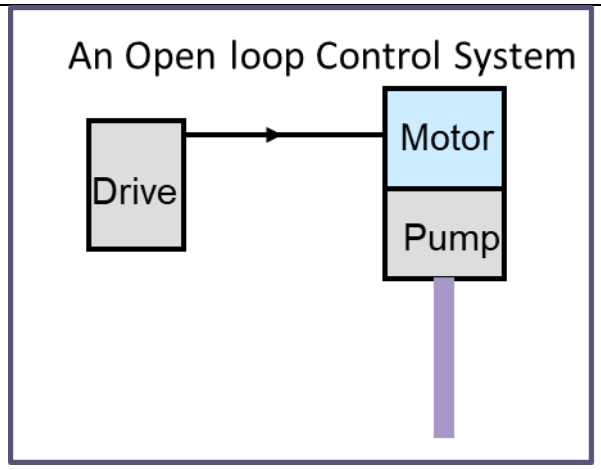
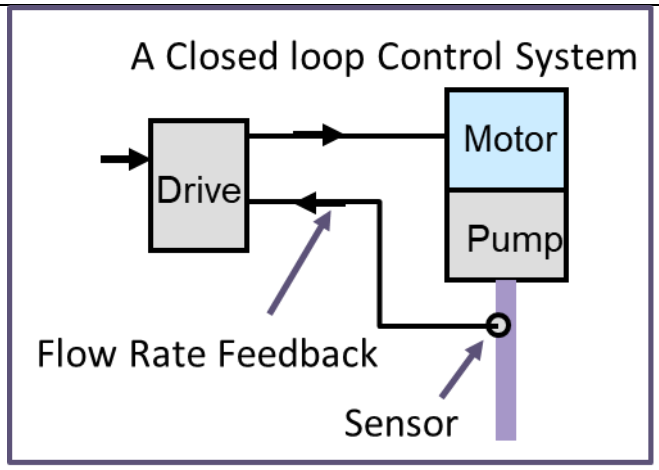
Optidrive Applications Support Library

Application Note	**AN-ODE-3-032**
Title	**PI Closed Loop Feedback Control Applications**
Related Products	**Optidrive E3**
Level **2**	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

In some applications, it is required to maintain a process variable at a preset level, for example to maintain a constant pressure or temperature within a system. These systems benefit from a "closed loop" control system.

In an open loop control system, the drive simply outputs a frequency with no reference to the result. In a closed loop system the 'variable' is measured with a sensor, and the drive compares this 'actual' value with the desired value (Setpoint), and adjusts the speed accordingly.

Open Loop System Example	Closed Loop System Example
	

Optidrive E3 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. In addition, more complex functions, such as differential pressure, constant motor current or even maintaining the DC link voltage for simple solar pumping applications can be achieved.

This document describes the setup procedure for each of the operating modes available.

PI Overview

A PI system requires:

Setpoint Signal (reference)

This is the desired operating point of the system such as a pressure level which the pump is required to maintain, e.g. 1.5 Bar.

Feedback Signal

This is the feedback measurement e.g. a pressure transducer to measure the system pressure.

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.

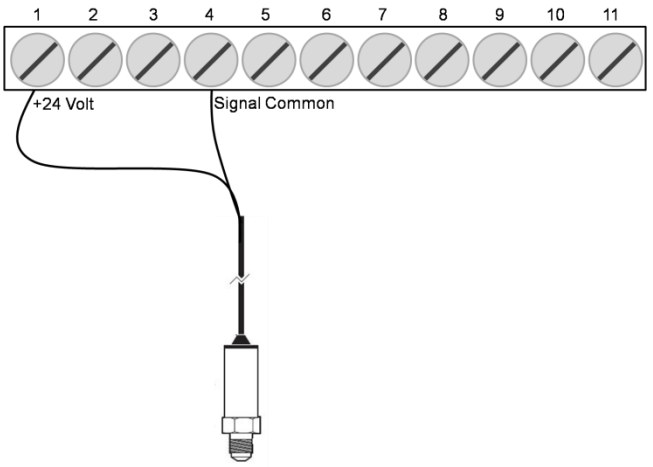
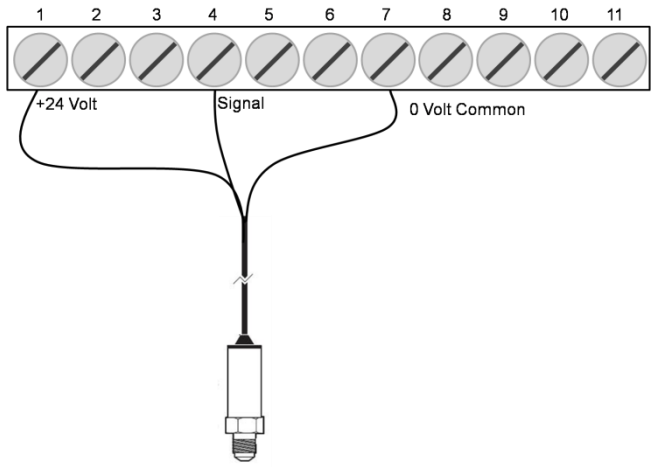
PI Parameters Overview

The following drive parameters relate to the PI function within the drive.

P-41	**PI Controller Proportional Gain**	0.0	30.0	1.0	-
	PI Controller Proportional Gain. Higher values provide a greater change in the drive output frequency in response to small changes in the feedback signal. Too high a value can cause instability				
P-42	**PI Controller Integral Time**	0.0	30.0	1.0	s
	PI Controller Integral Time. Larger values provide a more damped response for systems where the overall process responds slowly				
P-43	**PI Controller Operating Mode**	0	1	0	-
	0: Direct Operation. Use this mode if when the feedback signal drops, the motor speed should increase. **1: Inverse Operation**. Use this mode if when the feedback signal drops, the motor speed should decrease. **2: Direct Operation, Wake at Full Speed**. As setting 0, but on restart from Standby, PI Output is set to 100% **3: Reverse Operation, Wake at Full Speed**. As setting 0, but on restart from Standby, PI Output is set to 100%				
P-44	**PI Reference (Setpoint) Source Select**	0	1	0	-
	Selects the source for the PID Reference / Setpoint **0: Digital Preset Setpoint**. P-45 is used **1: Analog Input 1 Setpoint**. Analog input 1 signal level, readable in P00-01 is used for the setpoint.				
P-45	**PI Digital Setpoint**	0.0	100.0	0.0	%
	When P-44 = 0, this parameter sets the preset digital reference (setpoint) used for the PI Controller as a % of the feedback signal.				
P-46	**PI Feedback Source Select**	0	5	0	-
	Selects the source of the feedback signal to be used by the PI controller. **0: Analog Input 2** (Terminal 4) Signal level readable in P00-02. **1 : Analog Input 1** (Terminal 6) Signal level readable in P00-01 **2: Motor Current**. Scaled as % of P-08. **3 : DC Bus Voltage** Scaled 0 – 1000 Volts = 0 – 100% **4: Analog 1 – Analog 2**. The value of Analog Input 2 is subtracted from Analog 1 to give a differential signal. The value is limited to 0. **5: Largest (Analog 1, Analog 2)**. The larger of the two analog input values is always used for PI feedback.				
P-48	**Standby Mode Timer**	0.0	25.0	0.0	s
	When standby mode is enabled by setting P-48 > 0.0, the drive will enter standby following a period of operating at minimum speed (P-02) for the time set in P-48. When in Standby Mode, the drive display shows **StndbY**, and the output to the motor is disabled.				
P-49	**PI Control Wake Up Error Level**	0.0	100.0	5.0	%
	When the drive is operating in PI Control Mode (P-12 = 5 or 6), and Standby Mode is enabled (P-48 > 0.0), P-49 can be used to define the PI Error Level (E.g. difference between the setpoint and feedback) required before the drive restarts after entering Standby Mode. This allows the drive to ignore small feedback errors and remain in Standby mode until the feedback drops sufficiently.				

Connecting Feedback Signals

The default drive parameter settings are configured to allow connection of an analog signal such as a pressure transducer to analog input 2. There are generally two types of transducers. An example of how to connect each of these to the drive is shown below. When connecting a 2-wire feedback transducer, also known as a Loop Powered 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.

2 Wire or Loop Powered Transducer	3 or 4 Wire Transducer
	

Standby Function

The Standby function allows the motor to automatically switch off completely when not required i.e. when the setpoint level is maintained without requiring further effort. This can be useful in pump applications where there may be no flow demand during some time periods, and the system pressure will maintain even with the pump switched off.

The Standby function is enabled by setting P-48 > 0. When P-48 > 0 the drive will switch to Standby Mode if the output frequency remains at the 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.

Adjusting the P Gain and I Time

Each individual application requires the Proportional Gain P-41 and Integral Time P-42 to be adjusted to provide the optimal system response. In general, the simplest method is to use the scope function of Optitools Studio PC software to monitor the feedback signal and output frequency, and adjust the parameters to provide a smooth response.

In general, increasing the P-Gain tends to make the system more responsive, and results in a larger change in output frequency for a relatively smaller difference between the setpoint and the feedback. If the P-Gain is too high, the system tends to overshoot – to over compensate for errors – and becomes unstable.

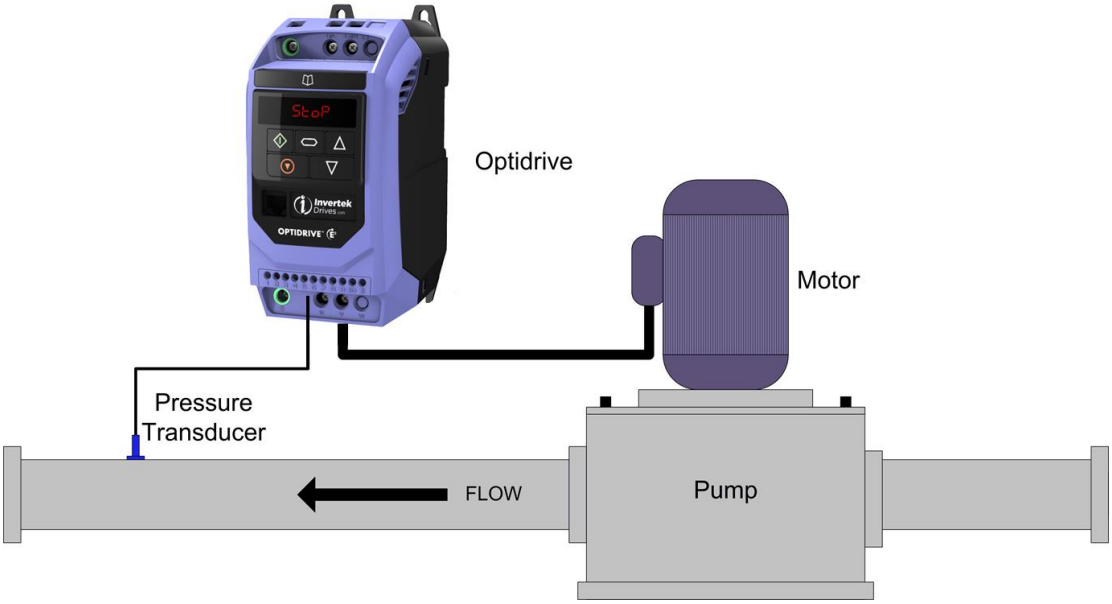
Systems where the measured variables changes very slowly e.g. applications controlling temperature will in general require longer integral time and lower proportional gain for optimum operation.

The following sections contain some example applications to provide an overview of the parameter settings.

Example 1: Pump Pressure Control with Fixed PI Setpoint

This application is based on the following:

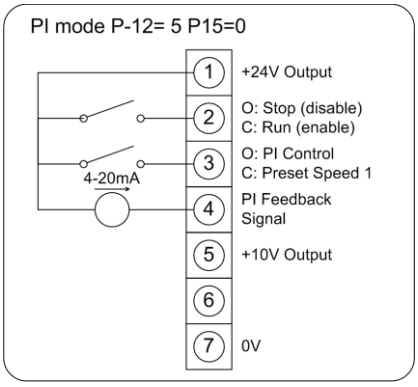
- A pressure feedback transducer is used with 0 – 10 bar range and 4 – 20mA output
- Standby mode is used to switch off when the pressure maintains at 4 bar without flow, and to restart the pump when pressure falls to 3.8 bar
- In the event of a transducer fault, or when required, the pump can operate at fixed speed



Parameter Settings

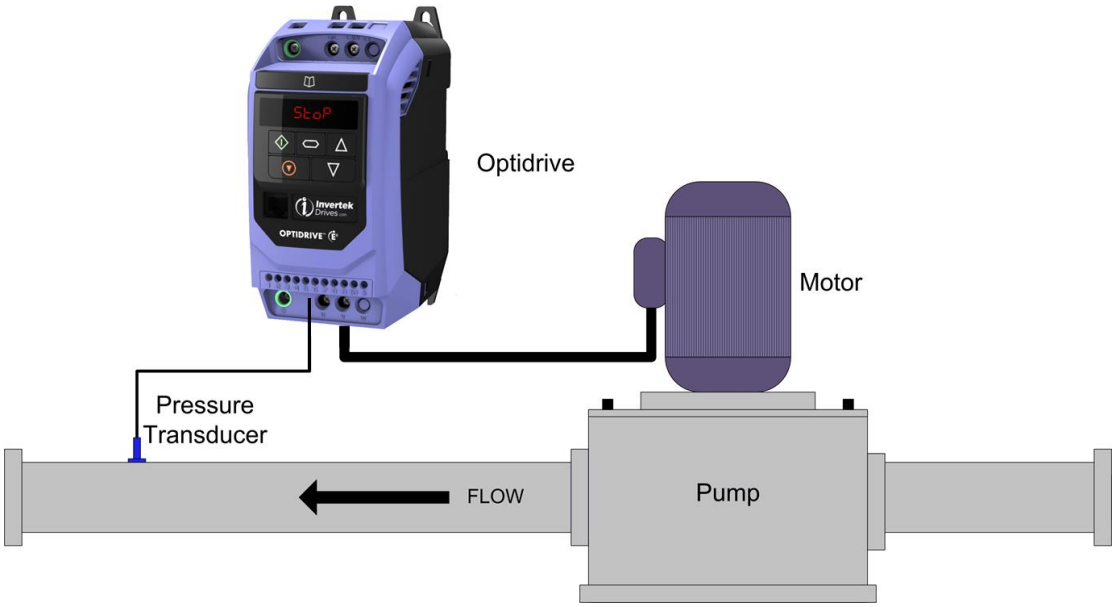
Par	Function	Example Setting	Explanation
P-02	Minimum Frequency / Speed	35 – 40Hz	The setting must be slightly higher than the pump speed where no flow is produced but pressure is maintained
P-03	Acceleration Ramp Time	10 – 30 seconds	Allows for smooth starting and stopping of the system
P-04	Deceleration Ramp Time	10 – 30 seconds	
P-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-13	Application Mode	1	Pump Mode optimises the drive parameters for pump applications
P-14	Access Code	101	Allows Access to PI Parameters
P-15	Terminal Configuration	0	See diagram below
P-20	Preset Speed 1	45.0Hz	If the transducer fails, the pump operated continuously at 45Hz
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	2	Direct Operation – When the feedback signal increases, the motor speed should reduce
P-44	PI Setpoint Selection	0	Digital Setpoint with level set in P-45
P-45	PI Setpoint (reference)	40.0%	Calculated by (Required Pressure (4 bar) / Transducer Range (10 bar)) x100%
P-47	2nd Analog Input Format	r 4-20mA	Set to match the transducer signal type, and configures signal loss option to use P-20 speed
P-48	Standby Mode Time	20 seconds	The pump remains at minimum speed for 20 seconds before switching off if the pressure is maintained at or above the setpoint.
P-49	PI Wake Error	2.0%	Calculated by (Setpoint(4 Bar) – Wake Level (3.8 Bar)) / Transducer Range (10 Bar) x 100.0%

Simple Connection Diagram



Example 2: Pump Pressure Control with direct speed control option.

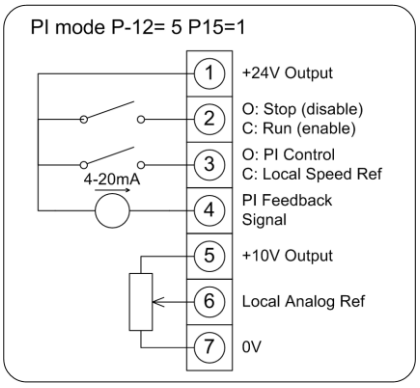
This application is very similar to the above option, but also adds the facility to control the pump speed directly from a potentiometer if required.



Parameter Settings

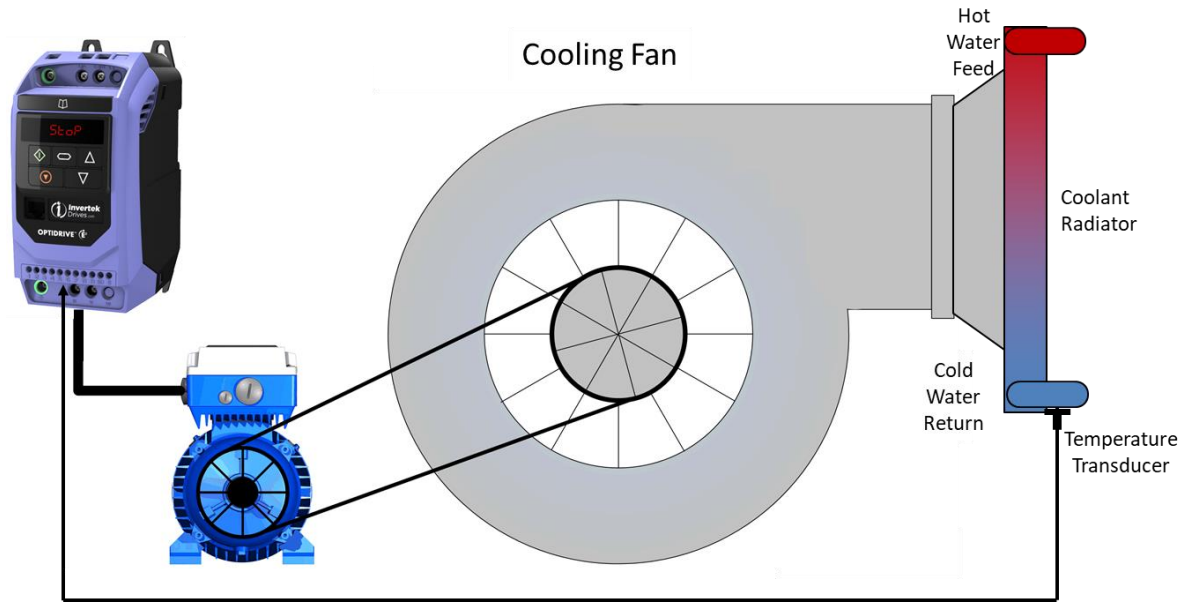
Par	Function	Example Setting	Explanation
P-02	Minimum Frequency / Speed	35 – 40Hz	The setting must be slightly higher than the pump speed where no flow is produced but pressure is maintained
P-03	Acceleration Ramp Time	10 – 30 seconds	Allows for smooth starting and stopping of the system
P-04	Deceleration Ramp Time	10 – 30 seconds	
P-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-13	Application Mode	1	Pump Mode optimises the drive parameters for pump applications
P-14	Access Code	101	Allows Access to PI Parameters
P-15	Terminal Configuration	1	See diagram below
P-20	Preset Speed 1	45.0Hz	If the transducer fails, the pump operated continuously at 45Hz
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	2	Direct Operation – When the feedback signal increases, the motor speed should reduce
P-44	PI Setpoint Selection	0	Digital Setpoint with level set in P-45
P-45	PI Setpoint (reference)	40.0%	Calculated by (Required Pressure (4 bar) / Transducer Range (10 bar)) x100%
P-47	2nd Analog Input Format	r 4-20mA	Set to match the transducer signal type, and configures signal loss option to use P-20 speed
P-48	Standby Mode Time	20 seconds	The pump remains at minimum speed for 20 seconds before switching off if the pressure is maintained at or above the setpoint.
P-49	PI Wake Error	2.0%	Calculated by (Setpoint(4 Bar) – Wake Level (3.8 Bar)) / Transducer Range (10 Bar) x 100.0%

Connections



Example 3: Cooling Fan Temperature Control

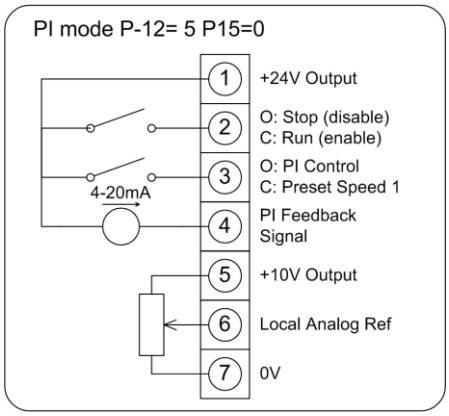
- In this application, a fan is used to force cooling air over a radiator, used for cooling a process.
- The temperature is measured using a temperature transducer that provides a 4- 20mA output for a range of 0 – 150°C
- The target is to maintain the cold water return temperature at 68°C



Parameter Settings

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-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-13	Application Mode	2	Fan Mode optimises the drive parameters for fan applications
P-14	Access Code	101	Allows Access to PI Parameters
P-15	Terminal Configuration	0	See diagram below
P-20	Preset Speed 1	45.0Hz	If the transducer fails, the pump operated continuously at 45Hz
P-41	PI Proportional Gain	0.5 – 2	System Dependant
P-42	PI Integral Time	5 – 30 seconds	System Dependant
P-43	PI Mode Select	1	Inverse Operation When the feedback signal increases, the motor speed should increase
P-44	PI Setpoint Selection	0	Digital Setpoint with level set in P-45
P-45	PI Setpoint (reference)	45.3%	Calculated by (Temperature Setpoint (68°C) / Transducer Range (150°C)) x 100%
P-47	2nd Analog Input Format	r 4-20mA	Set to match the transducer signal type, and configures signal loss option to use P-20 speed

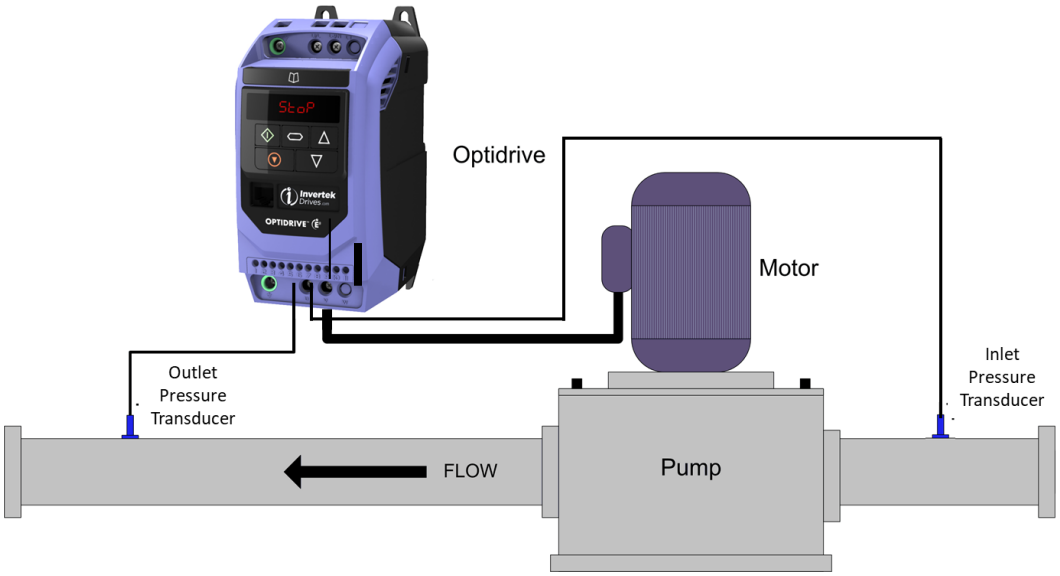
Connections



Example 4: Differential Pressure

This application is based on the following:

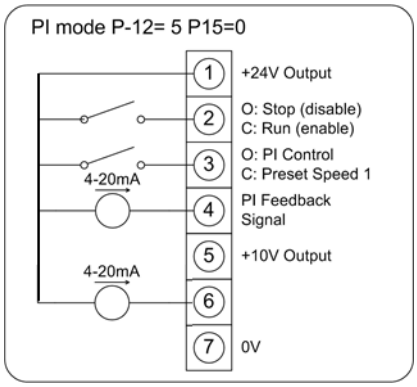
- A pump is required to maintain a constant pressure difference between the inlet and the outlet of 1 bar
- Pressure feedback transducers are fitted to the inlet and outlet side of the pump 0 – 10 bar range and 4 – 20mA output
- In the event of a transducer fault, or when required, the pump must stop



Parameter Settings

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-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-13	Application Mode	1	Pump Mode optimises the drive parameters for pump applications
P-14	Access Code	101	Allows Access to PI Parameters
P-15	Terminal Configuration	0	See diagram below
P-16	Analog Input 1 Signal format	t 4-20	4-20mA Input signal, drive trips if the signal is lost
P-20	Preset Speed 1	45.0Hz	If the transducer fails, the pump operated continuously at 45Hz
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	2	Direct Operation – When the feedback signal increases, the motor speed should reduce
P-44	PI Setpoint Selection	0	Digital Setpoint with level set in P-45
P-45	PI Setpoint (reference)	10.0%	Calculated by (Required Differential Pressure (1 bar) / Transducer Range (10 bar)) x100%
P-47	2nd Analog Input Format	t 4-20	4-20mA Input signal, drive trips if the signal is lost

Simple Connection Diagram



Appendix

Revision History

Issue	Comments	Author	Date
01	First release	KB	10/07/17