PID SET UP WITH FRENIC G11S series inverter.

1. Introduction.

This document describes briefly how to set up the FRENIC G11S 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 G11S inverter.

2. Preparation.

Before you can successfully set up a PID controller you have to check a few things. As an example we will use a setup 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 that can be connected directly to the G11 input?
  G11 accepts 0-10 V and 4-20 mA as standard input.

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.

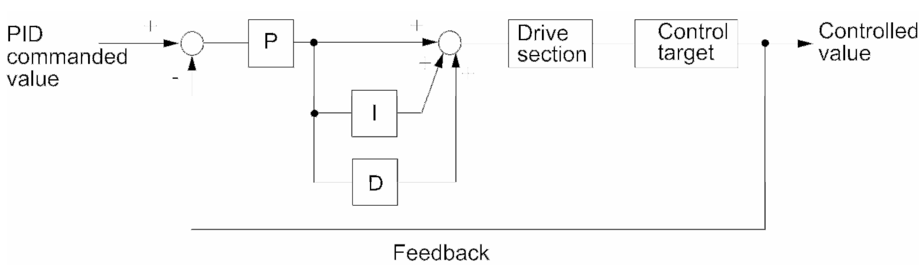


Figure 1. PID control structure diagram.

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 a correction 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 correction 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 **in**creased.
- ***PID command*** < ***PID feedback*** => Frequency is **de**creased.

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 the error signal is only depends on the momentary difference 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 correction signal 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 one can overcome the effect of the P controller never reaching the end value. The I part integrates the difference between the set and feedback value. Even when this difference is small, over 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 is to help overcome another drawback of the proportional controller. This is that the correction signal can never become larger than the difference between the set and feedbacksignal. The D part of the controller can amplify the difference a bit more so the correction signal to the process will become a bit higher (for a short time) and the process will reach the setpoint 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 G11.

In figure 2 we can see the PID function diagram of the G11S inverter. There are different alternatives, depending on the source of the PID setpoint and the PID feedback. Also depending on the direction of the action of the PID controller, i.e., if the maximum error makes the inverter run at maximum frequency or viceversa.

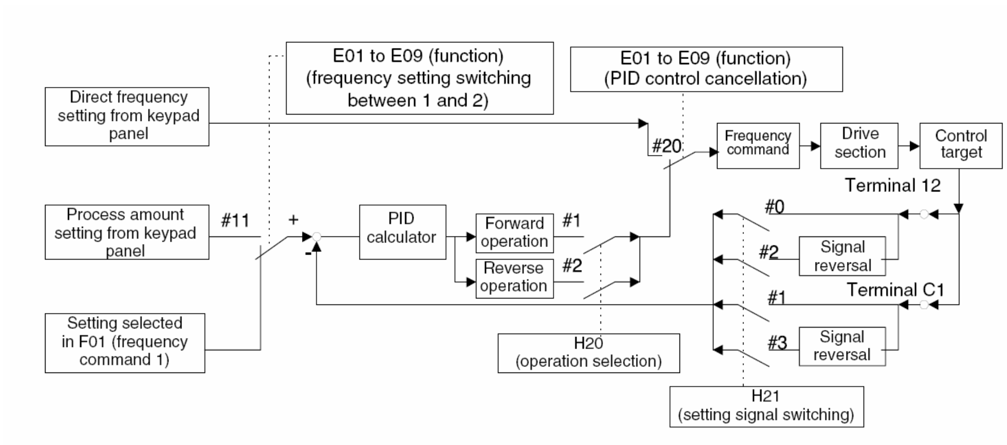


Figure 2. G11S PID function diagram .

4.1 Basic inverter configuration.

4.1.1 Fundamental functions.

F01. Frequency Command 1.
This function is used to set up the source of the frequency command of the inverter, but also the source of the PID command.
In this case this function can be set to different values depending on the desired configuration of the system:
0: Setting by keypad panel operation
1: Setting by voltage input, terminal [12] (0 to +10 V) + terminal [V2] (0 to +10 V)
Factory setting is 0.

F02. Operation Method.
This function is used to set up the source of the operation command (RUN/STOP) of the inverter.
In this case this function can be set to different values depending on the desired configuration of the system:
0: Keypad operation (FWD, REV, STOP keys)
1: Operation by external input (terminals [FWD], [REV])
Factory setting is 0.

F03. Maximum frequency 1.

This function sets the maximum output frequency for motor 1, in Hz.
Factory setting is 50.

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.

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.

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.

F07. Acceleration time 1.
This function sets the acceleration time for the output frequency from startup 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 6.0 (20.0).

F08. Deceleration time 1.
This function sets the deceleration time from maximum frequency to operation stop, in seconds. For PID control the value of this function has to be small, otherwise the system will become unstable.
Factory setting is 6.0 (20.0).

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	**5. Characteristics 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.

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.

4.1.2 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 (synchronous speed) is displayed on the LED.
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 measures and automatically writes motor data.
The options that can be selected are shown in the following table.

Set value	6. 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 (Io) 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.

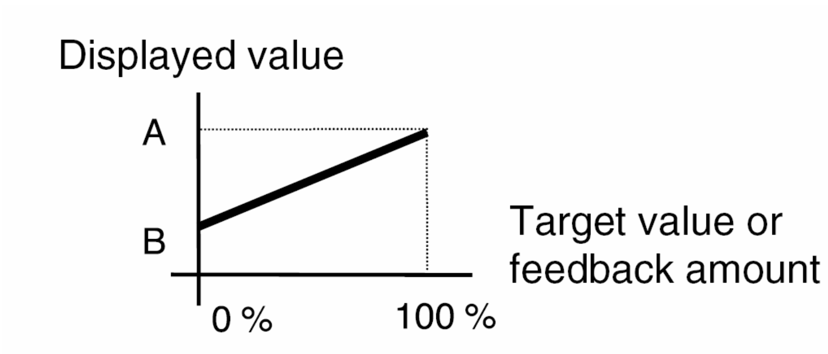
Factory setting is Fuji standard rated value.

P09. Slip compensation control.
This function sets the value of the motor slippage, in Hz.
Factory setting is 0.00

4.2 LED display configuration.

E40. 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.

E41. 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.



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 target value 1 (direct input from keypad panel)
- 11 PID target value 2 (input from frequency command F02 Frequency 1)
- 12 PID feedback value

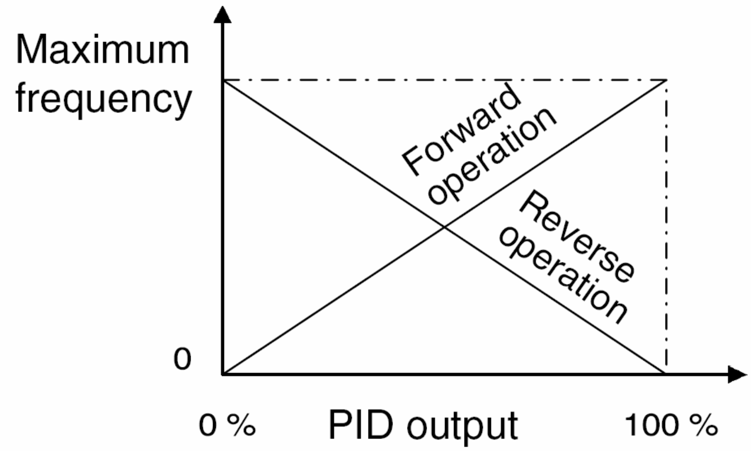
Factory setting is 0.

4.3 PID control configuration.

H20. 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

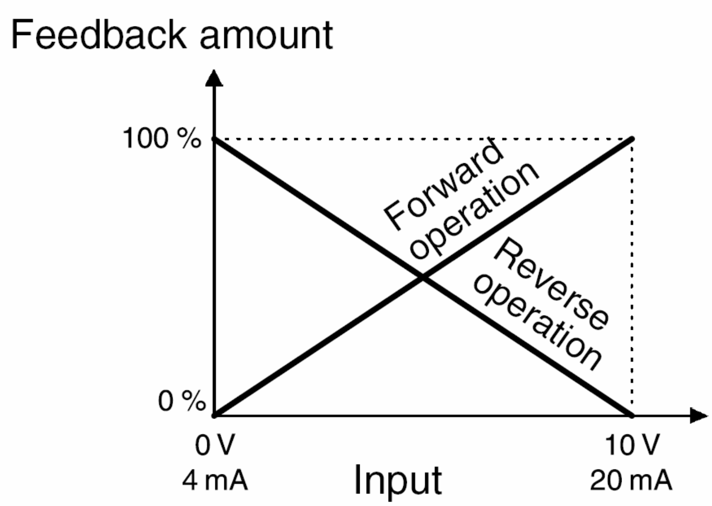
Factory setting is 0.



H21. PID control (feedback signal).
This parameter is used to setup the electrical specifications and signal level of the input used as a feedback signal. The alternatives are:

- 0 Control terminal 12, forward operation (0 to 10 V input).
- 1 Control terminal C1, forward operation (4 to 20 mA current input)
- 2 Control terminal 12, reverse operation (10 to 0 V input).
- 3 Control terminal C1, reverse operation (20 to 4 mA current input)

Factory setting is 1.



H22. 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.

H23. 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; with this value the PID will not work properly.

H24. 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

H25. PID control (Feedback filter).
This function is used to set the filter time constant of the PID control feedback filter, in seconds.
This function has to be tuned on site, the value depends on the application.

4.4 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 **4. I/O CHECK** in the Program menu screen and then go to the third screen (push 3 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 you can adjust the gain of the voltage input with C31 and C32.

When the sensor used is working inverted, i.e. at minimum pressure it has the maximum output. You can invert the signal to normal with the setting of H21.

When the feedback signal is very unstable you can average this unstable signal by using the feedback filter (H25). This however will slow down the response of the PID controller. Feedback can become unstable when for example the pressure sensor sensor is to close to the pump.

4.5 How to set-up a PID.

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.

- Set motor parameters F03..F06 and P01..P09 correctly.

- Set acceleration (function F07) and deceleration times (function F08) of the inverter as short as possible. Use 1.00 second as starting point.
- Check that the Frequency Limiter (functions F15, F16) do not obstruct the functioning of the PID 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 when using 0-10V input choose a sensor 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 little 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. Else oscillations 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, disable the I and D action by programming them to 0. Then Start with a P value of 1.000 and start the inverter. When the process oscillates lower the gain of P. When the process does not reach the set point but only goes half way of the set point you can slowly increase the P gain until 80-90% is achieved. Test the response of the system by adding different loads. When the process starts to oscillate lower the P gain again until a stable control is achieved. It may be possible that the set-up does not reach the set point. This can 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 you are sure the system does not oscillate with the P setting you can start to optimise the control loop by adding some I action. One could start by entering the value of the time lag of the process as the I parameter. After this, 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 take care that the system does not oscillate.

5. Application examples.

5.1 Application example 1.

Set-point set by keypad and feedback from a transducer (transmitter) connected in current input C1 (figure 3), forward operation.

F01=0 (Command Value: key-pad, up- and down-arrow-button)
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 command value from key pad)

PID parameters:

H20=1 (PID active, forward operation)
H21=1 (Feedback signal for the PID is current input C1)

H22 (PID control P-gain)
H23 (PID control I-gain)
H24 (PID control D-gain)
H25 (PID control Feedback filter)

H22, H23, H24 and H25 may be programmed as described in “How to set-up a PID”.

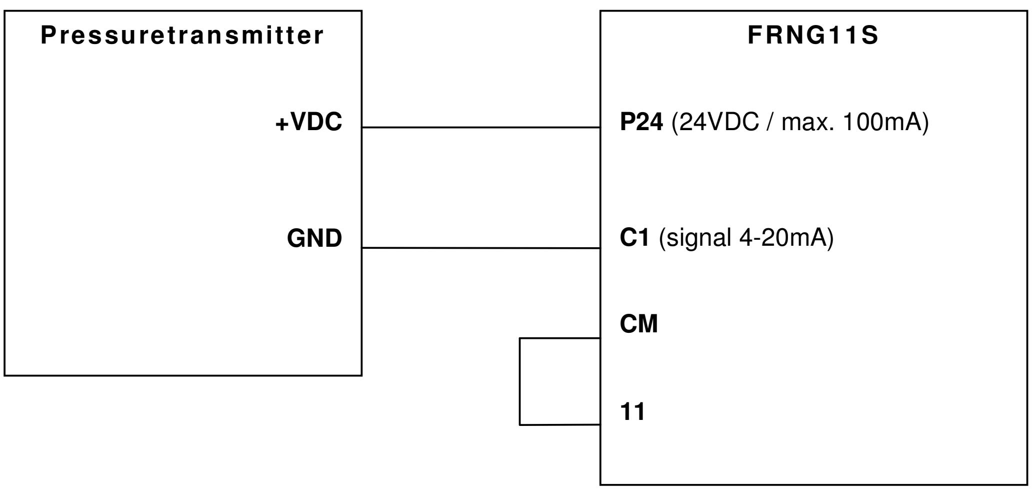


Figure 3. Pressure transmitter connected in current input C1.

5.2 Application example 2.

In this application we describe the settings for the G11 for using the PID controller with a potentiometer for the PID set value.

Connect the potentiometer to terminals 11, 12 and 13.
Connect the current output of the sensor to C1 and 11 input for the feedback signal.

The following parameters have to be programmed:

F01 = 1 (Command Value: analog input on terminal 12)
F07 = 1.00 (Acceleration time 1)
F08 = 1.00 (Deceleration time 1)

PID parameters:

H20 = 1 (PID active, forward operation)
H21 = 1 (Feedback signal for the PID is current input C1)

H22 (PID control P-gain)
H23 (PID control P-gain)
H24 (PID control P-gain)
H25 (PID control Feedback filter)

H22, H23, H24 and H25 may be programmed as described in “How to set-up a PID”.

In this configuration the potentiometer determines the PID set point.
With a small trick it is also possible to connect a 0-10 V sensor to the C1 input. In that case you must connect a resistor of 250 ohm (0.125 Watt, or more) in series with the current input. If you allow a small deviation at the beginning and end of the set value you can also use 220 ohm or 270 which are available on the market.