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Title	Imoticon ID700 Basic PID Loop Set-up
Summary	This document gives information on how to set up the Imoticon ID700 PID Loop for basic PID control

NOTE: Please read this document in conjunction with the Imoticon ID700 Easy Start Guide and Imoticon ID700 Advanced User Manual.

Overview

The Imoticon ID700 has a built in PID (proportional-integral-derivative) controller that can be used for a variety of process control applications. Some typical applications will include - temperature control, flow control, pressure & vacuum control etc.

This document describes the principles of PID control and the procedure for setting up the Imoticon ID700

Principles of PID Control

Industrial processes can often require a constant process value (such as temperature, pressure, fluid level, vacuum or flow rate etc.) to be maintained regardless of any variation in system operating parameters.

Example:

The level of liquid in a tank is to be maintained regardless of the number of output valves opened. This can be achieved by using a variable speed drive with PID control to vary the speed of the inlet pump and thus inlet flow to maintain a set level within the tank regardless of how many outlet valves are opened.

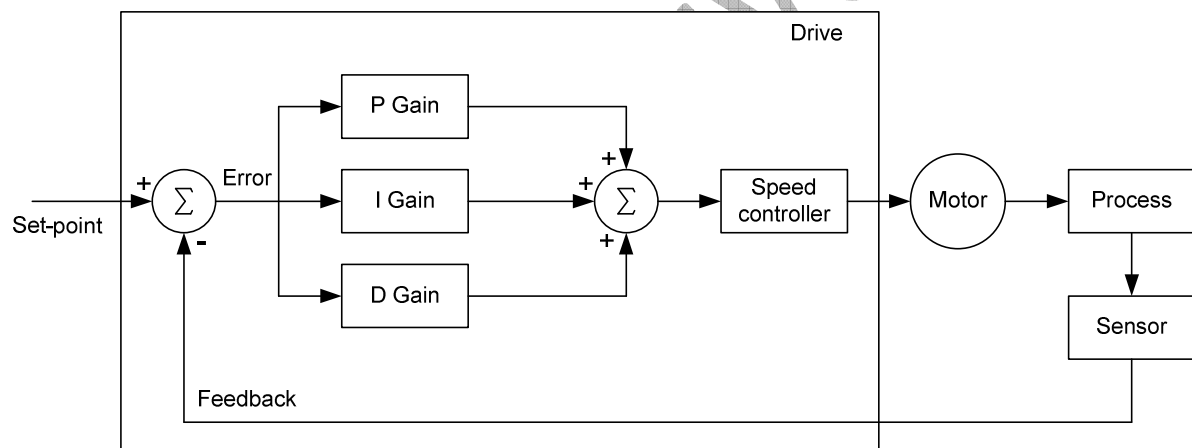
The PID control loop would need feedback from a sensor that represented the variable to be controlled and a set-point that represented the process level that was required to be maintained.

So for the example of the tank, a level sensor would be required to be placed in the tank to feedback the level of liquid to the ID700. A set-point would be programmed into the ID700 which would be the level to be maintained. The PID control loop would then modify the speed of the inlet pump depending on the outlet flow (number of outlet valves opened). If only one outlet valve was opened then the inlet pump would run at a slower speed to maintain the set-point level. If 3 outlet valves were opened then the inlet pump would run at a higher speed to maintain the set-point level.

The PID controller operates on the 'error value' or the difference between the measured process value and the programmed set-point. The PID control loop will attempt to eliminate the error (maintain the set-point) by adjusting the drives output speed and thus adjusting the flow, level, pressure, temperature within the system.

The PID controller will react to this error value and how the PID controller reacts depends on the size of the error and the time the error has existed. The PID controller corrects the error and for best performance corrects the error in the shortest possible time although this does depend on the type of application being controlled by the PID controller.

Basic PID controller diagram

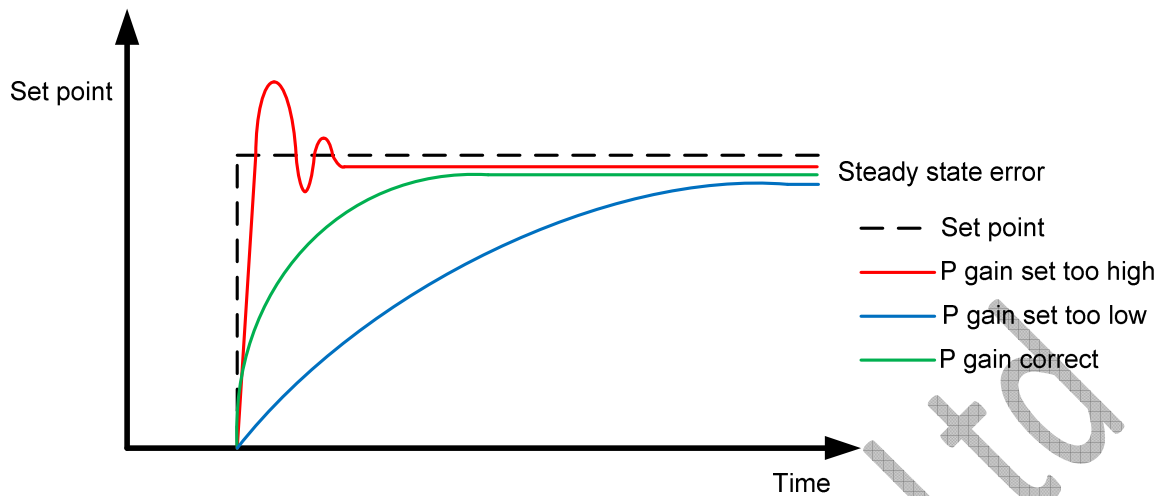


Proportional – P-Gain

The (P) proportional term in a PID function is simply a multiplier for the error signal. The P term directly affects the size of the error value seen by the PID controller and how quickly the Imoticon ID700 output responds. If the P gain value is set too low then the ID700 will take more time to modify its output and correct the error. If the P gain is set too high then the ID700 may respond too quickly and cause the system (and feedback) to overshoot the required set-point. This results in what are called 'oscillations' where the PID controller has to compensate for the overshoot. If the P gain is set significantly too high then the system can become 'unstable'.

When only a 'P' term is applied to the PID controller (no 'I' or 'D' term) then there will always be error in existence between the set-point and the feedback level. This error exists because the P term is a multiplier value and with no error to multiply, the output will start to decrease (in turn creating an error). The system will eventually balance out with a steady state error always present.

The following graph shows the affects of tuning the Proportional term:



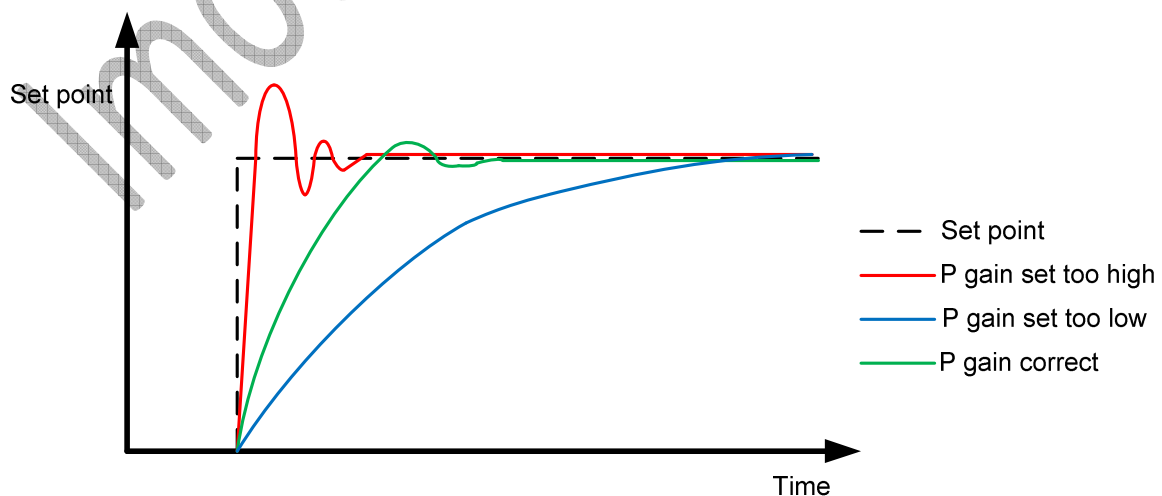
Integral – I-Gain

The (I) Integral term in a PID function samples the error present over a given time and takes an average of those values, hence the affect on the system is based on the accumulation of recent errors rather than the current or existing error. The I term is used to eliminate the steady state error (caused by only applying P term) and it adds longer term precision. The I term should always be used in conjunction with the P term.

A low value of I term results in a low sample time, making the drive output more responsive but more prone to instability. A high value of I term results in a high sample time that might make the drive output unresponsive or not fully eliminate the steady state error.

Small changes of Integral time can have a large affect on the system response and can very quickly lead to instability. Care should be taken in adjusting this value to ensure no instability is introduced into the system, especially resulting from a large change in error or set-point value resulting in a large error occurring.

The following graph shows the affects of tuning the Integral term (having tuned the P term):



Differential- D-Gain

The (D) Derivative term (sometimes referred to as the Differential term) in a PID function looks at the rate of change of error and attempts to respond proactively based on this behaviour. The D term effectively predicts where the drive is likely to be after a given time and adapts the output to create a more dynamic response. One of the issues associated with the D term is that it can cause high frequency oscillations and instability in the system if set incorrectly. The D term should always be used in conjunction with both the P and I terms.

A low value of D term results in a low sample time, and makes the drive output more responsive but more susceptible to instabilities. A high value of D term results in a high sample time that might make the drive output unresponsive.

Note: The majority of Standard Motor Control Applications do not require adjustment of the D term. By default the D term is set to '0' in the Imoticon ID700 which disables the function. Care should always be taken in adjusting this value and it is recommended only for experienced drive commissioning engineers with good practical experience of tuning the D term in PID control applications.

Drive Configuration and Commissioning

The following section will explain how to configure the Imoticon ID700 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 Imoticon ID700 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:

P00.01 = Motor Rated Voltage (230V/400V default) – Set to motor nameplate voltage

P00.02 = Motor Rated Current – Set to motor nameplate current

P00.03 = Motor Rated Frequency (50Hz default) – Set to motor nameplate frequency

Control mode

P00.04 = Control mode – Set to 1 - terminal control

Reference source select

P00.05 = Reference source select – Set to 8 - User programmed

Minimum and Maximum speeds

P00.06 = Minimum speed – Set to the required minimum speed (if required)

P00.07 = Maximum speed – Set to the required maximum speed (if required)

Acceleration & deceleration ramps

Usually for Fan and pump applications, the default acceleration ramp of 10s and deceleration ramp of 20s are acceptable as fast response is not usually required although for bigger fans, these values may need increasing.

P00.08 = Acceleration ramp (10s default) – Set to the required acceleration ramp time

P00.09 = Deceleration ramp (20s default) – Set to the required deceleration ramp time

PID Controller Enable

P15.07 – Set to 1 to enable PID controller

PID Reference Set-point Source

The PID reference set-point can either be from an analogue signal, digital reference or keypad.

Analogue set-point signal on Analogue input 2 (AI 2)

P15.01 = 8.18 – Analogue input 2 level as set-point

Digital set-point

P15.01 = 17.42 – User defined word variable as set-point

NOTE: P17.42 has a range of -300 to 300 which when programmed to P15.01 = 0 to 100% which can be read in P15.19.

Therefore, if P17.42 is set to 150, P15.19 = 50.0%

Keypad set-point

P15.01 = 1.09 – keypad reference as set-point

NOTE: With default frequency settings, the keypad has a range of 0 to 50.0 which when programmed to P15.01 = 0 to 100% which can be read in P15.19.

Therefore if the keypad reference is set to 25.0, P15.19 = 50.0%

PID Feedback Source

The PID feedback source is from an analogue signal and is fed into analogue input 1 (AI 1)

P15.02 = 8.17 - Analogue input 1 level as feedback source

The form of analogue input 1 can be changed using parameter P00.11.

AI 1 signal can be voltage or current:

0: 0mA-20mA

1: 20mA-0mA

2: 4mA-20mA (With F013 current loss trip if input current falls below 3mA)

3: 20mA-4mA (With F013 current loss trip if input current falls below 3mA)

4: 4 mA-20mA (Without trip)

5: 20mA-4mA (Without trip)

6: 0V-10V

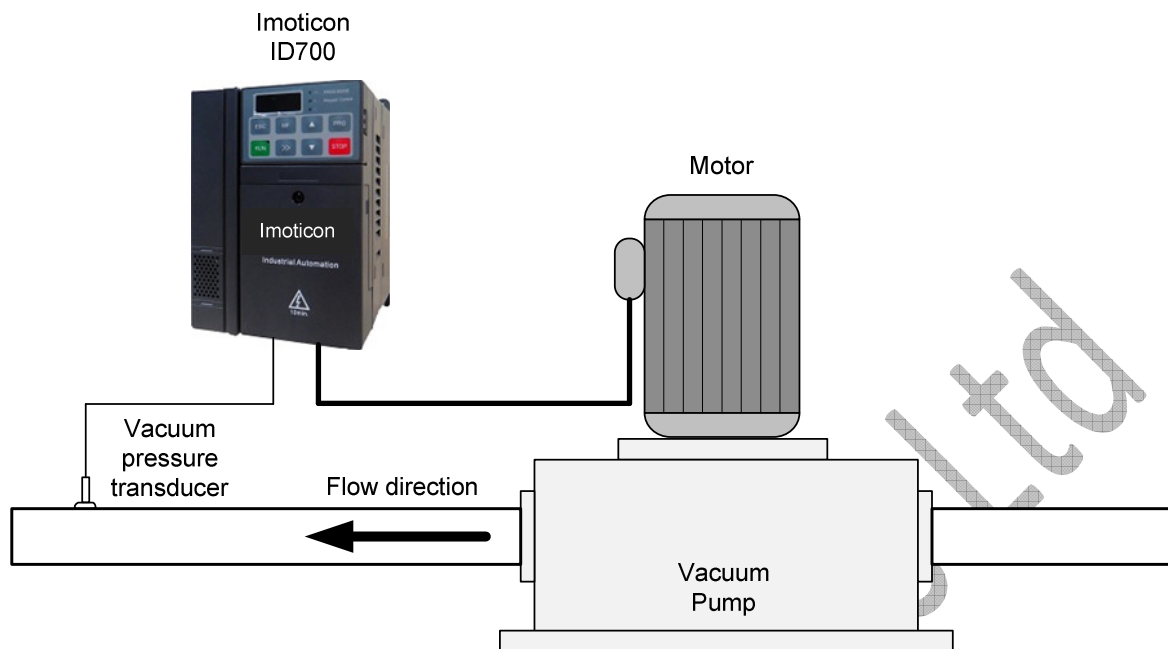
PID Output

P15.15 = 1.27 - PID output destination to User programmed main aux reference

The following pages give set up examples for ID700 PID controller.

Application Example 1

Pressure control – Simple fixed PID set-point



Consider a pumping application
 Feedback transducer = 4-20mA / 0 – 10 bar
 Pressure target level = 4 bar

We can calculate the digital set point for as follows:
 Set-point = 4 bar / 10 bar x 100.0% = 40.0%
 Set 15.01 = 17.42
 P17.42 = 0 to 300.0% Therefore 40% of 300 = 120.0
 Set **P17.42 = 120.0**

Parameter changes required from default

Par	Function	Example Setting	Explanation
P00.01	Motor rated voltage	-	Enter the values from the motor nameplate
P00.02	Motor rated current	-	
P00.03	Motor rated frequency	-	
P00.04	Control mode	1	Terminal control
P00.05	Reference source selector	8	Ref source to user programmable
P00.06	Minimum reference	-	System dependant
P00.08	Acceleration ramp time	10s	System dependant
P00.09	Deceleration ramp time	20s	System dependant
P00.11	Analogue input 1 format	2: 4 to 20mA with trip	Set to match the transducer signal type
P00.23	Extended parameter access	1	Allows extended parameter access
P03.01	Allow reverse	1	Disabled running reverse
P15.01	PID reference source	17.42	PID ref source from P17.42

Parameter changes required from default cont'd

Par	Function	Example Setting	Explanation
P15.02	PID feedback source	8.17	PID feedback from AI 1 level
P15.07	PID enable	1	Enabled PID controller
P15.09	PID P gain	1	System dependant
P15.10	PID I gain	0.5	System dependant
P15.15	PID output destination	1.27	PID output to user programmed reference
P17.42	User defined word variable 1	120.0	Sets PID set point to 40%

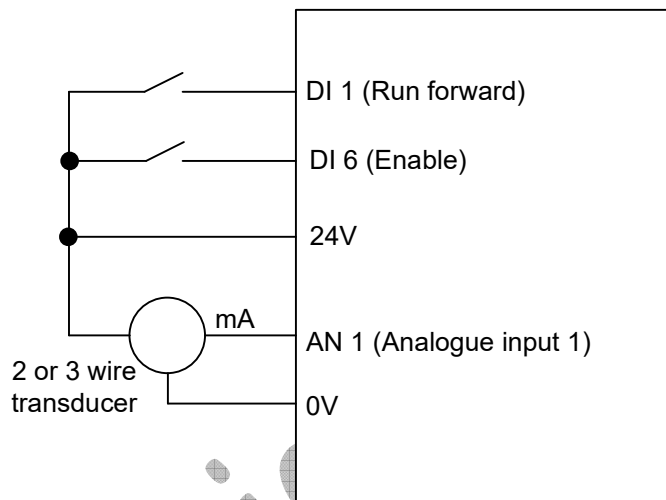
Digital set-point

P15.01 = P17.42 – User defined word variable as set-point

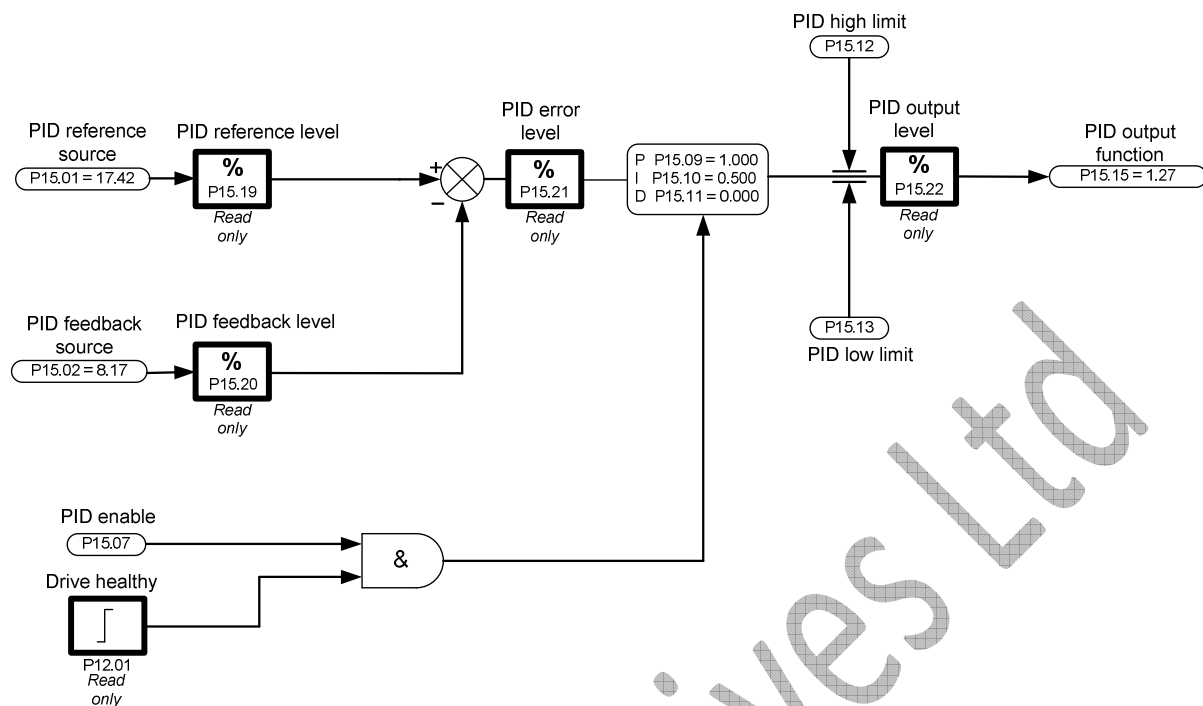
NOTE: P17.42 has a range of -300 to 300 which when programmed to P15.01 = 0 to 100% which can be read in P15.19.

Therefore, if P17.42 is set to 150, P15.19 = 50.0%

Connection diagram



PID diagram for above set-up



Operation

Close the enable signal on DI 6 which will allow the drive to run when the run forward signal is given. When the Run signal is given on terminal DI 1, the drive will enable and the motor will start to run and accelerate because the pressure in the system is low.

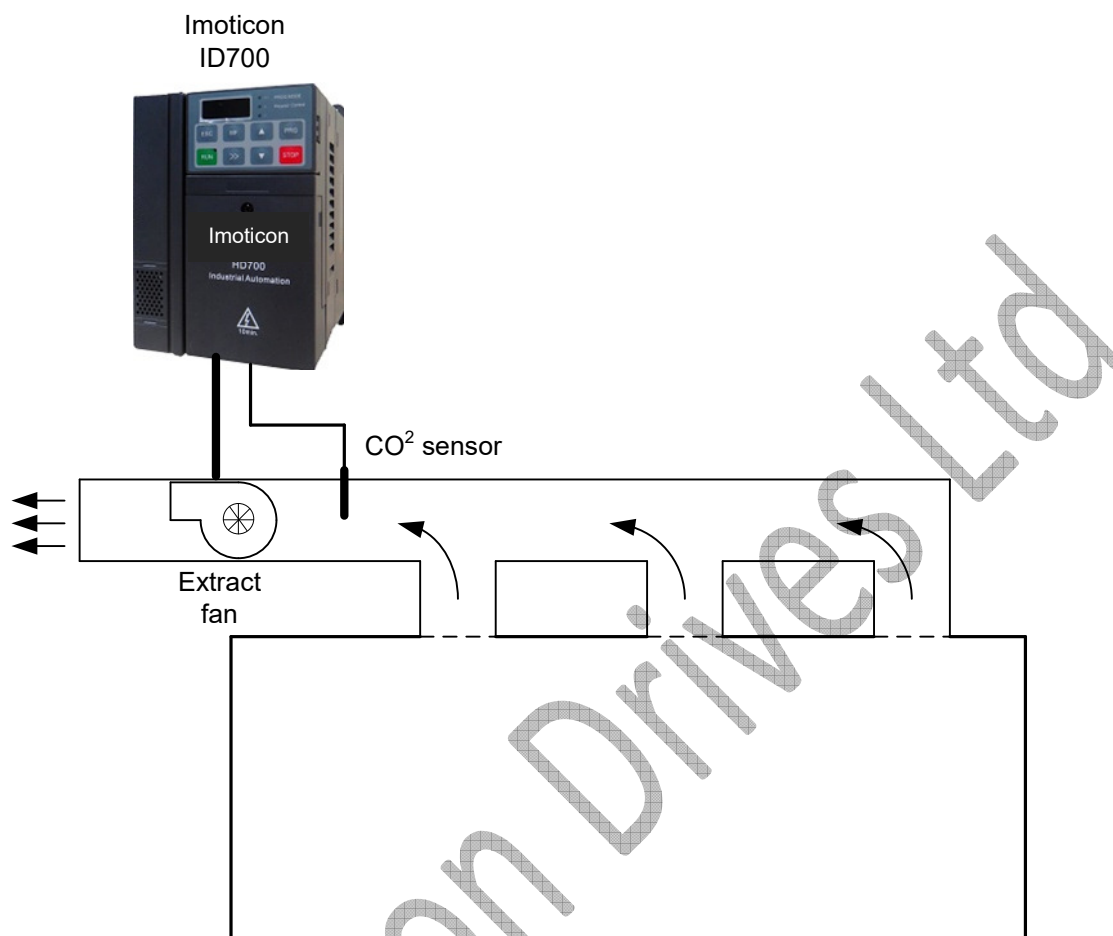
As the motor accelerates the pressure in the system will start to increase so therefore the feedback will increase.

When the pressure goes above 4 bar, the motor speed will slow down.

The system will now regulate the pressure around 4 bar by speeding up and slowing down the pump as the pressure increases and decreases.

Application Example 2

CO² Level control – Simple fixed PID set-point



Example Application

Consider an extract fan application.

Feedback Transducer = 0-10V / 0 – 2000ppm CO²

Pressure Target level = 600ppm

We can calculate the digital set point for as follows:

Set-point = $600\text{ppm} / 2000 \times 100.0\% = 30.0\%$

Set 15.01 = 17.42

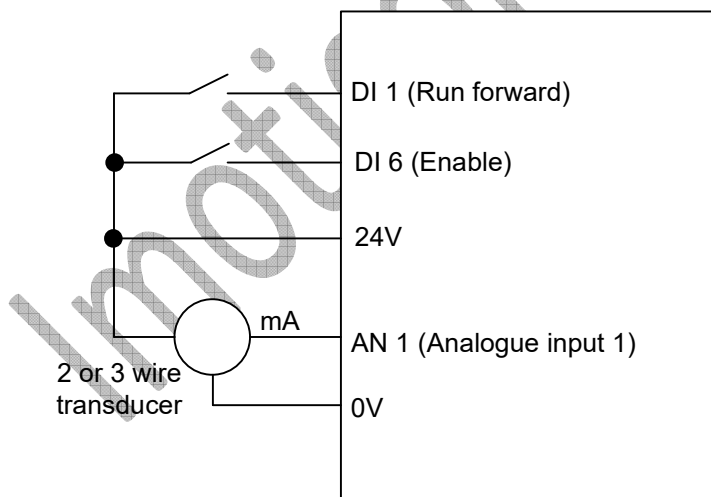
P17.42 = 0 to 300.0% Therefore 30% of 300 = 90.0

Set **P17.42 = 90.0**

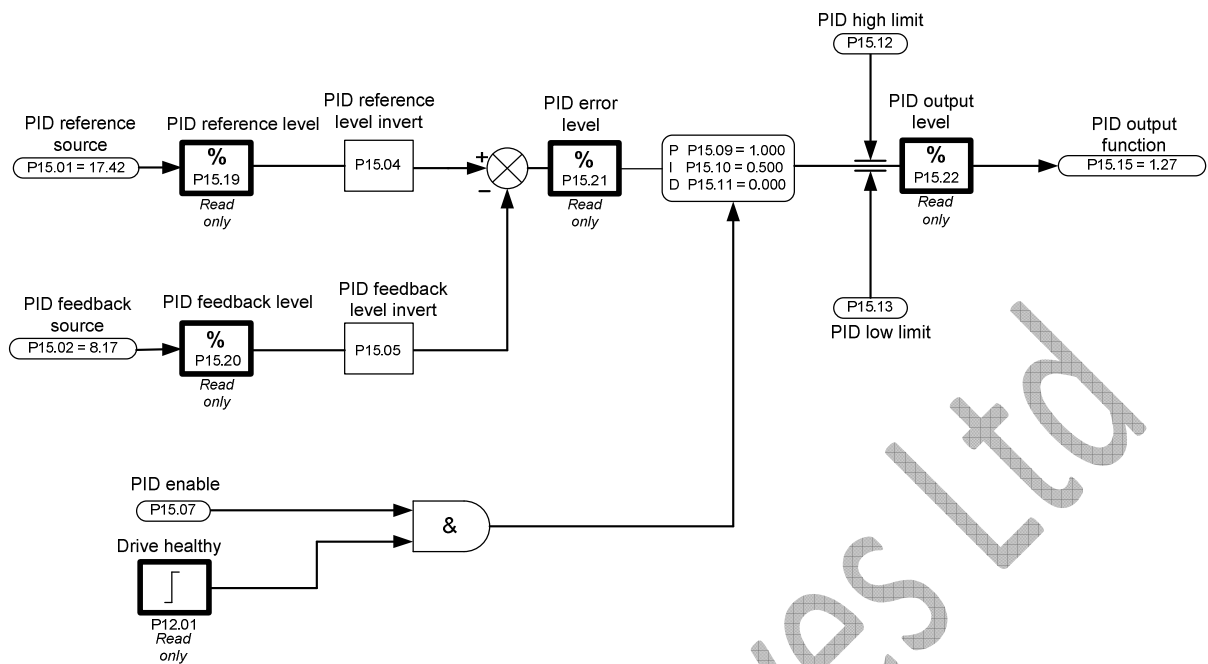
Parameter changes required from default

Par	Function	Example Setting	Explanation
P00.01	Motor rated voltage	-	Enter the values from the motor nameplate
P00.02	Motor rated current	-	
P00.03	Motor rated frequency	-	
P00.04	Control mode	1	Terminal control
P00.05	Reference source selector	8	Ref source to user programmable
P00.06	Minimum reference	-	System dependant
P00.08	Acceleration ramp time	10s	System dependant
P00.09	Deceleration ramp time	20s	System dependant
P00.11	Analogue input 1 format	2: 4 to 20mA with trip	Set to match the transducer signal type
P00.23	Extended parameter access	1	Allows extended parameter access
P03.01	Allow reverse	1	Disabled running reverse
P15.01	PID reference source	17.42	PID ref source from P17.42
P15.02	PID feedback source	8.17	PID feedback from AI 1 level
P15.04	PID reference invert	1	Inverts reference signal
P15.05	PID feedback invert	1	Inverts feedback signal
P15.07	PID enable	1	Enabled PID controller
P15.09	PID P gain	1	System dependant
P15.10	PID I gain	0.5	System dependant
P15.15	PID output destination	1.27	PID output to user programmed reference
P17.42	User defined word variable 1	90.0	Sets PID set point to 30%

Connection diagram



PID diagram for above set-up



Operation

Close the enable signal on DI 6 which will allow the drive to run when the run forward signal is given. When the Run signal is given on terminal DI 1, the drive will enable and the motor will start to run. Depending on the measured feedback CO² level, the motor will speed up and slow down to regulate to 600ppm. If the level of CO² goes above 600ppm, the motor speed will increase to extract the CO². If the CO² falls below 600ppm, the motor speed will decrease.

Application Example 3

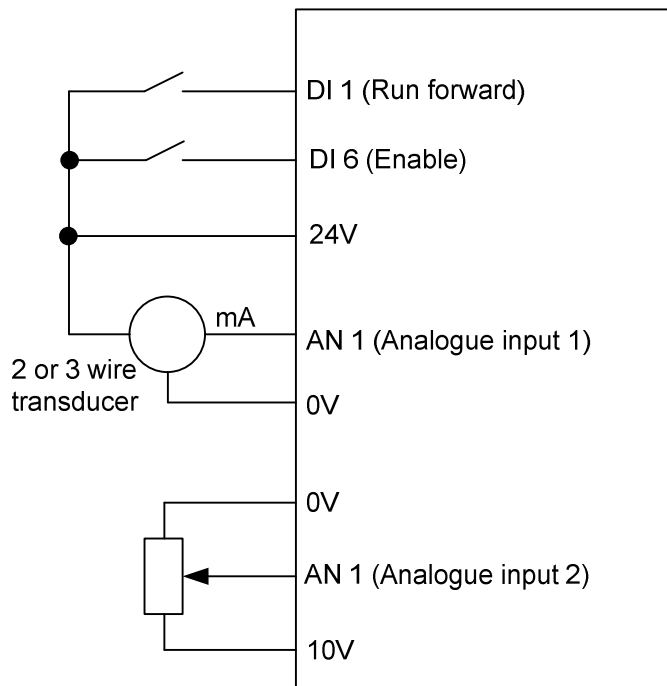
Pressure control – Simple variable PID set-point from potentiometer

This set-up uses Application Example 1 but with a variable set-point from a potentiometer

Parameter changes required from default

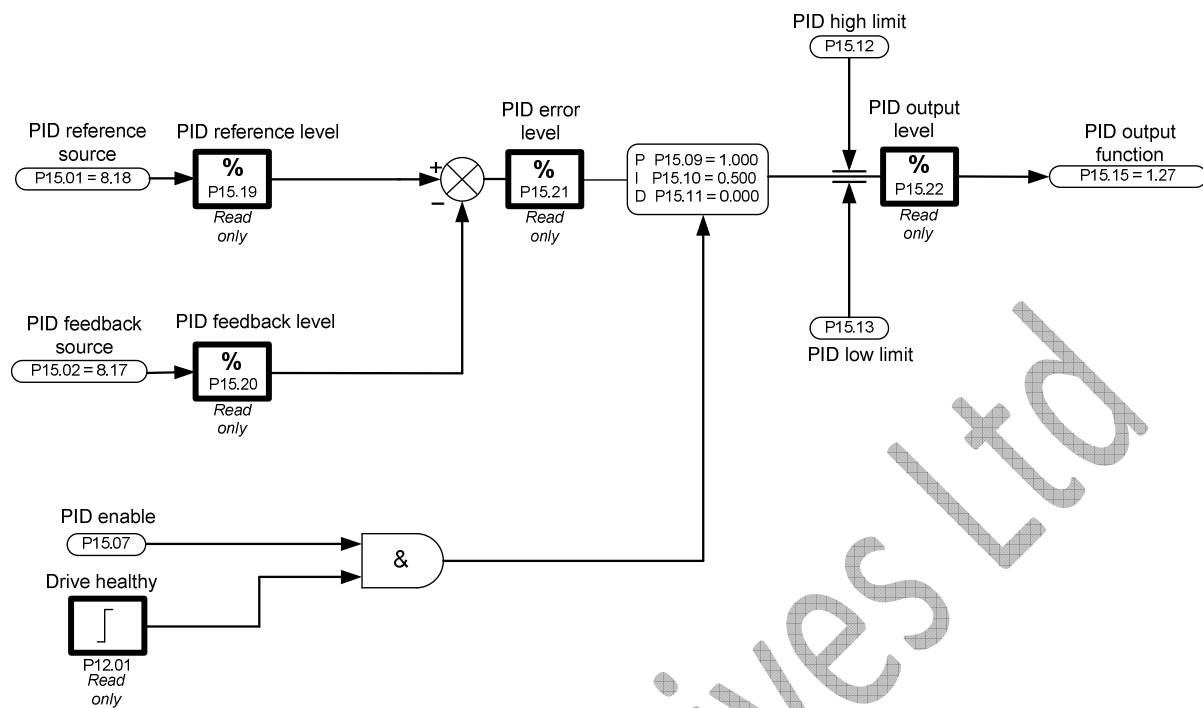
Par	Function	Example Setting	Explanation
P00.01	Motor rated voltage	-	Enter the values from the motor nameplate
P00.02	Motor rated current	-	
P00.03	Motor rated frequency	-	
P00.04	Control mode	1	Terminal control
P00.05	Reference source selector	8	Ref source to user programmable
P00.06	Minimum reference	-	System dependant
P00.08	Acceleration ramp time	10s	System dependant
P00.09	Deceleration ramp time	20s	System dependant
P00.11	Analogue input 1 format	2: 4 to 20mA with trip	Set to match the transducer signal type
P00.23	Extended parameter access	1	Allows extended parameter access
P03.01	Allow reverse	1	Disabled running reverse
P15.01	PID reference source	8.18	PID ref source from AI 2 level
P15.02	PID feedback source	8.17	PID feedback from AI 1 level
P15.07	PID enable	1	Enabled PID controller
P15.09	PID P gain	1	System dependant
P15.10	PID I gain	0.5	System dependant
P15.15	PID output destination	1.27	PID output to user programmed reference

Connection diagram



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PID diagram for above set-up



Operation

Close the enable signal on DI 6 which will allow the drive to run when the run forward signal is given. When the Run signal is given on terminal DI 1, the drive will enable and the motor will start to run. The potentiometer on analogue input 2 can be used to vary the set point on the PID reference source. When the feedback is below the set-point, the drive will increase speed. When the feedback is above the set-point, the drive will decrease speed.

Application Example 4

Pressure control – Simple variable PID set-point from the drives keypad

This set-up uses Application Example 1 but with a variable set-point which is set using the drives keypad UP and DOWN buttons.

Parameter changes required from default

Par	Function	Example Setting	Explanation
P00.01	Motor rated voltage	-	Enter the values from the motor nameplate
P00.02	Motor rated current	-	
P00.03	Motor rated frequency	-	
P00.04	Control mode	1	Terminal control
P00.05	Reference source selector	8	Ref source to user programmable
P00.06	Minimum reference	-	System dependant
P00.08	Acceleration ramp time	10s	System dependant
P00.09	Deceleration ramp time	20s	System dependant
P00.11	Analogue input 1 format	2: 4 to 20mA with trip	Set to match the transducer signal type
P00.23	Extended parameter access	1	Allows extended parameter access
P03.01	Allow reverse	1	Disabled running reverse
P15.01	PID reference source	1.09	PID ref source from keypad
P15.02	PID feedback source	8.17	PID feedback from AI 1 level
P15.07	PID enable	1	Enabled PID controller
P15.09	PID P gain	1	System dependant
P15.10	PID I gain	0.5	System dependant
P15.15	PID output destination	1.27	PID output to user programmed reference

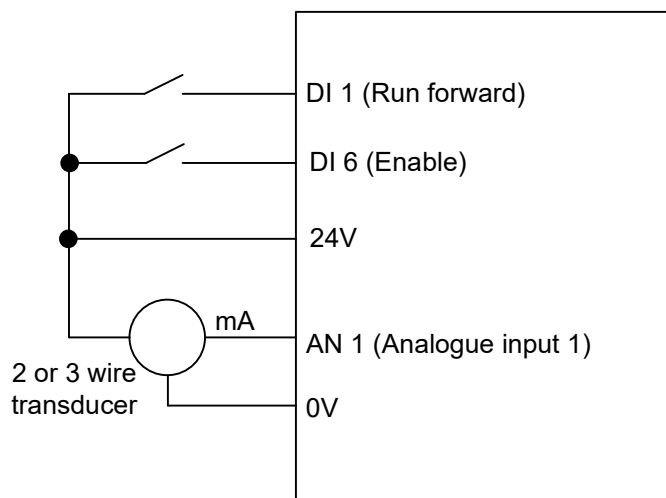
Keypad set-point

P15.01 = 1.09 – keypad reference as set-point

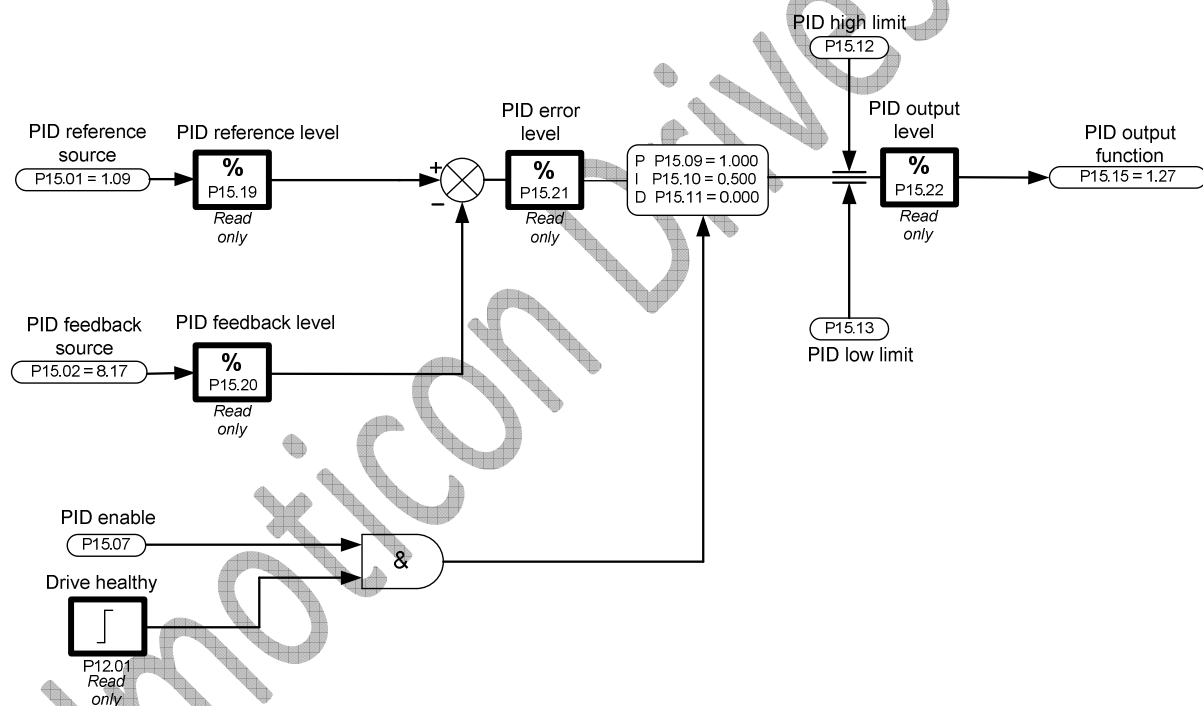
NOTE: With default frequency settings, the keypad has a range of 0 to 50.0 which when programmed to P15.01 = 0 to 100% which can be read in P15.19.

Therefore if the keypad reference is set to 25.0, P15.19 = 50.0%

Connection diagram



PID diagram for above set-up

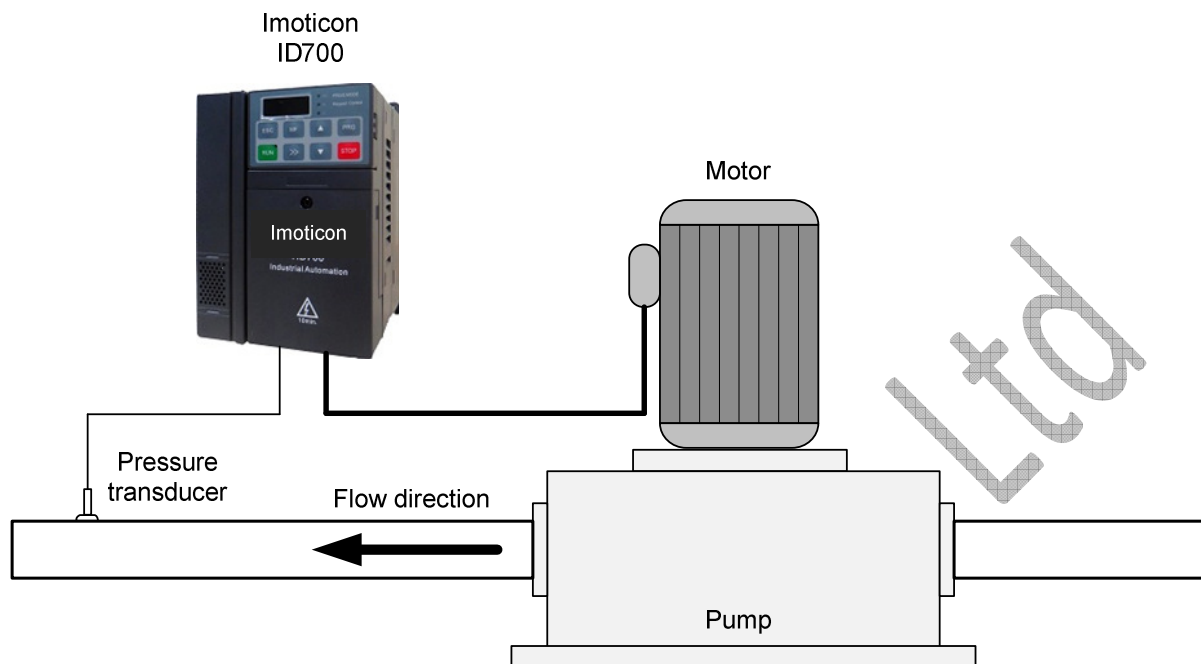


Operation

Close the enable signal on DI 6 which will allow the drive to run when the run forward signal is given. When the Run signal is given on terminal DI 1, the drive will enable and the motor will start to run. The drives keypad UP and DOWN buttons can be used to vary the set point on the PID reference source.

When the feedback is below the set-point, the drive will increase speed. When the feedback is above the set-point, the drive will decrease speed.

Application Example 5 Pressure control with two fixed PID set-points



Consider a pumping application
Feedback transducer = 4-20mA / 0 – 10 bar
Nominal running pressure target level (1st pressure set point) = 4 bar
2nd pressure set point = 5 bar

We can calculate the 1st digital set point for as follows:

Set-point = 4 bar / 10 bar x 100.0% = 40.0%
P17.42 = 0 to 300.0% Therefore 40% of 300 = 120.0
Set **P17.42 = 120.0**

We can calculate the 2nd digital set point for as follows:

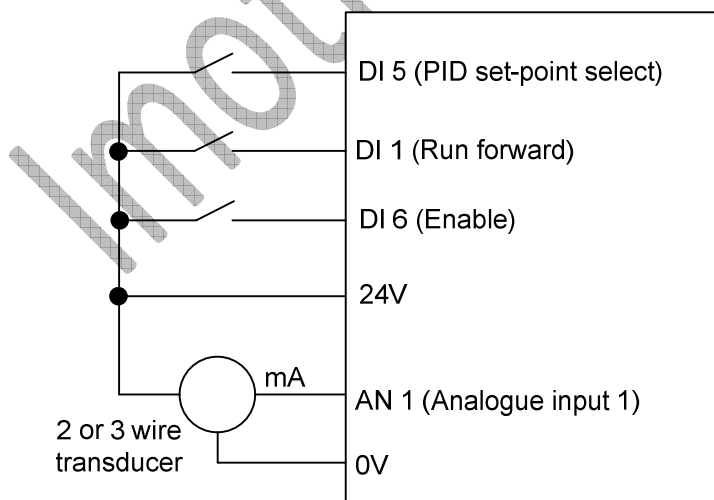
Set-point = 5 bar / 10 bar x 100.0% = 50.0%
P17.43 = 0 to 300.0% Therefore 50% of 300 = 150.0
Set **P17.43 = 150.0**

To realise the above set up, the drives binary sum and variable select function blocks will be used to send the values of P17.42 and P17.43 to P15.01 PID reference source. The set-points will be selected by digital input DI 5.

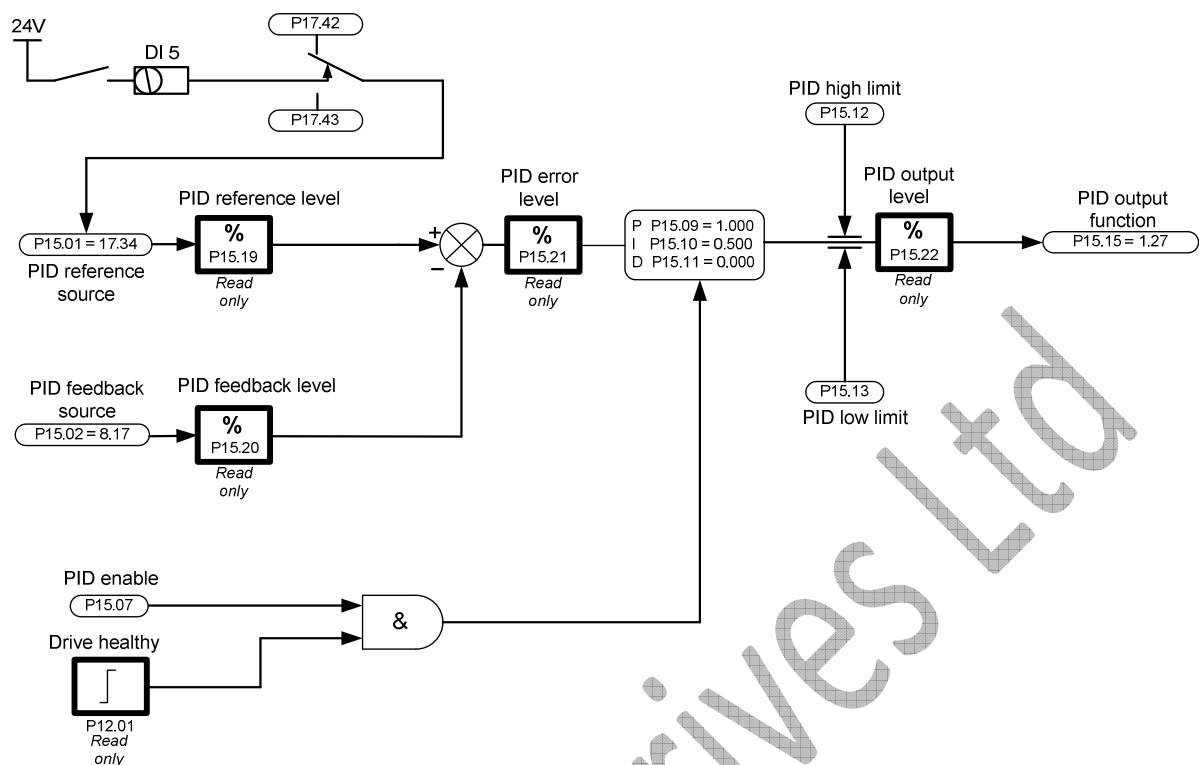
Parameter changes required from default

Par	Function	Example Setting	Explanation
P00.01	Motor rated voltage	-	Enter the values from the motor nameplate
P00.02	Motor rated current	-	
P00.03	Motor rated frequency	-	
P00.04	Control mode	1	Terminal control
P00.05	Reference source selector	8	Ref source to user programmable
P00.06	Minimum reference	-	System dependant
P00.08	Acceleration ramp time	10s	System dependant
P00.09	Deceleration ramp time	20s	System dependant
P00.11	Analogue input 1 format	2: 4 to 20mA with trip	Set to match the transducer signal type
P00.23	Extended parameter access	1	Allows extended parameter access
P03.01	Allow reverse	1	Disabled running reverse
P09.01	Digital input function control	1	Allows advanced settings
P09.06	Digital input 5 function	16.15	Binary sum 1's input
P15.01	PID reference source	17.34	Variable select 1 output level
P15.02	PID feedback source	8.17	PID feedback from AI 1 level
P15.07	PID enable	1	Enabled PID controller
P15.09	PID P gain	1	System dependant
P15.10	PID I gain	0.5	System dependant
P15.15	PID output destination	1.27	PID output to user programmed reference
P16.19	Binary sum output	17.15	Variable select 1 mode
P17.11	Variable select 1 source 1	17.42	User defined word variable 1
P17.12	Variable select 1 source 2	17.43	User defined word variable 2
P17.42	User defined word variable 1	120.0	Sets PID set point to 40%
P17.43	User defined word variable 2	150.0	Sets PID set point to 50%

Connection diagram



PID diagram for above set-up



Operation

Close the enable signal on DI 6 which will allow the drive to run when the run forward signal is given. When the Run signal is given on terminal DI 1, the drive will enable and the motor will start to run and accelerate because the pressure in the system is low.

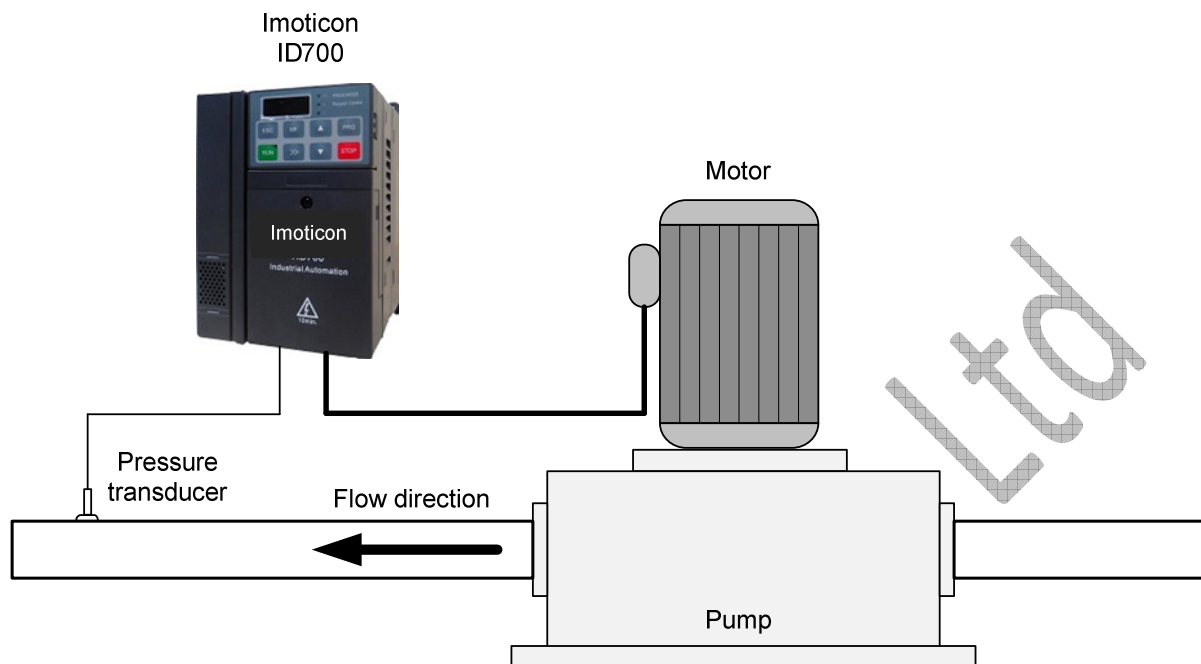
As the motor accelerates the pressure in the system will start to increase so therefore the feedback will increase.

When the pressure goes above 4 bar, the motor speed will slow down.

The system will now regulate the pressure around 4 bar by speeding up and slowing down the pump as the pressure increases and decreases.

The switch connected to Digital Input 5 can be connected to 24V to change the value of the PID reference source level to set point 2.

Application Example 6
HAND – Analogue input 1 speed control
AUTO - Pressure control – Simple fixed PID set-point



HAND Operation

Pump speed controlled from a potentiometer without feedback from pressure transducer.

AUTO Operation

Pump speed controlled by the drives PID loop with feedback from a pressure transducer.

Feedback transducer = 4-20mA / 0 – 10 bar

Pressure target level = 4 bar

We can calculate the digital set point for as follows:

Set-point = 4 bar / 10 bar x 100.0% = 40.0%

Set 15.01 = 17.42

P17.42 = 0 to 300.0% Therefore 40% of 300 = 120.0

Set **P17.42 = 120.0**

Parameter changes required from default

Par	Function	Example Setting	Explanation
P00.01	Motor rated voltage	-	Enter the values from the motor nameplate
P00.02	Motor rated current	-	
P00.03	Motor rated frequency	-	
P00.04	Control mode	1	Terminal control
P00.06	Minimum reference	-	System dependant
P00.08	Acceleration ramp time	10s	System dependant
P00.09	Deceleration ramp time	20s	System dependant
P00.11	Analogue input 1 format	6: 0-10V	Set to match the transducer signal type
P00.23	Extended parameter access	1	Extended parameter access
P03.01	Allow reverse	1	Disabled running reverse
P09.01	Digital input function control	1	Allows advanced parameters
P09.05	Digital input 4 to binary sum 4s input	16.17	
P09.08	Digital input 7 to PID enable	15.07	
P15.01	PID reference source	17.42	PID ref source from P17.42
P15.02	PID feedback source	8.17	PID feedback from AI 1 level
P15.09	PID P gain	1	System dependant
P15.10	PID I gain	0.5	System dependant
P15.15	PID output destination	1.27	PID output to user programmed reference
P16.18	Binary sum offset	4	
P16.19	Binary sum output to reference selector	1.01	
P17.42	User defined word variable 1	120.0	Sets PID set point to 40%

Digital set-point

P15.01 = 17.42 – User defined word variable as set-point

NOTE: P17.42 has a range of -300 to 300 which when programmed to P15.01 = 0 to 100% which can be read in P15.19.

Examples:

If P17.42 is set to 120, P15.19 = 40.0%

If P17.42 is set to 150, P15.19 = 50.0%

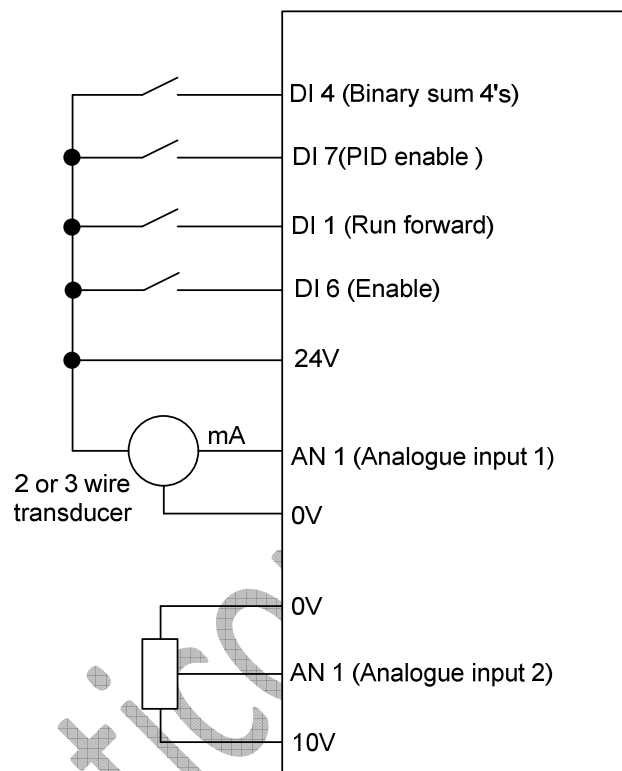
Connection diagram

An external switch is required which works as follows:

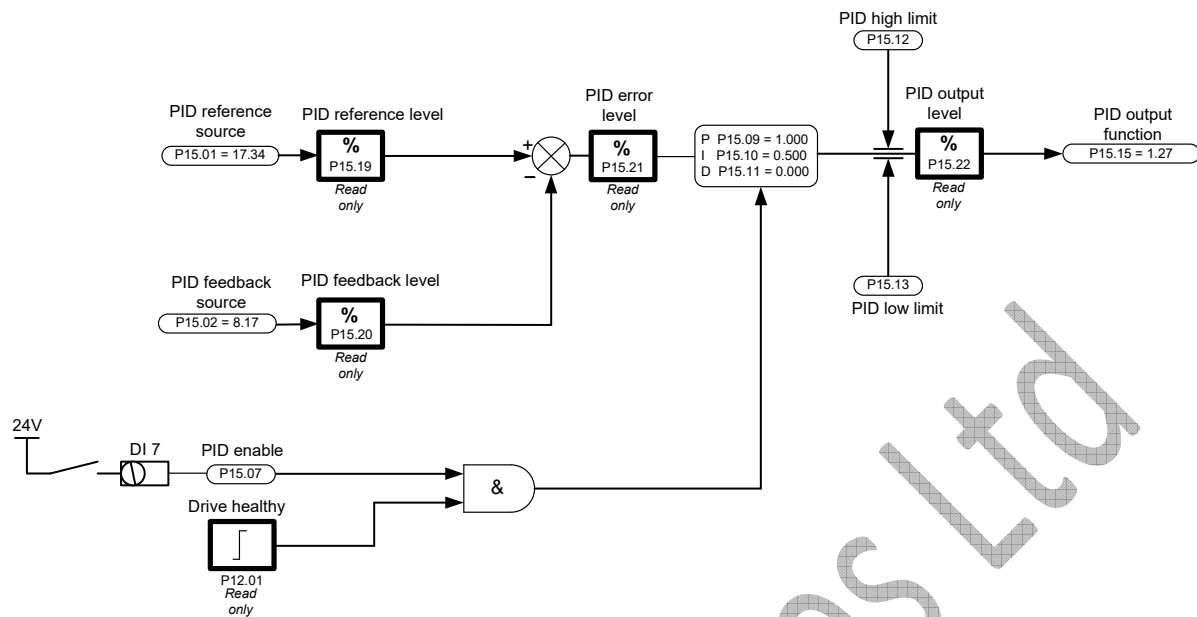
DI 6 (Enable) must be connected to 24V to allow drive to run.

HAND mode – Switch closes DI 1 (Run forward) only.

AUTO mode – Switch closes DI 1 (run forward), DI 4 (Binary sum 4's) and DI 7 (PID enable) at the same time.



PID diagram for above set-up



Operation

Close the enable signal on DI 6 which will allow the drive to run when the run forward signal is given.

When the HAND signal is given on terminal DI 1, the drive will run and the speed is controlled by analogue input 2.

When the AUTO signal is given on DI 1, DI 4 and DI 7 the drive will enable and the motor will start to run and accelerate because the pressure in the system is low.

As the motor accelerates the pressure in the system will start to increase so therefore the feedback will increase.

When the pressure goes above 4 bar, the motor speed will slow down.

The system will now regulate the pressure around 4 bar by speeding up and slowing down the pump as the pressure increases and decreases.