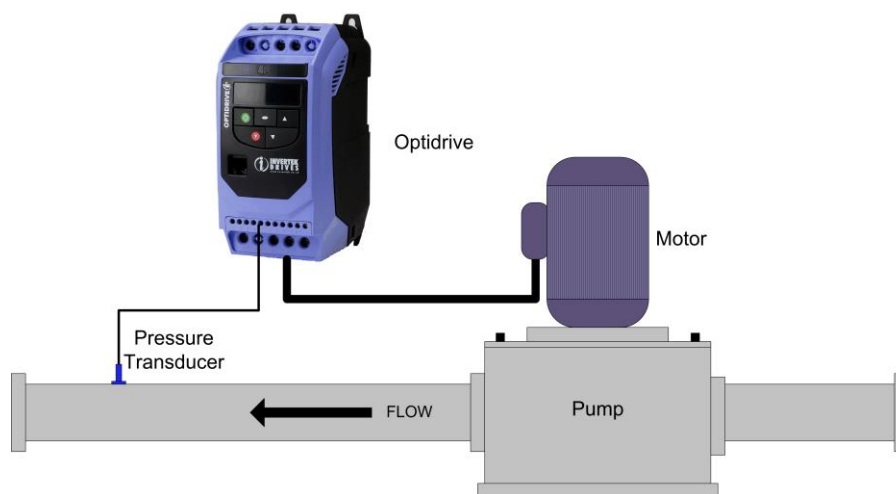
### Standby with Drive Firmware >=V1.10

From firmware version 1.10, the drive will switch to Standby Mode if the output frequency remains at minimum frequency / speed, set in P-02 for the time set in P-48. The drive will then remain in standby mode until the PI error exceeds the level set in P-49, and the PI output exceeds the minimum speed, P-02.

See the set up example below for further guidance.

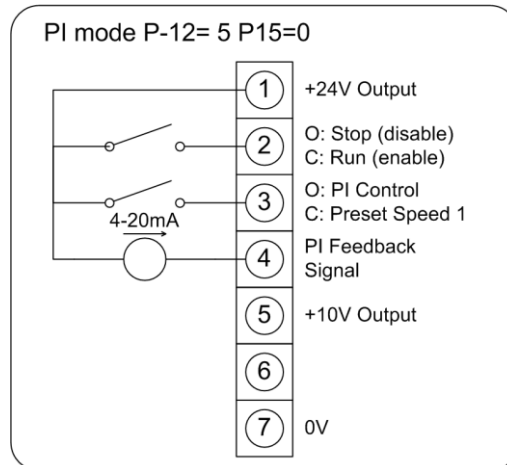
## Application Examples

### Pressure Control – Simple Fixed PI Setpoint



Par	Function	Example Setting	Explanation
P-03	Acceleration Ramp Time	10 – 30 seconds	Allows for smooth starting and stopping of the system
P-04	Deceleration Ramp Time	10 – 30 seconds	
P-06	Energy Optimiser	1	Energy optimiser enabled
P-07	Motor Rated Voltage	-	Enter the values from the motor nameplate, to avoid damaging the motor.
P-08	Motor Rated Current	-	
P-09	Motor Rated Frequency	-	
P-12	Control Selection	5	Enables PI Control
P-14	Access Code	101	Allows Access to PI Parameters
P-47	2 <sup>nd</sup> Analog Input Format	4-20mA	Set to match the transducer signal type
P-41	PI Proportional Gain	0.5 – 2	System Dependant
P-42	PI Integral Time	1 – 5 seconds	System Dependant
P-43	PI Mode Select	0	Direct Operation – <b>INCREASE</b> in motor speed signal for an <b>INCREASE</b> in feedback signal
P-44	PI Setpoint Selection	0	Digital Setpoint with level set in P-45
P-45	PI Setpoint (reference)	-	Set to desired operating level.

## Connections



### **Additional Settings for Standby Mode Function**

#### **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 :-

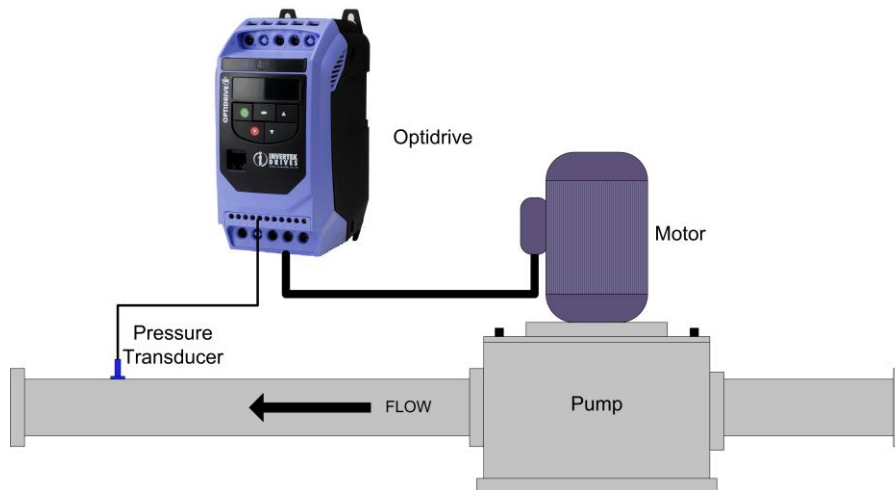
$$P-45 \text{ Setpoint} = 4\text{Bar} / 10 \text{ Bar} \times 100.0\% = 40.0\%$$

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 minimum speed, P-02 should be set slightly higher than this value.

$$P-49 \text{ Wake Up Error} = (4 \text{ Bar} - 3.5 \text{ Bar}) / 10 \text{ Bar} \times 100.0\% = 5.0\%$$

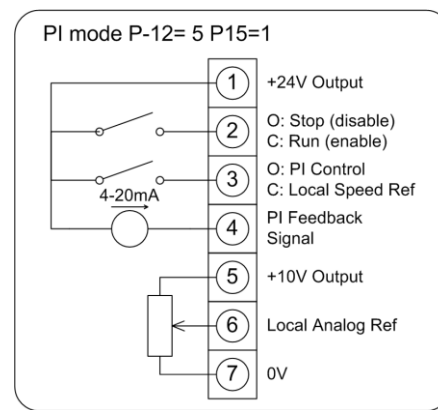
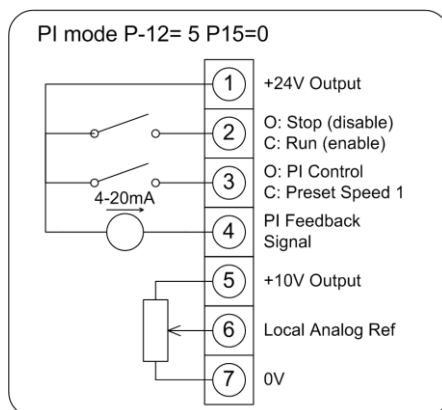
Note that when a low P Gain value (P-41) or long integral time (P-42) are used, there can be a time delay to restart the pump, as the PI output needs to climb to minimum speed. In this case, reduce the wake error level (P-49) or increase the P Gain (P-41), whilst avoiding unstable operation.

**Pressure Control – Variable PI Setpoint with local/ remote operation.**



Par	Function	Example Setting	Explanation
P-03	Acceleration Ramp Time	10 – 30 seconds	Allows for smooth starting and stopping of the system
P-04	Deceleration Ramp Time	10 – 30 seconds	
P-06	Energy Optimiser	1	Energy optimiser enabled
P-07	Motor Rated Voltage	-	Enter the values from the motor nameplate, to avoid damaging the motor.
P-08	Motor Rated Current	-	
P-09	Motor Rated Frequency	-	
P-12	Control Selection	5	Enables PI Control
P-14	Access Code	101	Allows Access to PI Parameters
P-15	Terminal Configuration		See below
P-47	2 <sup>nd</sup> Analog Input Format	4-20mA	Set to match the transducer signal type
P-41	PI Proportional Gain	0.5 – 2	System Dependant
P-42	PI Integral Time	1 – 5 seconds	System Dependant
P-43	PI Mode Select	0	Direct Operation – <b>INCREASE</b> in motor speed signal for an <b>INCREASE</b> in feedback signal
P-44	PI Setpoint Selection	0	Analog Setpoint with level set from external signal e.g. potentiometer

**Connections**



Remote Control (PI)

Control set by pressure level

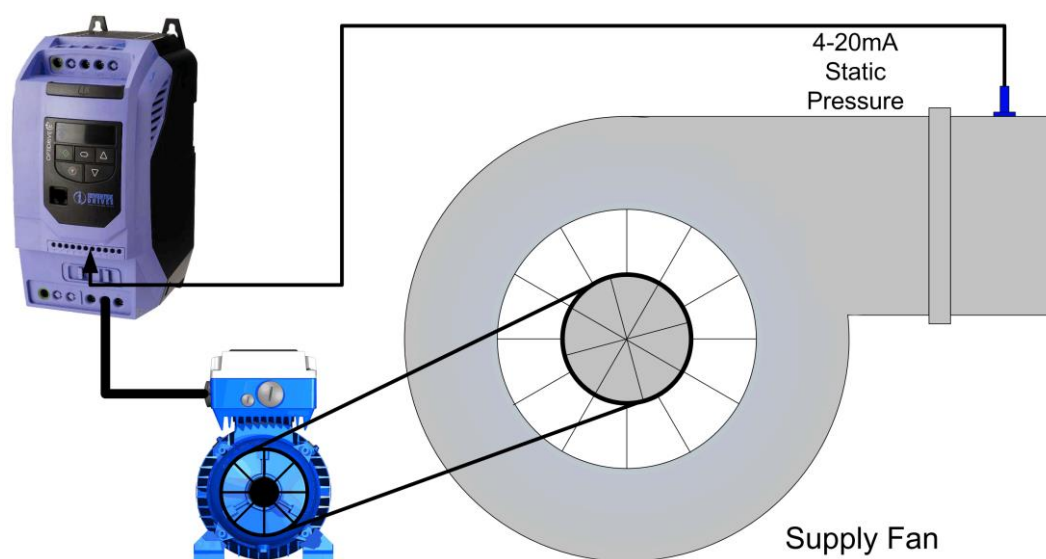
Control set by pressure level

Local Control

Speed Set by Preset Speed 1 (P-20)

Speed set by potentiometer

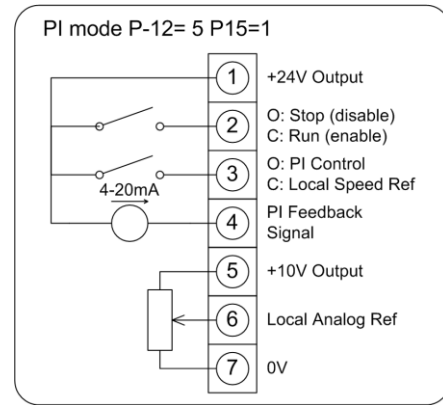
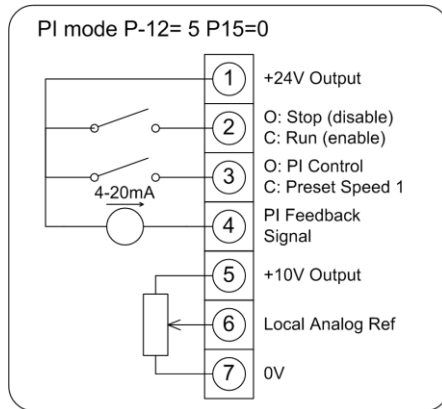
## Blower / Compressor Control using pressure feedback



Par	Function	Example Setting	Explanation
P-03	Acceleration Ramp Time	10 – 30 seconds	Allows for smooth starting and stopping of the system
P-04	Deceleration Ramp Time	10 – 30 seconds	
P-06	Energy Optimiser	1	Energy optimiser enabled
P-07	Motor Rated Voltage	-	Enter the values from the motor nameplate, to avoid damaging the motor.
P-08	Motor Rated Current	-	
P-09	Motor Rated Frequency	-	
P-12	Control Selection	5	Enables PI Control
P-14	Access Code	101	Allows Access to PI Parameters
P-15	Terminal Configuration		See below
P-47	2 <sup>nd</sup> Analog Input Format	4-20mA	Set to match the transducer signal type
P-41	PI Proportional Gain	0.5 – 2	System Dependant
P-42	PI Integral Time	1 – 5 seconds	System Dependant
P-43	PI Mode Select	0	Direct Operation – <b>INCREASE</b> in motor speed signal for an <b>INCREASE</b> in feedback signal
P-44	PI Setpoint Selection	0	Analog Setpoint with level set from external signal e.g. potentiometer



**Connections**

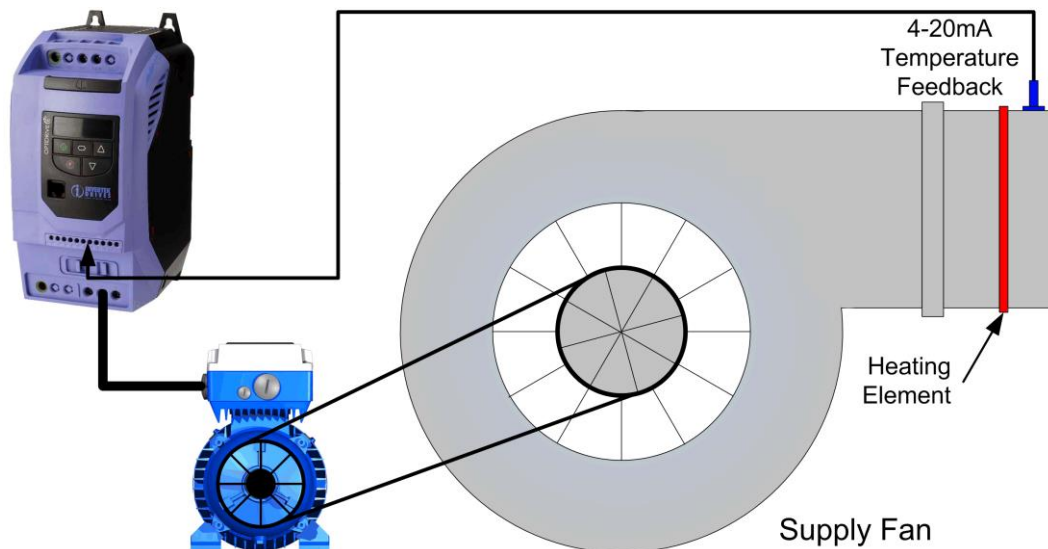


Remote Control (PI)  
Local Control

Control set by pressure level  
Speed Set by Preset Speed 1 (P-20)

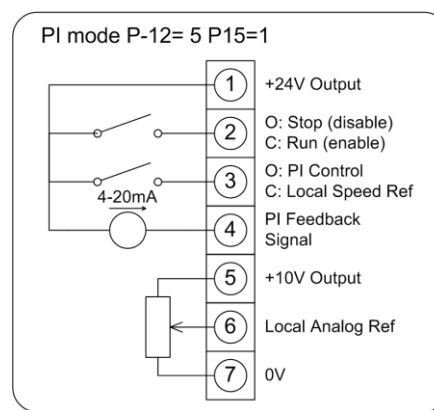
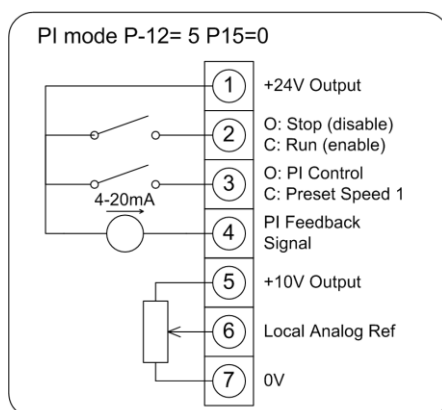
Control set by pressure level  
Speed set by potentiometer

### Temperature Control using temperature feedback



Par	Function	Example Setting	Explanation
P-03	Acceleration Ramp Time	10 – 30 seconds	Allows for smooth starting and stopping of the system
P-04	Deceleration Ramp Time	10 – 30 seconds	
P-06	Energy Optimiser	1	Energy optimiser enabled
P-07	Motor Rated Voltage	-	Enter the values from the motor nameplate, to avoid damaging the motor.
P-08	Motor Rated Current	-	
P-09	Motor Rated Frequency	-	
P-12	Control Selection	5	Enables PI Control
P-14	Access Code	101	Allows Access to PI Parameters
P-15	Terminal Configuration		See below
P-47	2 <sup>nd</sup> Analog Input Format	4-20mA	Set to match the transducer signal type
P-41	PI Proportional Gain	0.5 – 2	System Dependant
P-42	PI Integral Time	1 – 5 seconds	System Dependant
P-43	PI Mode Select	1	Inverse Operation – <b>INCREASE</b> in motor speed signal for a <b>DECREASE</b> in feedback signal
P-44	PI Setpoint Selection	0	Analog Setpoint with level set from external signal e.g. potentiometer

### Connections



Remote Control (PI) Control set by pressure level  
Local Control Speed Set by Preset Speed 1 (P-20)

Control set by pressure level  
Speed set by potentiometer

## Appendix

Revision History			
Issue	Comments	Author	Date
01	Previous version	PAE	03/02/09
02	Revised to new format	PAE	09/03/09
03	Revised numbering system implemented	KB	3/10/11
04	Format updated, revised text relating to Direct / Inverse operation	KB	19/4/12
05	PI Setpoint P-44 changed to in application example	KB	23/4/12
06	Revised to new format	KB	24/04/14
07	Changes added for V1.20 Firmware	KB	03/02/15