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Basic application V20 with PID control

Sinamics V20 PID control

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1 Task

1.1 Overview

SINAMICS V20 drives have a technology controller. Based on this controller, temperature, pressure, flow and many other process variables' actual value can be controlled as the same as the setpoint.

This document provides recommendations for configuring, parameterizing and optimizing control loops with the PID controller.

Examples for implementing control functions based on the technology controller are provided in the applications:

Process control using the technological controller, entry ID: 92556266

NOTE In this document chapter 5, it describes the principle of the PID tuning. It will guide you how to select the PID controller type and how to adjust the PID parameters according to the controller type and the response requirements.

2 Wiring

2.1 Wiring with the analog setpoint

The following figure displays the wiring with the analog PID setpoint:

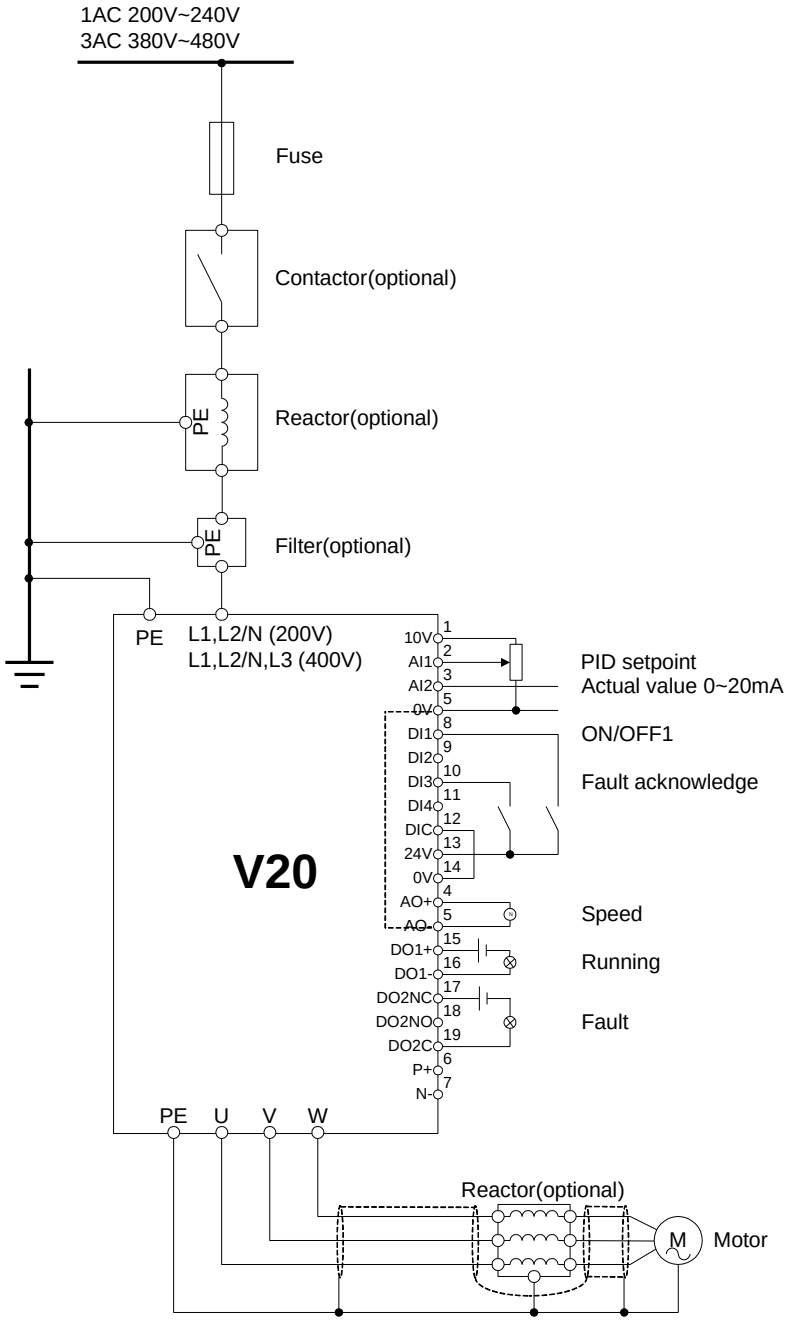


Figure 2-1 Wiring with the analog PID setpoint

The terminal assignment for the control unit is as following table 2-1:

Table 2-1

Signal	Terminal	Content
AI1	2	PID setpoint
AI2	3	Connection for the sensor, PID feedback
AO1	4	Actual speed output
0V	5	Common terminal for analog input and analog output
DI1	8	Start and stop drive, OFF1
DI3	10	Fault acknowledge pulse
DIC	12	Digital input common terminal, connect to 0 V, pin 14
24V	13	24V output for the power supply of the digital inputs
0V	14	Connect to pin 12 as the common input
DO1+	15	Drive status, drive is running, the common terminal of the DO1
DO1-	16	Drive status, drive is running, the output terminal
DO2NC	17	Drive status, drive is fault, the output terminal
DO2C	19	Drive status, drive is fault, the common terminal of the DO2

2.2 Wiring with the fixed setpoint

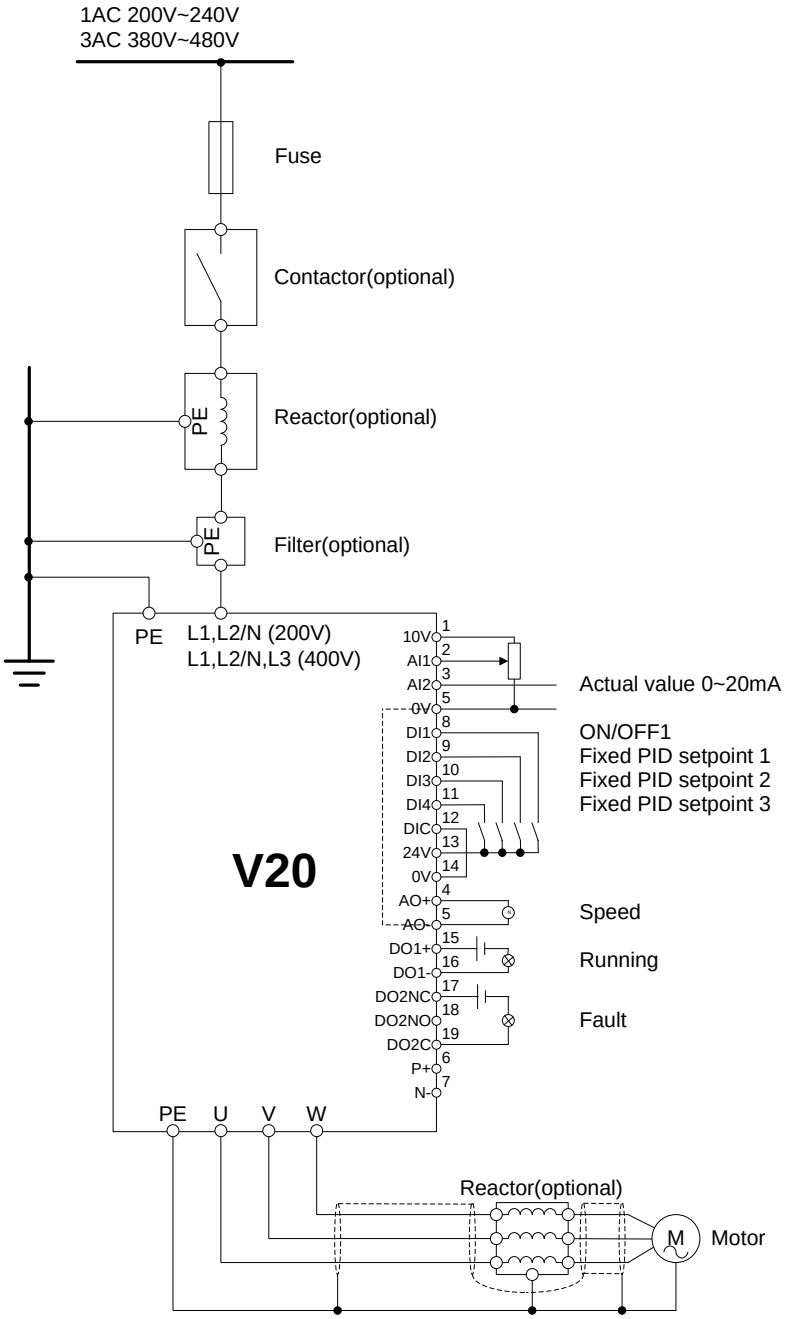


Figure 2-1 Wiring with the fixed PID setpoint

The terminal assignment for the control unit is as following table 2-2:

Table 2-2

Signal	Terminal	Content
AI2	3	Connection for the sensor, PID feedback
AO1	4	Actual speed output
0V	5	Common terminal for analog input and analog output
DI1	8	Start and stop drive, OFF1
DI2	9	Fixed PID setpoint 1
DI3	10	Fixed PID setpoint 2
DI4	11	Fixed PID setpoint 3
DIC	12	Digital input common terminal, connect to 0 V, pin 14
24V	13	24V output for the power supply of the digital inputs
0V	14	Connect to pin 12 as the common input
DO1+	15	Drive status, drive is running, the common terminal of the DO1
DO1-	16	Drive status, drive is running, the output terminal
DO2NC	17	Drive status, drive is fault, the output terminal
DO2C	19	Drive status, drive is fault, the common terminal of the DO2

2.3 Hardware and Software Components

2.3.1 Used Components

The application was generated with the following components:

Hardware components

Table 2-3

Component	No.	Article number	Note
Drive	1	6SL3210-5BB11-2UV0	V20 drive with FW 3.81.03
Motor	2	1LA9060-4KA10-Z	Triangle connection, 50HZ

Sample files and projects

The following list includes all files and projects that are used in this example.

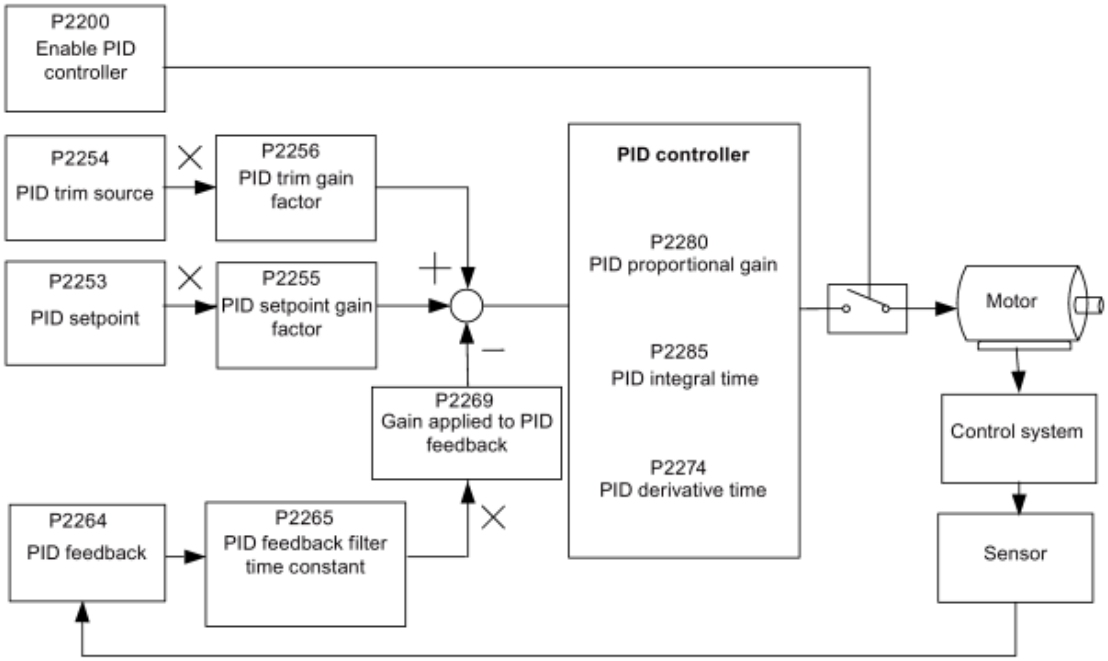
Table 2-4

Component	Note
Basic_application_V20_PID_control.pdf	This document.

3 Function mechanisms

3.1 PID overview

Figure 3-1



The integrated PID technology controller supports all kinds of simple process control tasks, such as pressure, flow rate, temperature etc. From this function chart, the PID controller has two setpoint, one is the main setpoint and the other is the trim setpoint. The PID controller specifies the speed of the motor in such a way that the process variable to be controlled as same as the setpoint, including the main setpoint and the trim setpoint.

3.2 Related parameters

In order to use the PID function, the following parameters should be paid attention. The main function parameter is in table 3-1.

Table 3-1

Parameter	Function	Setting
P2200[0…2]	BI: Enable PID controller	1: enable the PID controller 0: disable the PID controller
P2235[0…2]	BI: Enable PID-MOP (UP-cmd)	This parameter defines the source of the UP command.
P2236[0…2]	BI: Enable PID-MOP (DOWN-cmd)	This parameter defines the source of the DOWN command.

Normally if customer set the connection macro, then customer don’t need to set this main function parameters, it will be set by the connection macro automatically and customer can’t changed these parameters directly.

If the P2200 is set to 1, then the drive will automatically disable the normal ramp time set in P1120 and P1121, and also the normal frequency setpoints. For the acceleration and deceleration time, the PID function will follow the value set in P2257 and P2258. For the frequency setpoints, the PID function will follow the value set in P2253.

For the PID MOP up and MOP down command can be set to the BOP connection, digital input, USS connection and modbus connection.

There also has some additional parameters customer need to set as the table 3-2.

Table 3-2

Parameter	Function	Setting
P2201	Fixed PID setpoint 1	Value range from -200 to 200
P2202	Fixed PID setpoint 2	Value range from -200 to 200
P2203	Fixed PID setpoint 3	Value range from -200 to 200
P2204	Fixed PID setpoint 4	Value range from -200 to 200
P2205	Fixed PID setpoint 5	Value range from -200 to 200
P2206	Fixed PID setpoint 6	Value range from -200 to 200
P2207	Fixed PID setpoint 7	Value range from -200 to 200
P2208	Fixed PID setpoint 8	Value range from -200 to 200
P2209	Fixed PID setpoint 9	Value range from -200 to 200
P2210	Fixed PID setpoint 10	Value range from -200 to 200
P2211	Fixed PID setpoint 11	Value range from -200 to 200
P2212	Fixed PID setpoint 12	Value range from -200 to 200
P2213	Fixed PID setpoint 13	Value range from -200 to 200
P2214	Fixed PID setpoint 14	Value range from -200 to 200
P2215	Fixed PID setpoint 15	Value range from -200 to 200
P2216	Fixed PID setpoint mode	1: direct selection 2: binary selection
P2220	BI: fixed PID setpoint selection bit 0	
P2221	BI: fixed PID setpoint selection bit 1	
P2222	BI: fixed PID setpoint selection bit 2	
P2223	BI: fixed PID setpoint selection bit 3	
P2231	PID-MOP mode	Bit 0: if it’s 1, then the setpoint will be stored Bit 1: if it’s 1, then no on state for MOP necessary

P2232	Inhibit reverse direction of PID-MOP	0: reverse direction is allowed 1: reverse direction is inhibited
P2251	PID mode	1: PID as trim source 0: PID as the setpoint
P2253[0…2]	CI: PID setpoint	This parameter defines the setpoint source for PID setpoint input.
P2254[0…2]	CI: PID trim source	This parameter selects trim source for PID setpoint.
P2255	PID setpoint gain factor	Value range from 0 to 100
P2256	PID trim gain factor	Value range from 0 to 100
P2257	Ramp-up time for PID setpoint	Value range from 0 to 650
P2258	Ramp-down time for PID setpoint	Value range from 0 to 650
P2261	PID setpoint filter time constant [s]	Value range from 0 to 60
P2263	PID controller type	0: D component on feedback signal 1: D component on error signal
P2264[0…2]	CI: PID feedback	Analog input 1 as the default value
P2265	PID feedback filter time constant	Value range from 0 to 60
P2267	Maximum value for PID feedback	Value range from -200 to 200
P2268	Minimum value for PID feedback	Value range from -200 to 200
P2269	Gain applied to PID feedback	Value range from 0 to 500
P2270	PID feedback function selector	0: disabled 1: Square root 2: Square 3: Cube
P2271	PID transducer type	0: disabled 1: inversion of PID feedback signal
P2274	PID derivative time	Value range from 0 to 60
P2280	PID proportional gain	Value range from 0 to 65
P2285	PID integral time	Value range from 0 to 60
P2291	PID output upper limit	Value range from -200 to 200
P2292	PID output lower limit	Value range from -200 to 200

P2293	Ramp-up/down time of PID limit	Value range from 0 to 100
P2295	Gain applied to PID output	Value range from -100 to 100
P2350	PID autotune enable	0: PID autotuning disabled 1: PID autotuning via Ziegler Nichols standard 2: autotuning as 1 plus some overshoot 3: autotuning as 2 little or no overshoot 4: autotuning PI only, quarter damped response
P2354	PID tuning timeout length	Value range from 60 to 65000
P2355	PID tuning offset	Value range from 0 to 20

We need to optimize the parameters to achieve the performance. Especially for P2274, P2280 and P2285, if these PID parameters value is not suitable, the actual value may have vibration or have a long time delay.

For parameter P2267 and P2268 is used to restrict the range of the feedback signal, and parameter P2291 and P2292 is used to restrict the range of the actual PID output. If there is no range restriction, the PID output may be a very high frequency.

For parameter P2216, it defines two kinds of the fixed frequencies. One is the direct selection mode and the other is the binary selection mode. In the direct selection mode, if the fixed frequency selector (P2220 to P2223) only one is active, then it will only select the related fixed frequency; if several inputs are active together, the selected frequencies are summed. In the binary selection mode, up to 15 different fixed frequency values can be selected using this method.

The drive has the autotuning function, and it can adjust the PID gain according to different principle set in P2350. This tuning only changes values of P and I, and should be a quarter damped responses. The option to be selected depends on the application but broadly speaking option 1 will give a good response, whereas if a faster response is desired option 2 should be selected. If no overshoot is desired, then option 3 is the choice. For cases where no D term is wanted, then option 4 can be selected. The tuning procedure is the same for all options. It is just the calculation of P and I values that is different. After autotuning, this parameter is set to 0, and this means the autotuning is finished.

At the same time we can monitor some parameters to check the PID output function in table 3-3.

Table 3-3

Parameter	Function
R2224	CO: Actual fixed PID setpoint [%]
R2225.0	BO: PID fixed frequency status
R2245	CO: PID-MOP input frequency of the RFG [%]
R2250	CO: Output setpoint of PID-MOP[%]
R2260	CO: PID setpoint after PID-RFG [%]

R2262	CO: Filtered PID setpoint after RFG [%]
R2266	CO: PID filtered feedback [%]
R2272	CO: PID scaled feedback [%]
R2273	CO: PID error [%]
R2294	CO: Actual PID output [%]

We can use BOP operation to find the target r parameter to monitor the value of these parameters to do some diagnostic.

3.3 BOP operation

There is an internal BOP built in the V20 drive. Customer can use this BOP to commission and operate the drive. There is no commissioning tool installed in PC/PG for the V20 drive.

There is one LCD for displaying the drive details, one LED for displaying the drive status and six buttons for operating and commission the drive in the BOP. Please see the figure 3-2.

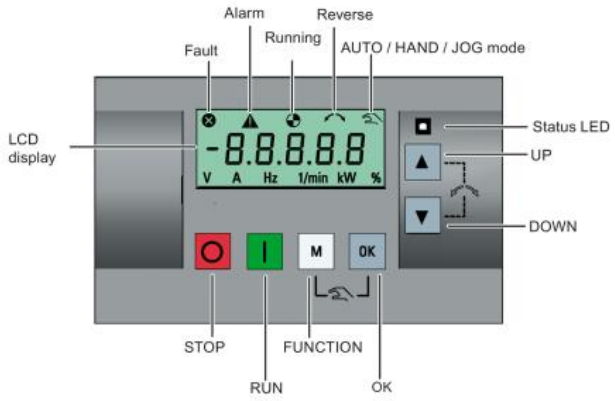


Figure 3-2

3.3.1 LED status

The V20 drive LED can display orange, green or red to indicate different status. See the table 3-4.

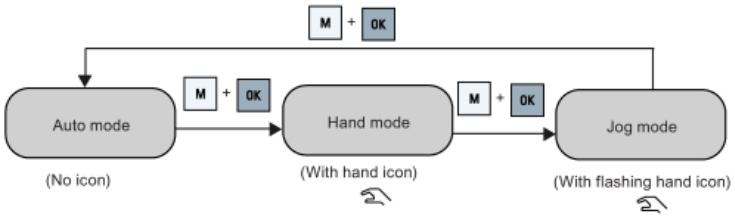
Table 3-4

Drive status	LED color
Drive is in starting up status	Orange color
Drive is in ready status	Green color
Drive is in quick commission status	Flashing at 0.5HZ with green color
Drive is in fault status	Flashing at 2HZ with red color
Drive is in cloning status	Flashing at 1HZ with orange color

3.3.2 Button functions

For these 6 buttons, customer press different combination, different time or different menu, the drive action is different. The details are in table 3-5.

Table 3-5

	**Stop button**	
	Single press	The drive will fall to OFF1 stop reaction. The ramp down time is set in P1121.
	Double press(<2s) or long press(>3s)	The drive will fall to OFF2 stop reaction. There is no ramp down time set in the drive.
	**Start button**	
	If the drive is stated in HAND/JOG/AUTO mode, the drive running icon will appear. This button is inactive if the drive is configured for control from terminals or USS/MODBUS in AUTO mode.	
	**Multi-function button**	
	Short press(<2s)	Enter the parameter setting menu or moves to the next screen in the setup menu Restarts the digit by digit editing on the selected item Returns to the fault code display If press twice in digit by digit editing, returns to the previous screen without changing the item being edited
	Long press(>2s)	Returns to the status screen Enters the setup menu
	**Confirm button**	
	Short press(<2s)	Switches between status values Enters edit value mode or change to the next digit Clears faults Returns to the fault code display
	Long press(>2s)	Quick parameter number or values edit Accesses fault information data
 + 	**Mode change button**	
	Press the “M” button together with “OK” button at the same time to switch between different modes.  Jog mode is only available if motor is stopped.	

	**Up button**
	When navigating through a menu, it moves the selection up through the screens available. When editing a parameter value, it increases the displayed value. When the drive is in run mode, it increases the speed. Long press(>2s) of the key quickly scrolls up through parameter numbers, indices or values.
	**Down button**
	When navigating through a menu, it moves the selection down through the screens available. When editing a parameter value, it decreases the displayed value. When the drive is in run mode, it decreases the speed. Long press(>2s) of the key quickly scrolls down through parameter numbers, indices or values.
 + 	**Direction button**
	Reverses the motor rotating direction. Pressing the two keys once activates reverse motor rotation. Pressing the two keys once again deactivates reverse rotation of the motor. The reserve icon on the display indicates that the output speed is opposite to the setpoint.

3.3.3 Status icons

For the LED can display the drive status, but the LCD also can display some icons and identify some status. See the table 3-6.

Table 3-6

Icon	Content
	Drive at least has one fault.
	Drive at least has one alarm.
	Drive is running and the motor speed is 0 rpm.
 (flashing)	Drive may be energized unexpectedly. For example, in frost protection mode.
	Motor rotates in the reversed direction.
	Drive is in HAND mode.
 (flashing)	Drive is in JOG mode.

With these icons, we can diagnose the drive working status.

3.3.4 Menu structure

Customer can use the “M” and “OK” key to switch the menu. The figure 3-3 displays the working flow.

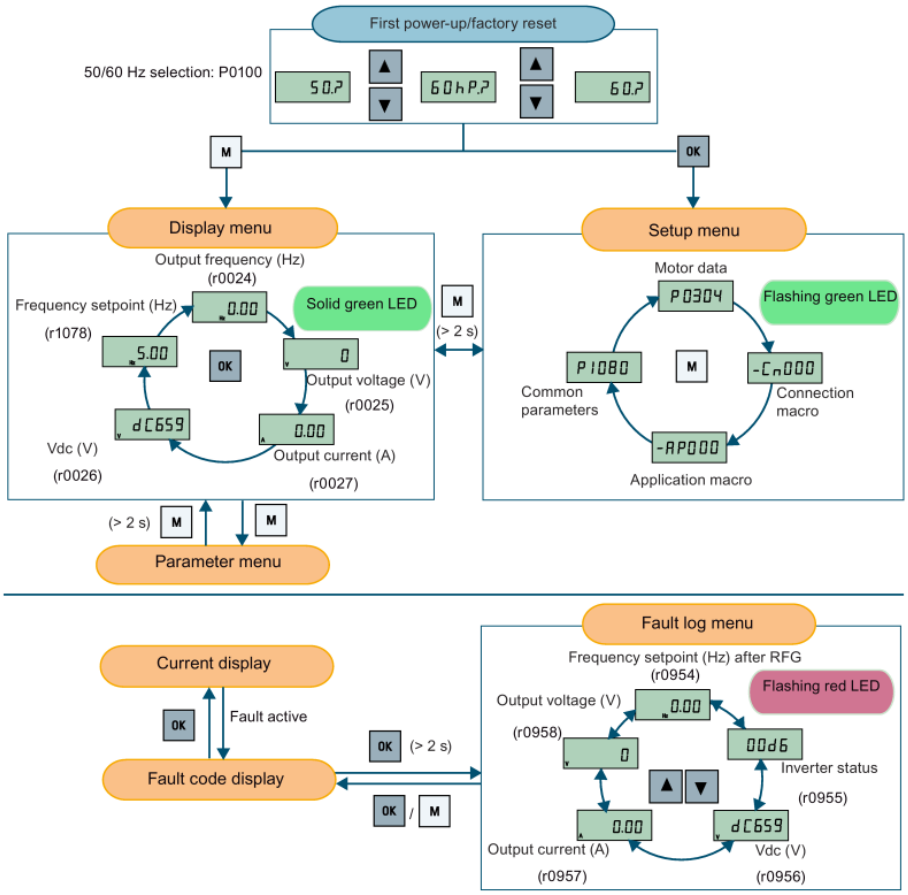


Figure 3-3

The table 3-7 will describe the main function of each menu.

Table 3-7

Menu	Description
50/60 Hz selection menu	This menu is visible only on first power on or after a factory reset.
Display menu (default display)	Basic monitoring view of key parameters such as frequency, voltage, current, DC-link voltage and so on.
Setup menu	Access to parameters for quick commissioning of the drive. Such as motor data, connection macro, application macro and some common parameters.
Parameter menu	Access to all available drive parameters.

3.3.5 Setting connection macro

This menu selects which macro is required for standard wiring arrangements. The default one is “Cn000” for connection macro 0. All connection macros only change the CDS0 parameters. The CDS1 parameters are used for the BOP control. When

commission the drive, the connection macro setting is a one-time setting. If you want to set a different connection macro, you can do a factory reset or repeat the quick commissioning process and change the connection macro. The connection macro setting process is as the figure 3-4

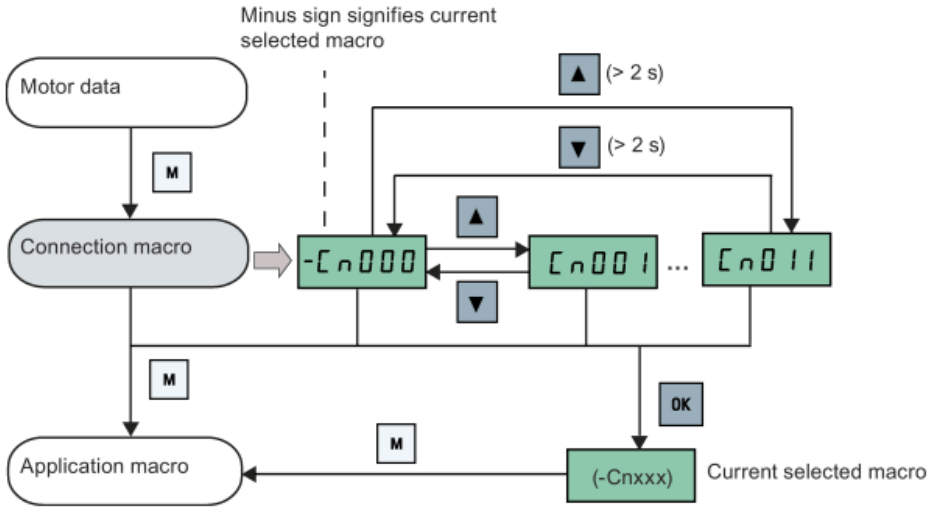


Figure 3-4

In the figure 3-4, if there is a minus signal in front of the Cn number, this means this connection is the currently selected macro. There are 12 connection macros show in table 3-8, for the details of the wiring of each macro, please check the manual.

Table 3-8

Connection macro	Description
Cn000	Factory default setting, no parameter is changed.
Cn001	BOP as the only control source.
Cn002	Control from the terminals, PNP/NPN digital inputs
Cn003	Fixed speed with directly selection mode
Cn004	Fixed speed with binary selection mode
Cn005	Analog input and fixed frequency
Cn006	External push button control
Cn007	External push button with analog setpoint
Cn008	PID control with analog setpoint
Cn009	PID control with fixed setpoint
Cn010	USS control
Cn011	MODBUS RTU control

3.3.6 Setting application macro

This menu defines certain common applications. Each application macro provides a set of parameters setting for a specific application. After you select an application macro, the corresponding settings are applied to the drive to simplify the

commissioning process. The default application macro is “AP000” for application macro 0. If none of the application macros fits your application, select the one that is the closest to your application and make further parameter changed as desired. The application macro setting is also one-time setting. If you want to set a different application macro, you can do a factory reset or repeat the quick commissioning process and change the application macro. The application macro setting process is as the figure 3-5.

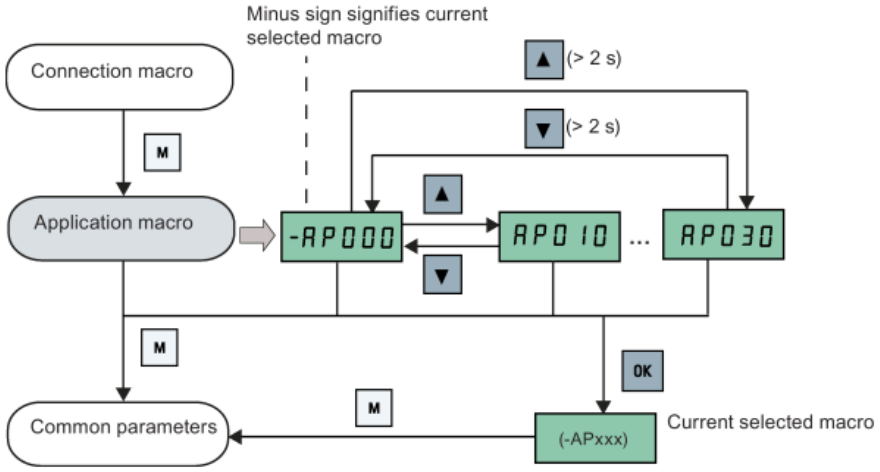


Figure 3-5

In the figure 3-5, if there is a minus signal in front of the AP number, this means this application is the currently selected macro. There are 5 application macros show in table 3-9, for the details of each macro, please check the manual.

Table 3-8

Application macro	Description
AP000	Factory default setting, no parameter is changed.
AP010	Simple pump application.
AP020	Simple fan application.
AP021	Compressor application.
AP030	Conveyor application.

4 Commission

This part will describe the PID function commissioning flow.

4.1 Commissioning flow with analog setpoint

Follow the table 4-1 to set the drive to the factory setting mode.

Table 4-1

Step	Setting	Content
1	P3=3	Standard user access level.
2	P10=30	Factory setting.
3	P970=21	Reset to factory default value, and delete user parameters if stored in the drive.

After setting the parameter P970, the drive LCD will displays “8 8 8 8 8” and then the screen shows P970. The P970 and P10 will be automatically reset to the default value 0.

After the drive reset and startup again, the 50/60 Hz selection menu is visible. Follow the table 4-2 to select the motor base frequency.

Table 4-2

Step	Setting	Content
1	Press “OK”	Select the motor base frequency to 50Hz.

Customer need to follow the motor name plate to fulfill the motor data. Follow the table 4-3.

Table 4-3

Step	Setting	Content
1	P304=230	Rated motor voltage, unit [V]
2	P305=0.71	Rated motor current, unit [A]
3	P307=0.12	Rated motor power, unit [KW]
4	P308=0.65	Rated motor power factor
5	P309=0	Rated motor efficiency, internal calculation value
6	P310=50	Rated motor frequency, unit [HZ]
7	P311=1395	Rated motor speed, unit [RPM]
8	P1900=2	Select motor data identification for all parameters in standstill

After the motor data identification, P1900 will be reset to the default value 0.

After input the motor data, customer need to select the related connection macro and application macro, for the connection macro, need to follow the wiring to select it, but the application macro, need to follow the actual application to select it or select the default macro. Follow the table 4-4 to select it.

Table 4-4

Step	Setting	Content
1	Cn008	PID control with analog setpoint
2	AP000	Factory default setting, no parameter is changed.

After the connection and the application macro selected, customer need to set some common parameters, such as the minimum and maximum frequency, jog function and some fixed setpoint. Follow table 4-5 to set the minimum frequency and the maximum frequency.

Table 4-5

Step	Setting	Content
1	P1080=5Hz	Minimum motor frequency.
2	P1082=50Hz	Maximum motor frequency.

Press the “M” key for more than 2 seconds to exit the quick commission process. Then set the related PID function and performance parameter in table 4-6.

Table 4-6

Step	Setting	Content
1	P3=3	Standard user access level.
2	P2263=	PID controller type.
3	P2280=	PID proportional gain.
4	P2285=	PID integral time.
5	P2274=	PID derivative time.

The value of related parameter should follow the actual application requirements, otherwise, customer can use the default value.

4.2 Commissioning flow with the fixed setpoint

Follow the table 4-7 to set the drive to the factory setting mode.

Table 4-7

Step	Setting	Content
1	P3=3	Standard user access level.
2	P10=30	Factory setting.
3	P970=21	Reset to factory default value, and delete user parameters if stored in the drive.

After setting the parameter P970, the drive LCD will displays “8 8 8 8 8” and then the screen shows P970. The P970 and P10 will be automatically reset to the default value 0.

After the drive reset and startup again, the 50/60 Hz selection menu is visible. Follow the table 4-8 to select the motor base frequency.

Table 4-8

Step	Setting	Content

1	Press “OK”	Select the motor base frequency to 50Hz.

Customer need to follow the motor name plate to fulfill the motor data. Follow the table 4-9.

Table 4-9

Step	Setting	Content
1	P304=230	Rated motor voltage, unit [V]
2	P305=0.71	Rated motor current, unit [A]
3	P307=0.12	Rated motor power, unit [KW]
4	P308=0.65	Rated motor power factor
5	P309=0	Rated motor efficiency, internal calculation value
6	P310=50	Rated motor frequency, unit [HZ]
7	P311=1395	Rated motor speed, unit [RPM]
8	P1900=2	Select motor data identification for all parameters in standstill

After the motor data identification, P1900 will be reset to the default value 0.

After input the motor data, customer need to select the related connection macro and application macro, for the connection macro, need to follow the wiring to select it, but the application macro, need to follow the actual application to select it or select the default macro. Follow the table 4-10 to select it.

Table 4-10

Step	Setting	Content
1	Cn009	PID control with analog setpoint
2	AP000	Factory default setting, no parameter is changed.

After the connection and the application macro selected, customer need to set some common parameters, such as the minimum and maximum frequency, jog function and some fixed setpoint. Follow table 4-11 to set the minimum frequency and the maximum frequency.

Table 4-11

Step	Setting	Content
1	P1080=5Hz	Minimum motor frequency.
2	P1082=50Hz	Maximum motor frequency.

Press the “M” key for more than 2 seconds to exit the quick commission process. Then set the related PID function and performance parameter in table 4-12.

Table 4-12

Step	Setting	Content
1	P3=3	Standard user access level.
2	P2201 to P2215=	Each fixed PID setpoint value.
3	P2216=	Fixed PID setpoint mode.

2	P2263=	PID controller type.
4	P2280=	PID proportional gain.
5	P2285=	PID integral time.
6	P2274=	PID derivative time.

The value of related parameter should follow the actual application’s requirements, otherwise customer can use the default value.

5 Additional function

5.1 FFB function

Additional signal interconnections in the inverter can be established by means of the free function blocks, which we call FFB function. Every digital and analog signal available via BICO technology can be routed to the appropriate inputs of the free function blocks. The outputs of the free function blocks are also interconnected to other functions using BICO technology.

In PID application, sometimes the default connection macro can't fit customer's requirement, we need to use the FFB function to accomplish the application. Use figure 5-1 as an example.

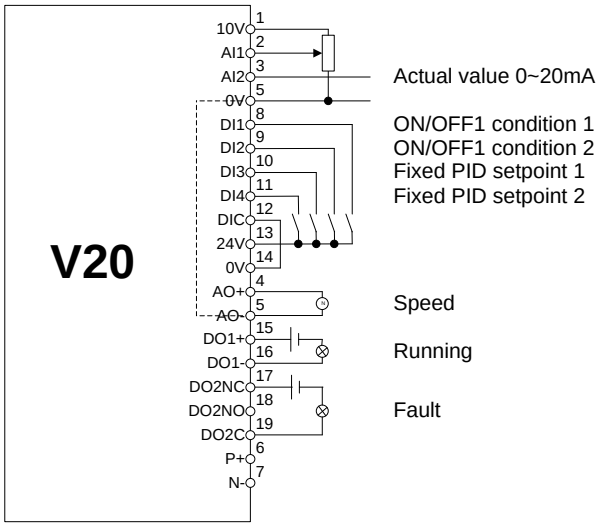


Figure 5-1

In this application, we use the fixed PID connection macro but it is a little different with the standard application. Because the digital input function is different. Compare the figure 2-2 and figure 5-1, the difference is show in table 5-1.

Table 5-1

Signal	Terminal	Figure 2-2 function	Figure 5-1 function
DI1	8	ON/OFF1	ON/OFF1 condition 1
DI2	9	Fixed PID setpoint 1	ON/OFF1 condition 2
DI3	10	Fixed PID setpoint 2	Fixed PID setpoint 1
DI4	11	Fixed PID setpoint 3	Fixed PID setpoint 2

In the figure 2-2, we use one digital input to start and stop the drive and use another three digital inputs to select the PID setpoint with the different fixed value. But in figure 5-1, we use two digital inputs to start and stop the drive and use the other two digital inputs to select the PID setpoint with the different fixed value.

The ON/OFF1 logic is in the table 5-2 and the setpoint logic is in the table 5-3.

Table 5-2

Item	DI1 status	DI2 status	Drive situation
1	0	0	OFF1

2	0	1	OFF1
3	1	0	OFF1
4	1	1	ON

Table 5-3

Item	DI3 status	DI4 status	Setpoint
1	0	0	No setpoint
2	0	1	Fixed setpoint 1
3	1	0	Fixed setpoint 2
4	1	1	Fixed setpoint 3

According to the table 5-2 and table 5-3, we can conclude the drive control logic as the figure 5-2 and the setpoint control logic as the figure 5-3.

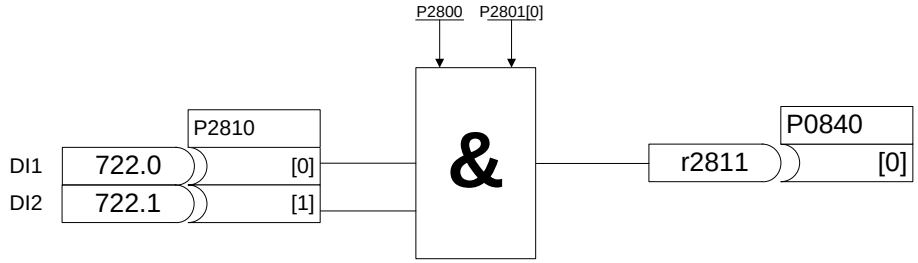


Figure 5-2

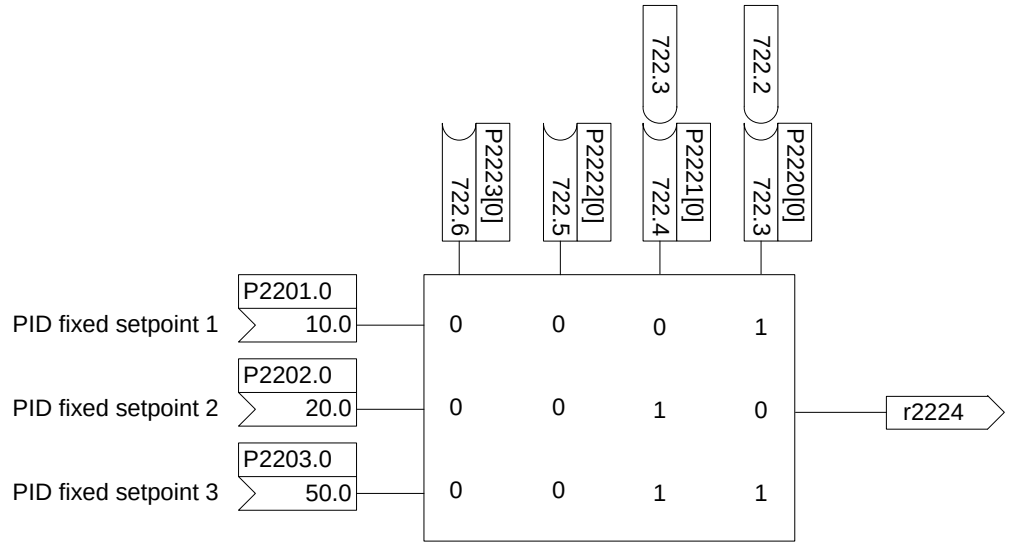


Figure 5-3

This is also a fixed PID setpoint application, so we can use the standard commission flow to finish the PID function, following the chapter 4.2 to commission it. But the digital input function is different with this standard application, so we need to use the FFB function to finish the digital input function, the parameter need to be set in V20 drive is in table 5-4.

Table 5-4

Item	Parameter	Setting	Content
1	P0701[0]	99	Enable BICO parameterization
2	P0702[0]	99	Enable BICO parameterization
3	P0703[0]	99	Enable BICO parameterization
4	P0704[0]	99	Enable BICO parameterization
5	P0840[0]	2811	The first and logic output as the ON/OFF1 source
6	P2201[0]		Fixed PID setpoint 1
7	P2202[0]		Fixed PID setpoint 2
8	P2203[0]		Fixed PID setpoint 3
9	P2216[0]	2	Fixed PID setpoint mode
10	P2220[0]	722.2	Digital input 3 as the source of fixed PID setpoint select bit 0
11	P2221[0]	722.3	Digital input 4 as the source of fixed PID setpoint select bit 1
12	P2800	1	Enable FFB function
13	P2801[0]	1	Enable the first and logic
14	P2810[0]	722.0	Digital input 1 as the source of the first and logic input
15	P2810[1]	722.1	Digital input 2 as the source of the first and logic input

In this application, the default connection macro has already set the digital input as a default function, if you need to use the digital input freely, the first step need to set the related digital input function to 99, otherwise this digital input can’t be used freely. For example, if the P701[0] is not equal to 99, then you can’t set P2810[0] to 722.0, in the related list which can be set to this parameter, you can’t find the value 722.0.

6 Related literature

Table 6-1

	Topic	Title / Link
\1\	Siemens Industry Online Support	http://support.industry.siemens.com
\2\	Download page of this entry	https://support.industry.siemens.com/cs/ww/en/view/109483275https://support.industry.siemens.com/cs/ww/en/view/Item_Number
\3\		

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8 History

Table 8-1

Version	Date	Modifications
V1.0	MM/YYYY	First version