

PID SET UP WITH FRENIC Eco series inverter.

1. Introduction.

This document describes briefly how to set up the FRENIC Eco series inverter to implement a PID control, for example, a pressure control with a pump, where the pump is moved by a motor controlled by a FRENIC Eco inverter.

2. Preparation.

Before setting up a PID controller few items have to be checked. As an example we will describe a set up for controlling pressure.

- Is the sensor capable of sensing the expected range?
When we want to control the pressure in a system to 2 Bar, the sensor must be capable of measuring more. Preferably 1.5 times more, i.e. 3 Bar.
- Does it have an output signal that can be connected directly to the FRENIC Eco input?
FRENIC Eco has inputs for 0-10 V and 4-20 mA signals.

3. PID Basics.

3.1 PID Basic Concept.

A PID regulator is a control structure that will try to control a certain magnitude (pressure, flow rate, temperature, ...) to a desired value, which is called **PID command** (or set-point) value. To do so this structure needs information of the actual status of the system by means of the proper measurement device (pressure, flow or temperature sensor). This signal is called the **PID Feedback**. This control structure normally has three control actions: Proportional (P), Integral (I) and Derivative (D) that have to be tuned according to the real system.

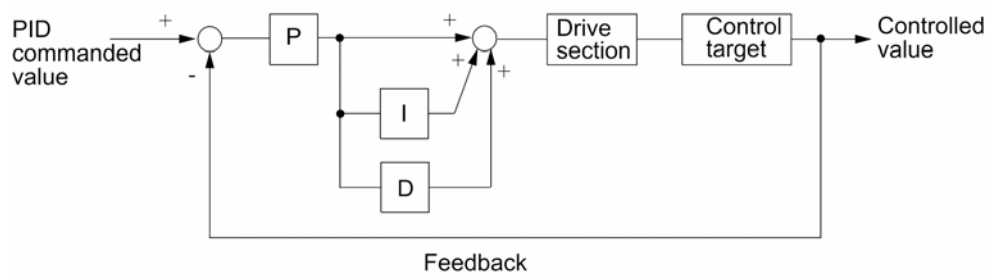


Figure 1. PID control structure diagram.

What happens in this picture?

In the picture you can see that the signals from the **PID command** and the **PID Feedback** are subtracted resulting in an error signal. When the **PID command** and the **PID feedback** signal are the same no correction is needed and the drive will run at the same frequency. When the **PID command** is larger than the **PID feedback** the error signal will be positive and the drive frequency will increase until the **PID Feedback** signal is the same. This is a continuous process. As soon as a difference in the feedback is detected the drive frequency will be adjusted accordingly.

- **PID command = PID feedback** => No frequency change.
- **PID command > PID feedback** => Frequency is **increased**.
- **PID command < PID feedback** => Frequency is **decreased**.

The example above is a simple representation of the process. In real world processes there usually is a time delay between changing the drive frequency and the response of the PID feedback signal.

3.2 P-control.

The P part of a PID controller is the Proportional part. This means that the action of the P part only depends on the momentary difference (error) between the set value and the feedback. The drawback using only a P controller is that the more the feedback signal approaches the set value, the smaller the action (correction) signal from P control becomes, slowing the settling of the process. In theory the set value will never be reached.

3.3 I-control.

With the I (integrating) part of the controller, the effect of the P controller never reaching the end value can be solved. The I part integrates the difference between the set and feedback value. Even when this difference is small, after some time, the correction to the error signal will become larger, helping the process to reach the Set value.

3.4 D-control.

The D-part (differentiate) part of the controller helps to overcome another drawback of the proportional controller. This is that the correction signal can never become larger than the difference between the set and feedback signal (error). The D part of the controller can amplify the difference (error) a bit more so the correction signal to the process will become higher (for a short time) and the process will reach the set-point faster. It is recommended not to use this part unless a good response is not achieved with the P and I control.

4. Explanation of the PID set up for FRENIC Eco

Many books and software packages have been written to explain and simulate a PID controller. Therefore this application note is not meant to be complete. The description below is a starting point for setting the PID parameters and to stay out of trouble.

In order to set-up a PID-Control you have to follow 3 Steps.

1st Step: **Basic set up of the inverter**

In order to do this you have to set the following Parameters:

Fundamental Parameters:

F03. Maximum frequency 1.

This function sets the maximum output frequency for motor 1, in Hz.

Factory setting is 50 Hz.

F04. Base frequency 1.

This function sets the maximum output frequency in the constant-torque range of motor 1 or the output frequency at the rated output voltage, in Hz.

Factory setting is 50 Hz.

F05. Rated voltage 1 (at Base frequency 1).

This function sets the rated value of the voltage output to motor 1, in volts. Note that a voltage greater than the supply (input) voltage cannot be output.

Factory setting is 400 V.

F06. Maximum output voltage 1 (at Maximum frequency 1).

This function sets the maximum value of the voltage output for motor 1, in volts. Note that a voltage higher than the supply (input) voltage cannot be output.

Factory setting is 400 V.

F07. Acceleration time 1.

This function sets the acceleration time for the output frequency from 0 to maximum frequency, in seconds. For PID control the value of this function has to be small, otherwise the system will become unstable.

Factory setting is 20.0 s.

F08. Deceleration time 1.

This function sets the deceleration time from maximum frequency to 0, in seconds. For PID control the value of this function has to be small, otherwise the system will become unstable.

Factory setting is 20.0 s.

F09. Torque boost 1.

This function is used to select the torque boost characteristic that the inverter will use. The following can be selected:

Setting range	Characteristic selected
0.0	Automatic torque boost characteristic where the torque boost value of a constant torque load (a linear change) is automatically adjusted
0.1 to 0.9	Square law reduction torque for fan and pump loads
1.0 to 1.9	Proportional torque for middle class loads between square law reduction torque and constant torque (linear change)
2.0 to 20.0	Constant torque (linear change)

Factory setting is 0.0.

F15. Frequency limiter (High).

This function sets the upper limit for the setting frequency, in Hz.

Factory setting is 70 Hz.

F16. Frequency limiter (Low).

This function sets the lower limit for the setting frequency, in Hz.

Recommended value for PID control is zero or, at least, very low.

Factory setting is 0 Hz.

Motor parameters:

P01. Number of motor 1 poles.

This function sets the number of poles of motor 1 to be driven. If this setting is not made, an incorrect motor speed (in rpm) is displayed on the LED display.

Factory setting is 4.

P02. Motor 1 Capacity.

This function should be set according to the motor capacity, in kW.

Factory setting depends on the inverter size.

P03. Motor 1 Rated Current.

This function sets the rated current value of motor 1, in Amperes.

Factory setting depends on the inverter size.

P04. Motor 1 Tuning.

This function sets the method of tuning used to measure the motor data.

The options that can be selected are shown in the following table.

Set value	Operation
0	Inactive
1	Measure the primary resistance (%R1) of the motor and leakage reactance (%X) of the base frequency when the motor is stopped and automatically write both values in P07 and P08 (static tuning)
2	Measure the primary resistance (%R1) of the motor and leakage reactance (%X) of the base frequency when the motor is stopped, measure the no-load current (I ₀) when the motor is running, and automatically write these values in P06, P07 and P08 (dynamic tuning).

Factory setting is 0

P06. Motor 1 No-load current

This function sets the no-load (exciting current) of motor 1, in Amperes.
Factory setting depends on the inverter size.

P07. Motor 1 (%R1 setting)

This function sets the primary resistance (%R1) of motor 1.
Factory setting is Fuji standard rated value.

P08. Motor 1 (%X setting)

This function sets the leakage reactance (%X) of motor 1.
Factory setting is Fuji standard rated value.

LED display configuration

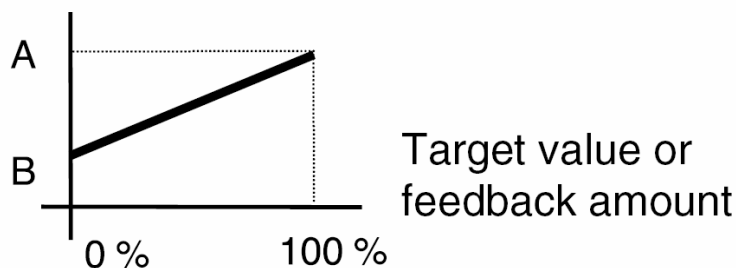
E40. PID Display coefficient A

This function is used to set the value that will be shown in the LED display when the PID target/feedback takes the maximum value (see figure below).

E41. PID Display coefficient B

This function is used to set the value that will be shown in the LED display when the PID target/feedback takes the minimum value (see figure below).

Displayed value



E43. LED Monitor (Function).

This function is used to setup the function that will be displayed in the LED display during operation. The alternatives related with the PID controller are:

- 10 PID process command value
- 12 PID feedback value
- 14 PID output value

The Factory setting is 0.

2nd Step: Set up the PID Controller

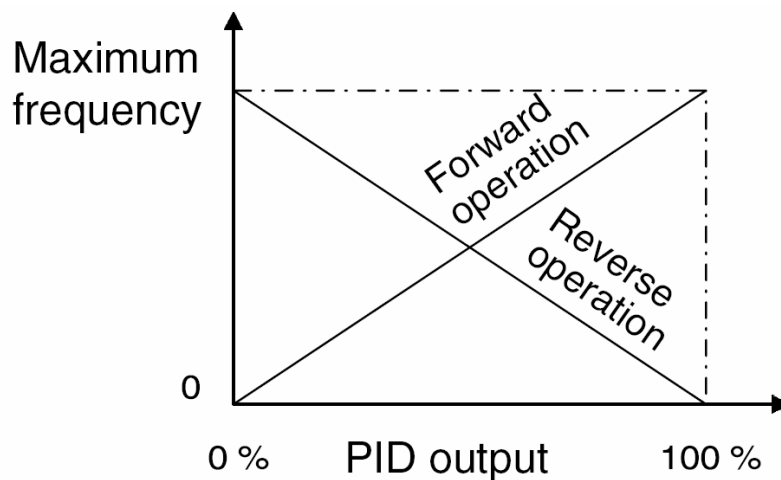
In order to set up the PID controller the following parameters have to be set:

J01. PID control (Mode select).

This function is used to setup the operation mode of the PID controller. The alternatives are:

- 0 PID inactive
- 1 PID active, forward operation
- 2 PID active, reverse operation

Factory setting is 0.



J02. Remote process command.

This parameter is used to set the source of the Set Value for the PID Controller.

- 0 Enable set by Keypad
- 1 PID process command 1
- 3 Enable terminal command (up)/(down) control
- 4 Command via communication link

When setting J02 to 1, we have to specify the source of this command. In order to do so we have to program one of the following functions to 3 (PID process command 1):

- E61 to 3 when using terminal 12 (0 to 10V DC)
- E62 to 3 when using terminal C1 (4 to 20mA)
- E63 to 3 when using terminal V2 (0 to 10 V DC)

The second signal that we have to set is the source of the PID Feedback. This also will be done using the functions mentioned above, depending on the kind of feedback signal that the inverter receives from the sensor:

- E61 to 5 when using terminal 12 (0 to 10V DC)
- E62 to 5 when using terminal C1 (4 to 20 mA)
- E63 to 5 when using terminal V2 (0 to 10V DC)

Note: if these functions are set up with the same data, the operation priority is given in the following order E61 > E62 > E63.

J03. PID control (P-gain).

This parameter is used to set the proportional (P) gain of the PID controller. This parameter has to be tuned on site, the value depends on the application. Factory setting is 0.10.

J04. PID control (I-gain).

This function is used to set the integral (I) time of the PID controller. This function has to be tuned on site, the value depends on the application. Factory setting is 0.0 s; with this value the PID will not work properly.

J05. PID control (D-gain).

This function is used to set the derivative (D) gain of the PID controller. This function has to be tuned on site, the value depends on the application. Factory setting is 0.00 s.

J06. PID control (Feedback filter).

This function is used to set the time constant of the filter for PID control feedback signal, in seconds.

This function has to be tuned on site, the value depends on the application. Factory setting is 0.5 s.

The following 3 parameters are especially designed for pump applications. These function codes specify the data for the slow flowrate stop in pump control, a feature that stops the inverter when there is no water consumption.

Slow flowrate stop function

When the discharge pressure has increased, decreasing the reference frequency (output of the PID processor) below the stop frequency for slow flowrate level (J15) for more than the elapsed stopping time on slow flowrate level stop latency (J16), the inverter decelerates to stop, while PID control itself continues to operate. When the discharge pressure decreases, increasing the reference frequency (output of the PID processor) above the starting frequency (J17), the inverter resumes operation. If we need to have a signal indicating the state in which the inverter is stopped due to the slow flowrate stop feature, we have to assign PID-STP function (Inverter stopping due to slow flowrate under PID control) to one of the general-purpose output terminal (function code data = 44).

J15. PID Control (Stop frequency for slow flowrate).

Specifies the frequency which triggers slow flowrate stop of inverter. Factory setting is 0 Hz.

J16. PID Control (Slow flowrate level stop latency).

Specifies the elapsed time from when the inverter stops operation due to slow flowrate level condition. Factory setting is 30 s.

J17. PID Control (Starting frequency).

Specifies the starting frequency. Select a frequency higher than the slow flowrate level stop frequency. If the specified starting frequency is lower than the slow flowrate level stop frequency, the later stop frequency is ignored; the slow flowrate level stop is triggered when the output of the PID processor drops below the specified starting frequency.

Factory setting is 0 Hz.

3rd Step: Tuning of the System

- Set acceleration (function F07) and deceleration times (function F08) of the inverter as small as possible. Use 1.00 second as starting point.
- Check that the Frequency Limiter (functions F15, F16) do not obstruct the operation of the PID controller or the system.
- Check if the sensor levels and responses are fitted for the application. When controlling a process up to 8 Bar do not use an 8 Bar sensor but for example a 12 Bar sensor.
- Try to keep the set-point of the PID to a lower value of its operating range. This means for example when using 0-10V input, choose a source that has an output value of 8 Volt at the set value.
- When setting up a control system make sure the motor has sufficient capacity. There is no good control when the set value of a compressor is set to 4 Bar when the maximum achievable pressure of the system is 4 Bar.
- Measure or estimate the time lag between the process control and the feedback signal of the process. It is important to anticipate on the time lag of the process or instability can easily occur. It is important to know this time. One can determine this time in many ways. One way can be to change the set-point of the controller and monitor the feedback value for a change. The time it takes is the time lag of the control loop.

When setting up a PID, we start disabling the I and D action by programming them to 0. Then we set a P value of 1.000 and we operate the inverter. When the process oscillates we lower the gain of P. When the process does not reach the set-point but only goes half way of the set-point we can slowly increase the P gain until 80-90% is achieved. We have to test the response of the system by adding different loads. When the process starts to oscillate we have to lower the P gain again until a stable control is achieved. It may be possible that the feedback does not reach the set-point. This will be solved with the I action of the PID controller. At this moment it is only important that no oscillation occurs when the load of the process is changed.

When we are sure that the system does not oscillate with the P setting we can start to optimise the control loop by adding some I action. We could start by entering the value of the time lag of the process as the I parameter. After this, we have to test if the system is stable when applying different loads.

The D action is seldom needed for drives and processes that take seconds to settle. When using D we have to take care that the system does not oscillate.

5. Tips and Tricks

PID control can be activated (deactivated) from a digital input by setting function 20 in this input (PID control cancel [Hz/PID]). For example, if we want to use input X1 to activate/deactivate PID control we may program E01 = 20.

It is recommended to start the set up of the inverter from a known configuration. Therefore it is recommended to set all functions to factory setting by means of function H03 (setting to 1), prior to change the functions described in this document.

To check that PID command and/or PID feedback signals are connected properly to the inverter select option **4. I/O CHECK** from the Multifunction Keypad (TP-G1) menu and then go to the fifth screen (push 4 times the down arrow key). In that screen it is displayed the actual value of the voltage in terminal 12 (12 =) and the actual value of the current in terminal C1 (C1 =).

When using a sensor with 0 to 5 volt output we can adjust the gain of the voltage input with C31 to C33 for terminal 12 and C42 to C44 for terminal V2.

To adjust the gains for the current input (terminal C1) refer to the parameters C37 to C39.

When the feedback signal is very unstable we can average this unstable signal by using the feedback filter (J06). This however will slow down the response of the PID controller. Feedback can become unstable when for example the pressure sensor sensor is too close to the pump.

6. Application examples.

6.1 Application example 1.

Set-point set by keypad and feedback from a transducer (transmitter) connected in current input C1 (figure 2), forward operation.

F02=0 (Start-Stop: key-pad, FWD/REV button)

F07=1.0 (Acceleration time 1)

F08=1.0 (Deceleration time 1)

E40=7.00 (7 bar max)

E41=0.00 (0 bar min)

E43=10 (PID set-point value)

PID parameters:

J01=1 (PID active, forward operation)

J02=0 (PID set value from keypad)

E62=5 (PID feedback value by current input C1)

J03 (PID control P-gain)

J04 (PID control I-gain)

J05 (PID control D-gain)

J06 (PID control Feedback filter)

J03, J04, J05 and J06 may be programmed as described in previous chapters.

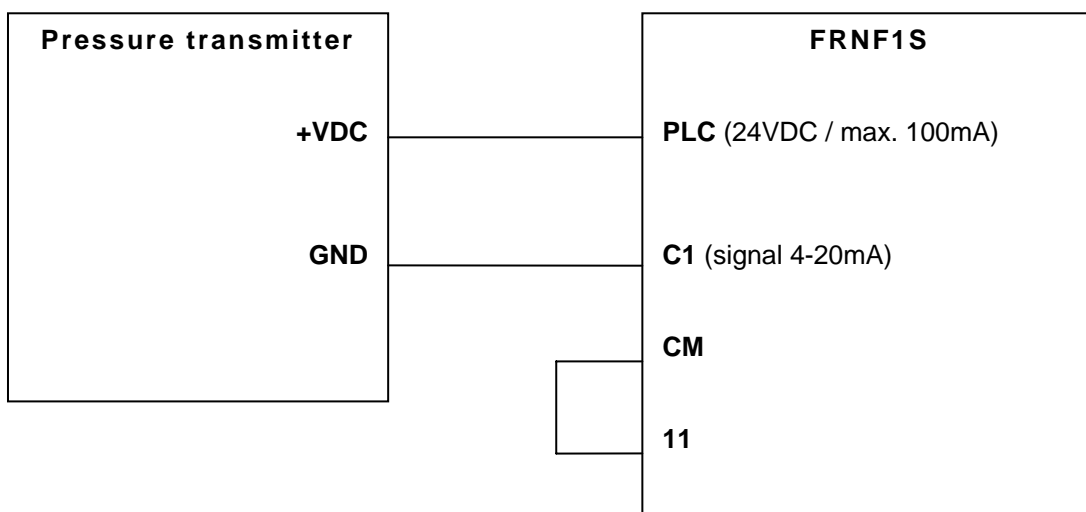


Figure 2. Pressure transmitter connected in current input C1.

6.2 Application example 2.

In this application we describe the settings of FRENIC Eco using the PID controller with a potentiometer for the PID set-point.

Connect the potentiometer to terminals 11, 12 and 13.
Connect the signal output of the sensor to C1 and 11 inputs for the feedback signal (figure 2).

The following parameters have to be programmed:

F07 = 1.00 (Acceleration time 1)
F08 = 1.00 (Deceleration time 1)

PID parameters:

J01 = 1 (PID active, forward operation)
J02 = 1 (PID set-point by PID process command 1)
E62 = 3 (PID process command 1 assigned to terminal 12)
E63 = 5 (PID feedback value assigned to terminal C1)

J03 (PID control P-gain)
J04 (PID control P-gain)
J05 (PID control P-gain)
J06 (PID control Feedback filter)

J03, J04, J05 and J06 may be programmed as described in previous chapters.

In this configuration the potentiometer determines the PID set-point.

If we want to use an additional voltage sensor for the feedback signal we have to program E64 to 5 and be sure to program E63 to 0, because of the priority order of these parameters, and connect the sensor to V2 and 11.