MyCNC closed loop configuration

A proportional–integral–derivative controller (PID controller) is a control loop feedback mechanism widely used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value E(t) as the difference between the desired setpoint position (POS) and a real position measured by encoders (ENC) and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively).

PID controller formula implemented in myCNC is

$$U_{PID} = K_0 + K * V + K_p * E(t) + K_i * \int_0^t E(t)\,dt + K_d * dE(t)/dt$$

where

- **Kp** is the proportional gain, a tuning parameter,
- **Ki** is the integral gain, a tuning parameter,
- **Kd** is the derivative gain, a tuning parameter,
- **E(t)** = (POS − ENC) is the position error (difference between a job position real position measured by encoder),
- **t** is the time (the present).

Digital-Analogue Converter (DAC) output voltage is the sum of the **PID** and a **DAC offset** volage

$$U_{OUT} = U_{PID} + U_{Offset}$$

Enable/Disable PID control does not affect the DAC voltage offset.

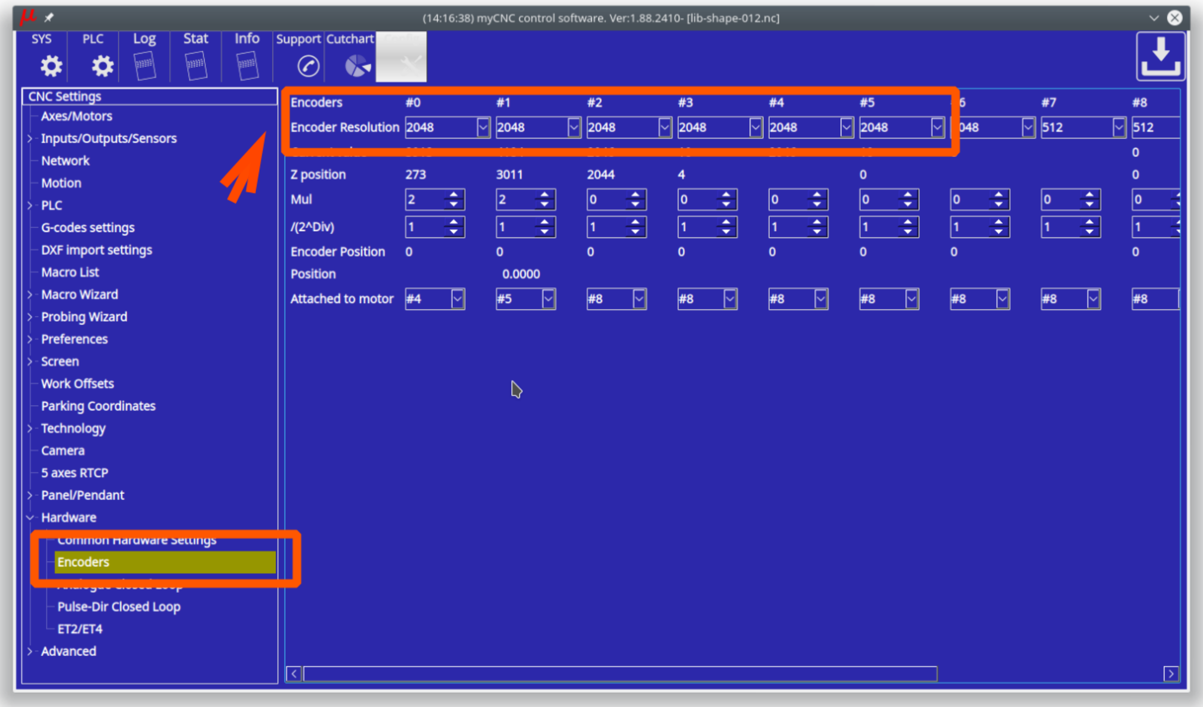
If PID control is disabled for selected channel, output voltage is equal to DAC Offset

```
U_out = U_offset
```

PID controllers setup

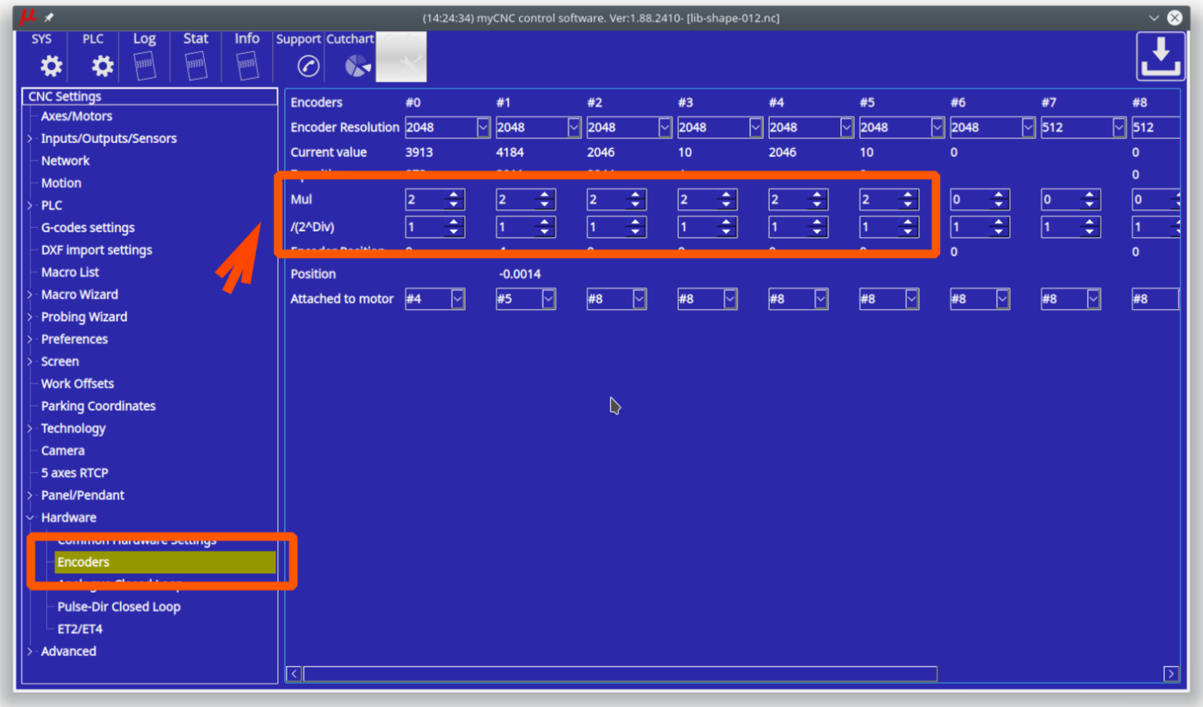
To setup Closed-loop analogue PID

- Goto “Encoders” configuration widget. Setup Encoder resolution for each channel you going to use



Encoders	#0	#1	#2	#3	#4	#5	6	#7	#8
Encoder Resolution	2048	2048	2048	2048	2048	2048	048	512	512
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			0
Z position	273	3011	2044	4		0			0
Mul	2	2	0	0	0	0	0	0	0
/(2^Div)	1	1	1	1	1	1	1	1	1
Encoder Position	0	0	0	0	0	0	0		0
Position		0.0000							
Attached to motor	#4	#5	#8	#8	#8	#8	#8	#8	#8

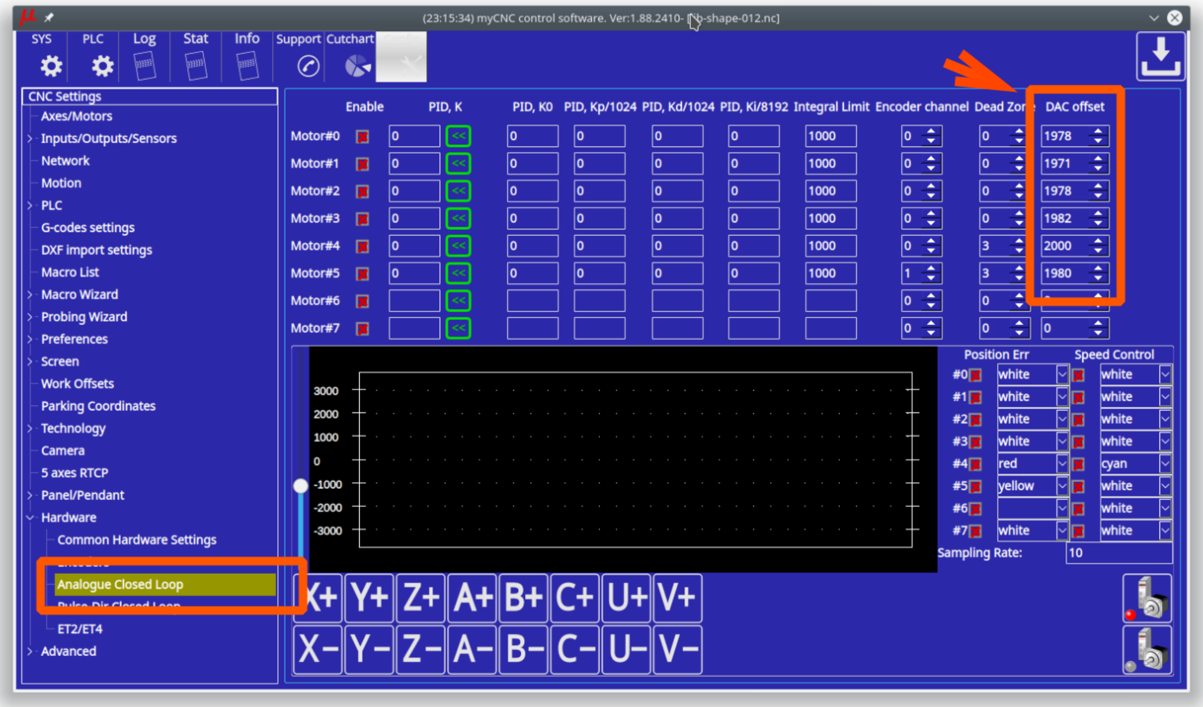
- Set Multiplication ratio to “2” and divider (/2^Div) ratio to “1” to get result ratio **2/(2^1)=1**



Encoders	#0	#1	#2	#3	#4	#5	#6	#7	#8
Encoder Resolution	2048	2048	2048	2048	2048	2048	2048	512	512
Current value	3913	4184	2046	10	2046	10	0		0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			0
Mul	2	2	2	2	2	2	0	0	0
/(2^Div)	1	1	1	1	1	1	1	1	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0		0
Position		-0.0014							
Attached to motor	#4	#5	#8	#8	#8	#8	#8	#8	#8

```
Multiplicator and divider ratio needed for pulse-dir closed loop system
to adjust encoder resolution (encoder lines-per-rotation) to motor driver
pulse-dir resolution.
For Analogue closed loop system this ratio should be "1"
```

- Adjust DAC offset ratio to get “0V” value on DAC output for each channel. Theoretical DAC value for 0V is the middle of 12bits range
  4096/2=**2048**.
  A real value may vary +/-5%.

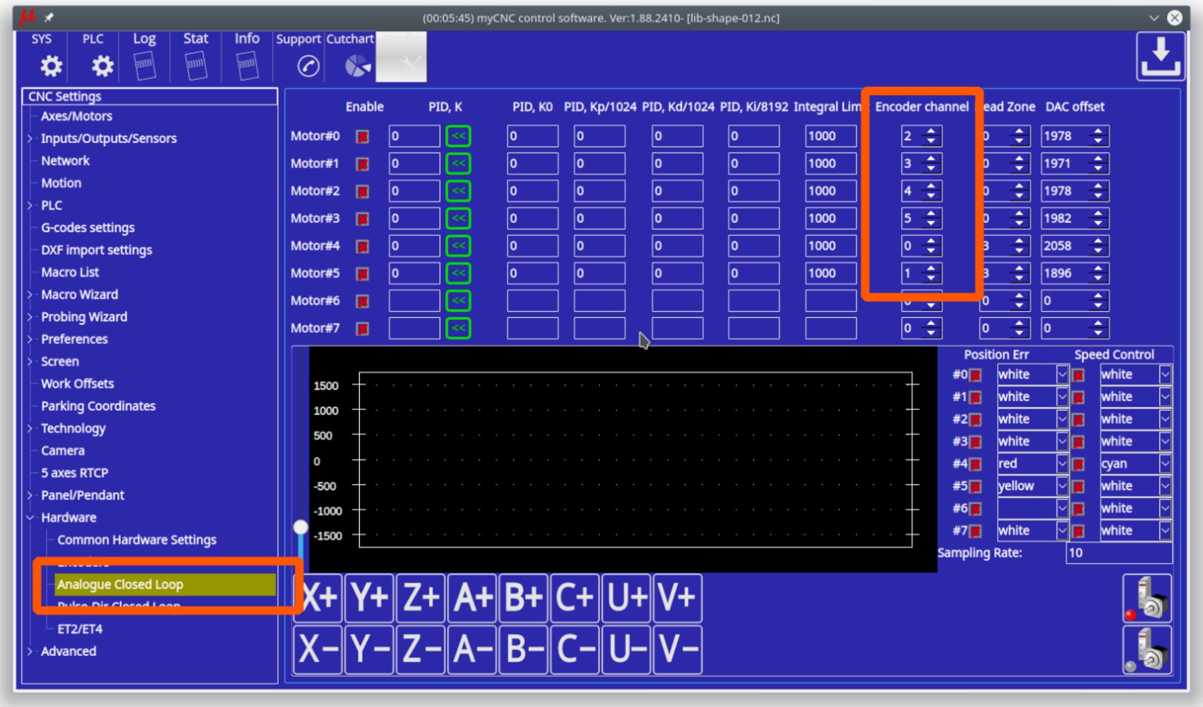

(23:15:34) myCNC control software. Ver:1.88.2410- [lib-shape-012.nc]

	Enable	PID, K	PID, K0	PID, Kp/1024	PID, Kd/1024	PID, Ki/8192	Integral Limit	Encoder channel	Dead Zone	DAC offset
Motor#0		0	0	0	0	0	1000	0	0	1978
Motor#1		0	0	0	0	0	1000	0	0	1971
Motor#2		0	0	0	0	0	1000	0	0	1978
Motor#3		0	0	0	0	0	1000	0	0	1982
Motor#4		0	0	0	0	0	1000	0	3	2000
Motor#5		0	0	0	0	0	1000	1	3	1980
Motor#6								0	0	0
Motor#7								0	0	0

	Position Err	Speed Control
#0	white	white
#1	white	white
#2	white	white
#3	white	white
#4	red	cyan
#5	yellow	white
#6		white
#7	white	white

Sampling Rate: 10

- Fill Encoder channel for each PID (Motor#).

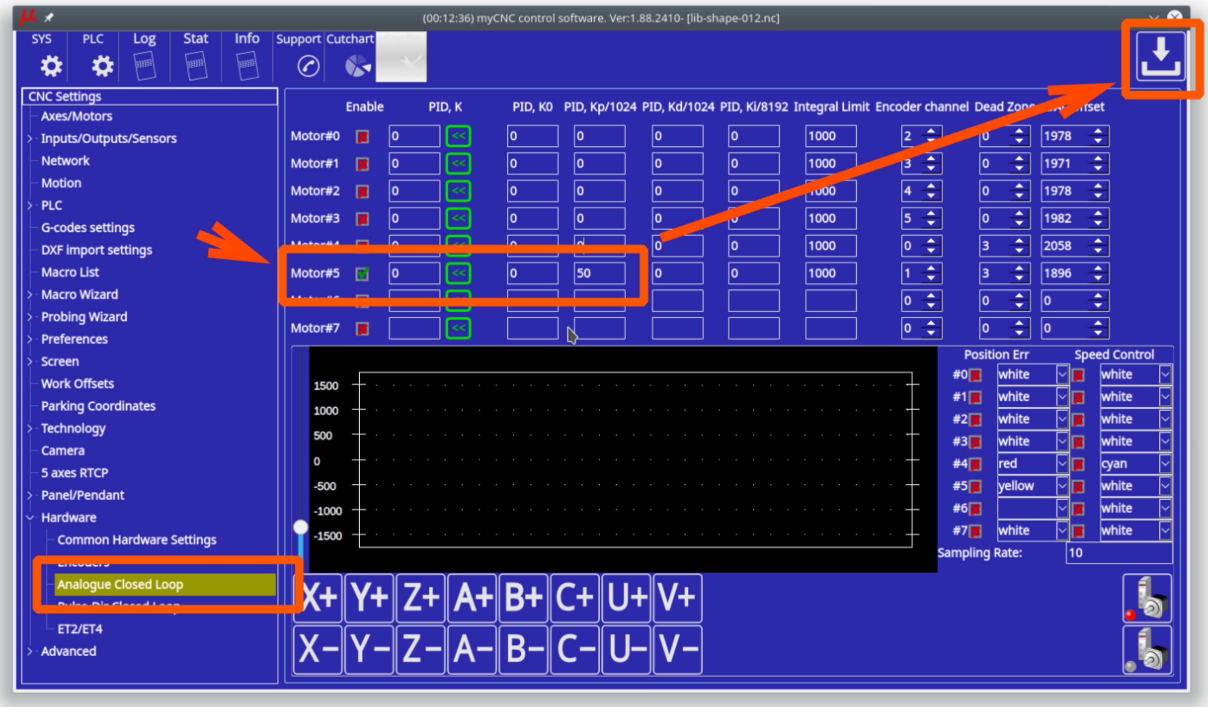

(00:05:45) myCNC control software. Ver:1.88.2410- [lib-shape-012.nc]

	Enable	PID, K	PID, K0	PID, Kp/1024	PID, Kd/1024	PID, Ki/8192	Integral Limit	Encoder channel	Dead Zone	DAC offset
Motor#0		0	0	0	0	0	1000	2	0	1978
Motor#1		0	0	0	0	0	1000	3	0	1971
Motor#2		0	0	0	0	0	1000	4	0	1978
Motor#3		0	0	0	0	0	1000	5	0	1982
Motor#4		0	0	0	0	0	1000	0	3	2058
Motor#5		0	0	0	0	0	1000	1	3	1896
Motor#6								0	0	0
Motor#7								0	0	0

	Position Err	Speed Control
#0	white	white
#1	white	white
#2	white	white
#3	white	white
#4	red	cyan
#5	yellow	white
#6		white
#7	white	white

Sampling Rate: 10

- To test selected channel, check “Enable” checkbox for the channel and enter initial value of “50” for Proportional P-ratio of PID controller. Press “Save” button to save the changes. We test PID#5 (motor channel #5) on the screenshot below.

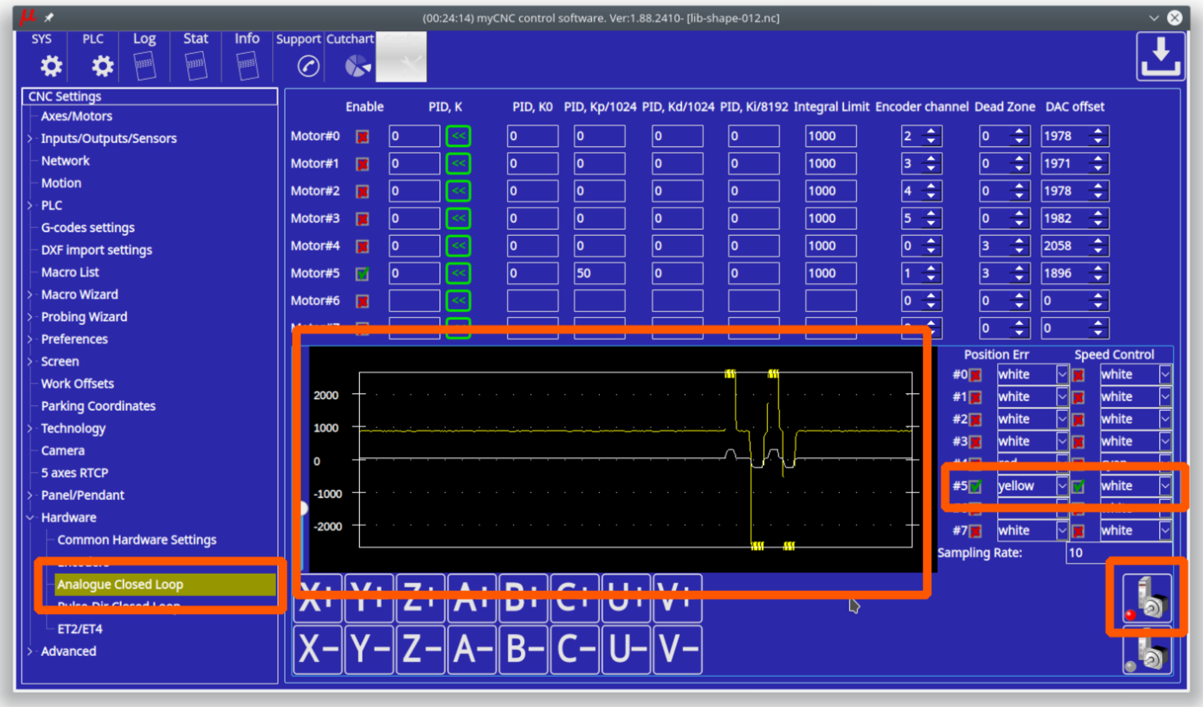

(00:12:36) myCNC control software. Ver:1.88.2410- [lib-shape-012.nc]

	Enable	PID, K	PID, K0	PID, Kp/1024	PID, Kd/1024	PID, Ki/8192	Integral Limit	Encoder channel	Dead Zone	DAC offset
Motor#0	🟥	0	0	0	0	0	1000	2	0	1978
Motor#1	🟥	0	0	0	0	0	1000	3	0	1971
Motor#2	🟥	0	0	0	0	0	1000	4	0	1978
Motor#3	🟥	0	0	0	0	0	1000	5	0	1982
Motor#4	🟥	0	0	0	0	0	1000	0	3	2058
Motor#5	✓	0	0	50	0	0	1000	1	3	1896
Motor#6								0	0	0
Motor#7	🟥							0	0	0

	Position Err	Speed Control
#0	🟥 white	🟥 white
#1	🟥 white	🟥 white
#2	🟥 white	🟥 white
#3	🟥 white	🟥 white
#4	🟥 red	🟥 cyan
#5	🟥 yellow	🟥 white
#6	🟥	🟥 white
#7	🟥 white	🟥 white

Sampling Rate: 10

- Click on “Servo-ON” button to reset & enable selected PID and turn ON “Servo-ON” signal. Servo-On procedure will …
  - Reset position error registers - **E(t)** and its Integral value.
  - Turn ON Servo-ON output to enable a servo driver
  - Turn ON all “Enabled” PID controllers (Checkboxes “Enable” are checked).
- Select the channel for a scope widget to control and tune PID controller ratios.

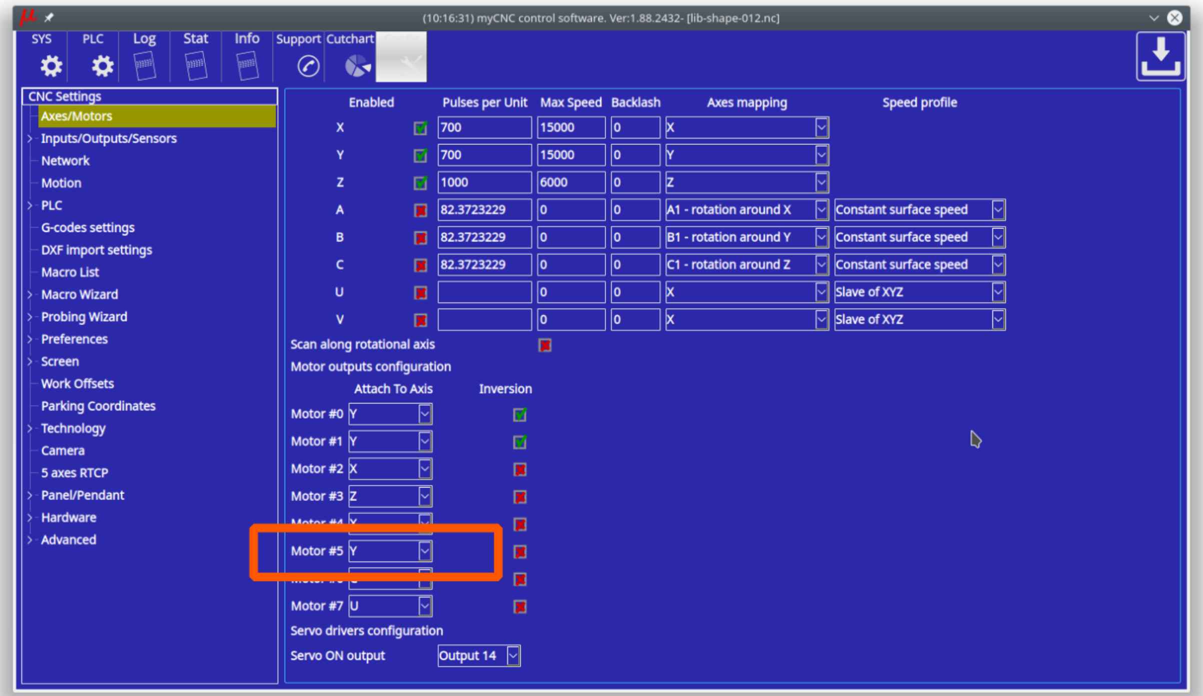

(00:24:14) myCNC control software. Ver:1.88.2410- [lib-shape-012.nc]

	Enable	PID, K	PID, K0	PID, Kp/1024	PID, Kd/1024	PID, Ki/8192	Integral Limit	Encoder channel	Dead Zone	DAC offset
Motor#0	🟥	0	0	0	0	0	1000	2	0	1978
Motor#1	🟥	0	0	0	0	0	1000	3	0	1971
Motor#2	🟥	0	0	0	0	0	1000	4	0	1978
Motor#3	🟥	0	0	0	0	0	1000	5	0	1982
Motor#4	🟥	0	0	0	0	0	1000	0	3	2058
Motor#5	✓	0	0	50	0	0	1000	1	3	1896
Motor#6	🟥							0	0	0
Motor#7									0	0

	Position Err	Speed Control
#0	🟥 white	🟥 white
#1	🟥 white	🟥 white
#2	🟥 white	🟥 white
#3	🟥 white	🟥 white
#5	✓ yellow	✓ white
#7	🟥 white	🟥 white

Sampling Rate: 10

- Check which Axis the PID controller attached to (Y axis for the screenshot below).



	Enabled	Pulses per Unit	Max Speed	Backlash	Axes mapping	Speed profile
X	✓	700	15000	0	X	
Y	✓	700	15000	0	Y	
Z	✓	1000	6000	0	Z	
A	🟥	82.3723229	0	0	A1 - rotation around X	Constant surface speed
B	🟥	82.3723229	0	0	B1 - rotation around Y	Constant surface speed
C	🟥	82.3723229	0	0	C1 - rotation around Z	Constant surface speed
U	🟥		0	0	X	Slave of XYZ
V	🟥		0	0	X	Slave of XYZ

Scan along rotational axis 🟥

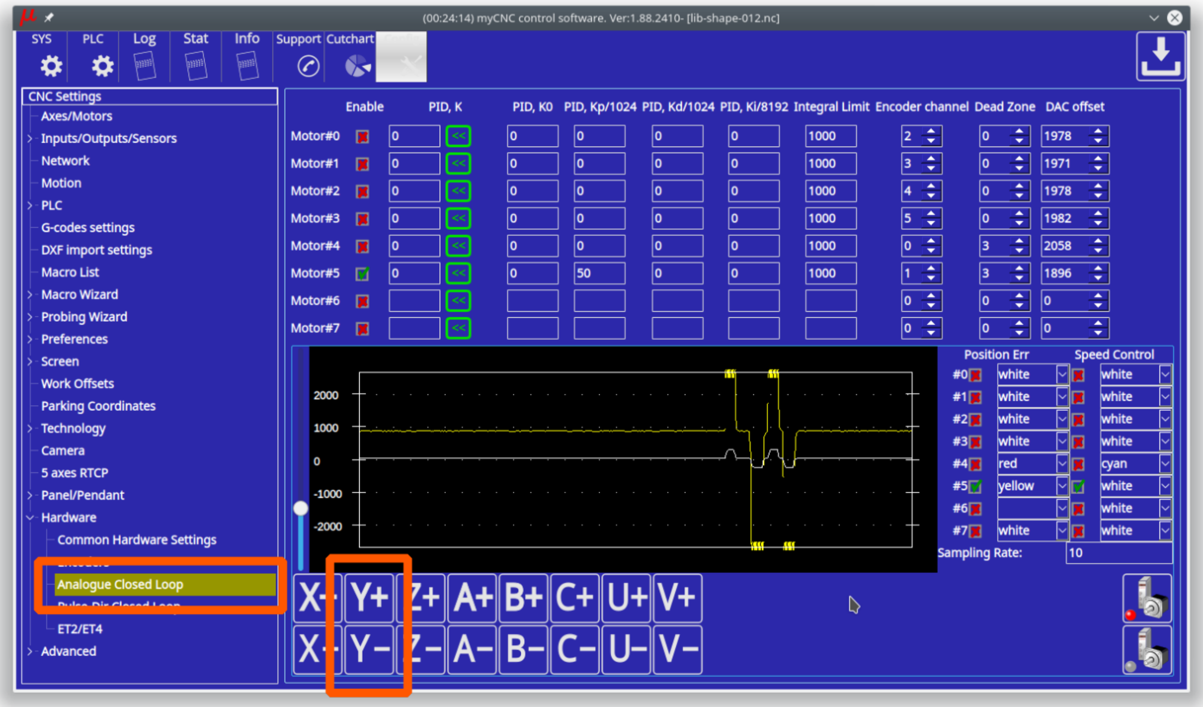
Motor outputs configuration

	Attach To Axis	Inversion
Motor #0	Y	✓
Motor #1	Y	✓
Motor #2	X	🟥
Motor #3	Z	🟥
Motor #4	Y	🟥
Motor #5	Y	🟥
Motor #6		🟥
Motor #7	U	🟥

Servo drivers configuration

Servo ON output: Output 14

- Jog buttons can be used to move the axis while testing and tuning the PID coefficients.

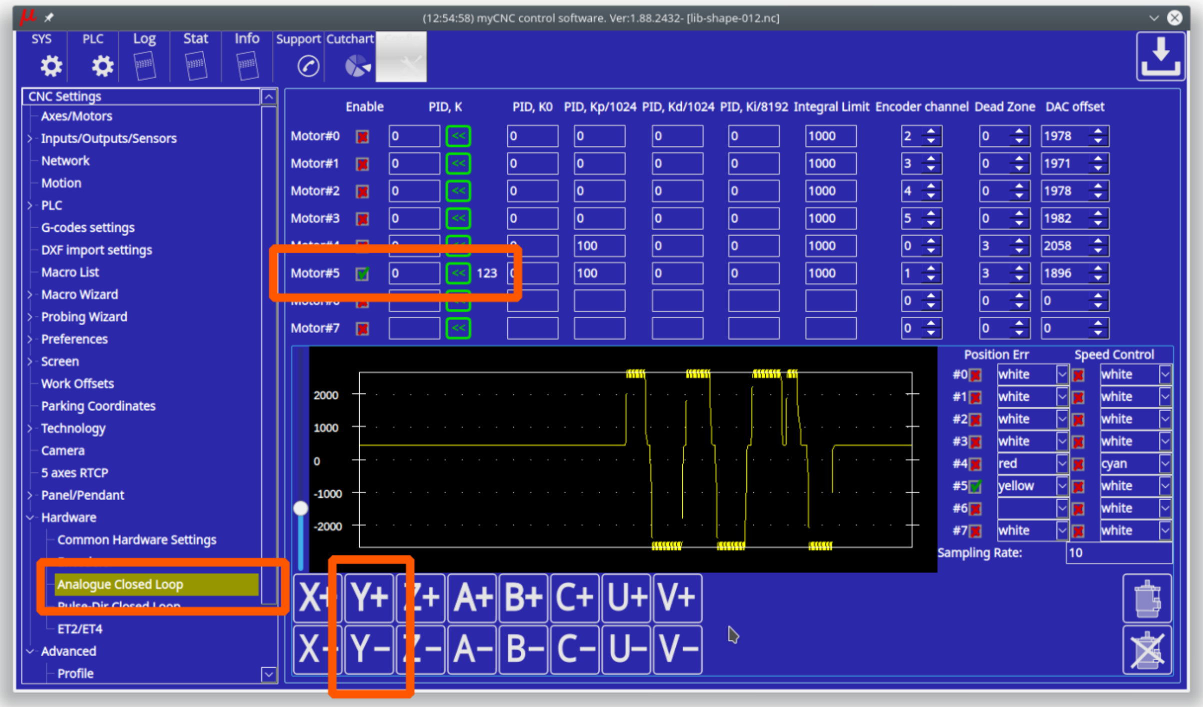


	Enable	PID, K		PID, K0	PID, Kp/1024	PID, Kd/1024	PID, Ki/8192	Integral Limit	Encoder channel	Dead Zone	DAC offset
Motor#0	🟥	0	<<	0	0	0	0	1000	2	0	1978
Motor#1	🟥	0	<<	0	0	0	0	1000	3	0	1971
Motor#2	🟥	0	<<	0	0	0	0	1000	4	0	1978
Motor#3	🟥	0	<<	0	0	0	0	1000	5	0	1982
Motor#4	🟥	0	<<	0	0	0	0	1000	0	3	2058
Motor#5	✓	0	<<	0	50	0	0	1000	1	3	1896
Motor#6	🟥		<<						0	0	0
Motor#7	🟥		<<						0	0	0

	Position Err		Speed Control	
#0	🟥	white	🟥	white
#1	🟥	white	🟥	white
#2	🟥	white	🟥	white
#3	🟥	white	🟥	white
#4	🟥	red	🟥	cyan
#5	✓	yellow	✓	white
#6	🟥		🟥	white
#7	🟥	white	🟥	white

Sampling Rate: 10

- An analogue servo driver normally has a linear function of rotation speed depends on input voltage. A linear coefficient of this function depends on Servo driver and motor, gears, ball-screw etc.
  PID **K** value represent this coefficient.

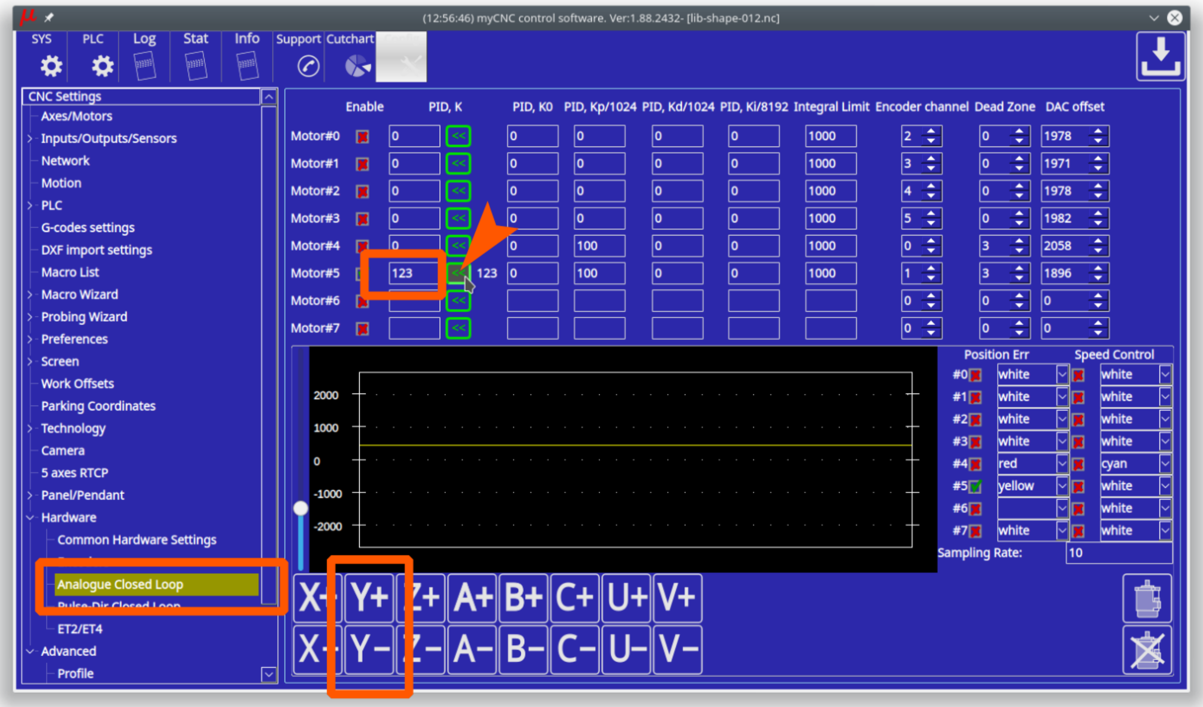


	Enable	PID, K		PID, K0	PID, Kp/1024	PID, Kd/1024	PID, Ki/8192	Integral Limit	Encoder channel	Dead Zone	DAC offset
Motor#0	✗	0	<<	0	0	0	0	1000	2	0	1978
Motor#1	✗	0	<<	0	0	0	0	1000	3	0	1971
Motor#2	✗	0	<<	0	0	0	0	1000	4	0	1978
Motor#3	✗	0	<<	0	0	0	0	1000	5	0	1982
Motor#4	✗	0	<<	0	100	0	0	1000	0	3	2058
Motor#5	✓	0	<< 123	0	100	0	0	1000	1	3	1896
Motor#6	✗		<<						0	0	0
Motor#7	✗		<<						0	0	0

	Position Err		Speed Control	
#0	✗	white	✗	white
#1	✗	white	✗	white
#2	✗	white	✗	white
#3	✗	white	✗	white
#4	✗	red	✗	cyan
#5	✓	yellow	✗	white
#6	✗		✗	white
#7	✗	white	✗	white

Sampling Rate: 10

The value can be tuned manually. If rotate a motor shaft with speed more than 20 turns/sec, the controller calculates real Speed/Voltage coefficient and print it on the configuration widget. You can use this value as information to tune the PID **K** ratio. A button « to the right of **PID K** input line can be used to copy the measured **K** ratio to **PID K**.



	Enable	PID, K		PID, K0	PID, Kp/1024	PID, Kd/1024	PID, Ki/8192	Integral Limit	Encoder channel	Dead Zone	DAC offset
Motor#0	✗	0	<<	0	0	0	0	1000	2	0	1978
Motor#1	✗	0	<<	0	0	0	0	1000	3	0	1971
Motor#2	✗	0	<<	0	0	0	0	1000	4	0	1978
Motor#3	✗	0	<<	0	0	0	0	1000	5	0	1982
Motor#4	✗	0	<<	0	100	0	0	1000	0	3	2058
Motor#5		123	<< 123	0	100	0	0	1000	1	3	1896
Motor#6	✗		<<						0	0	0
Motor#7	✗		<<						0	0	0

	Position Err		Speed Control	
#0	✗	white	✗	white
#1	✗	white	✗	white
#2	✗	white	✗	white
#3	✗	white	✗	white
#4	✗	red	✗	cyan
#5	✓	yellow	✗	white
#6	✗		✗	white
#7	✗	white	✗	white

Sampling Rate: 10

Servo ON handling

Depends on machine configuration you may want

- On-Screen buttons to turn ON/OFF your Servo drivers

- Automatic turn ON Servo Drivers when CNC control loaded and ready to go

Both options can be implemented with myCNC control software.

There are few ways to Enable/Disable Servo PID loops in myCNC software

1. On-Screen button. To enable/disable Servo PID control button should have actions:

```
action="servo-pid-on"  (enable pid)
action="servo-pid-off"  (disable pid)
```

For example

Buttons for Servo-ON and Servo-OFF

```
<gitem where="toolbar-servo" image="motor/motor-start" action="servo-pid-on"
height="80" event="pressed-delay-1000" type="button"/>
<gitem where="toolbar-servo" image="motor/motor-stop" action="servo-pid-off"
height="80" type="button"/>
```

Popup widget container for Servo Pid On/Off buttons

```
<quick-popup-layout>
<current>popup-servo</current>
<layout stretch="0" name="popup-servo" wa="80;160;right"
orientation="vertical" skin="skin/metal-01">
    <widget stretch="1" spacing="0" name="toolbar-servo"
orientation="vertical">myitems</widget>
</layout>
</quick-popup-layout>
```

Button to show containner with 2 buttons for servo-on/servo-off buttons and led to show current servo pid state

```
<gitem where="magic" position="960;0" width="80" height="80"
image="motor/servo-driver"
action="mypopup-toggle:popup-servo" xattr="56;4;20;20;led;green;round"
address="outputs" number="47" type="xbutton" />
```

2. Using Global Variables API. Global variables 60000 and 60001 are mapped to turning On and Off Servo PID control.

- Write “1” to register number **60000** will turn ON Motor closed-loop control PIDs
- Write “1” to register number **60001** will turn OFF Motor closed-loop control PIDs

Reading this registers has no effect and return zero value. Read more about Servo ON/Servo OFF commands in this short manual: Servo ON/OFF.

3. Automatic Servo ON/OFF. There are 2 handler procedures in Software PLC can be used to automatic PID ON/OFF.

- **_HANDLER_INIT** - procedure executed once just after CNC control software loaded, connection

with myCNC controller established and a complete configuration is sent to the controller.
- **_HANDLER_EXIT** - procedure executed while myCNC control software shut down the process.

To handle automatic Servo ON/OFF writing to registers 60000, 60001 should be added to handler procedures. Example is below

__HANDLER_INIT.PLC

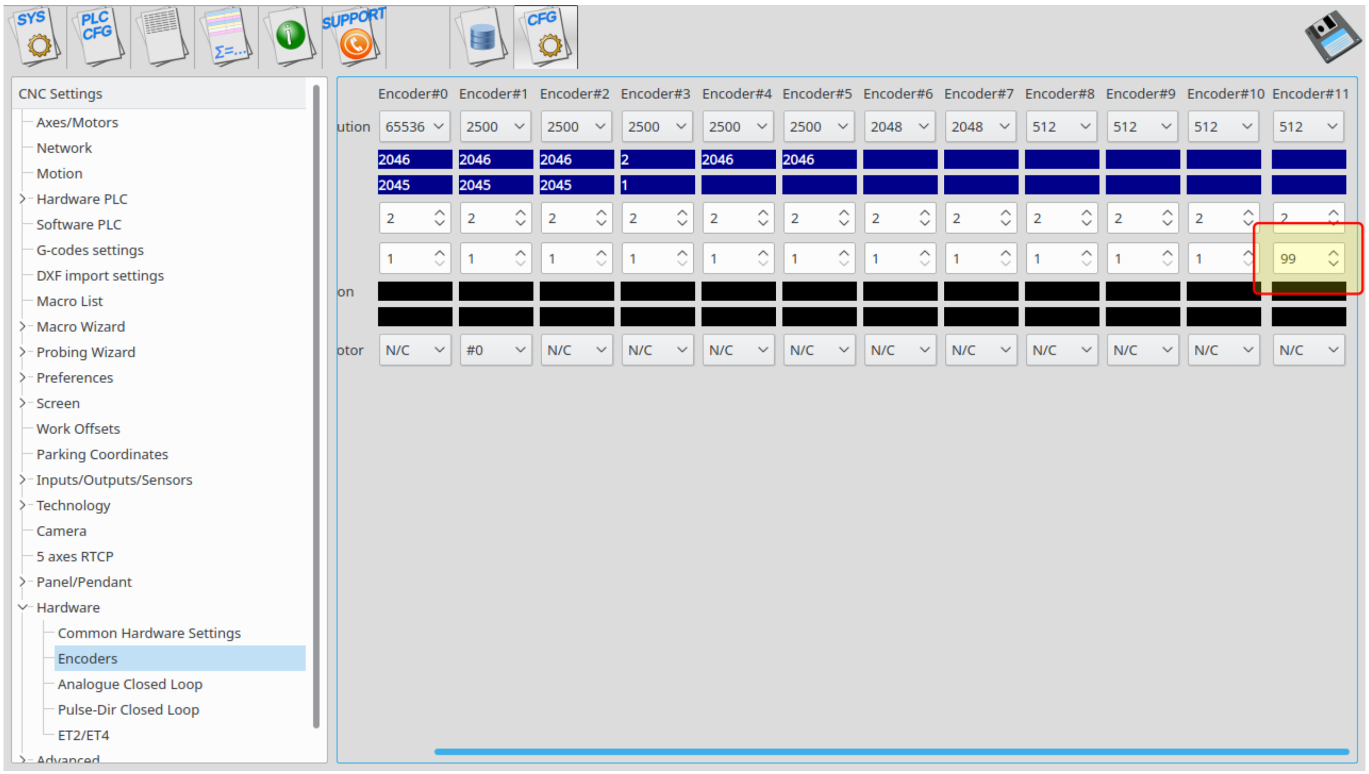
```
main()
 {
  gvarset(60000,1);  //turn Servo PIDs On
  exit(99);
 };
```

__HANDLER_EXIT.PLC

```
main()
 {
  gvarset(60001,1);  //turn Servo PIDs Off
  exit(99);
 };
```

Analogue -10V/+10V outputs Test Mode

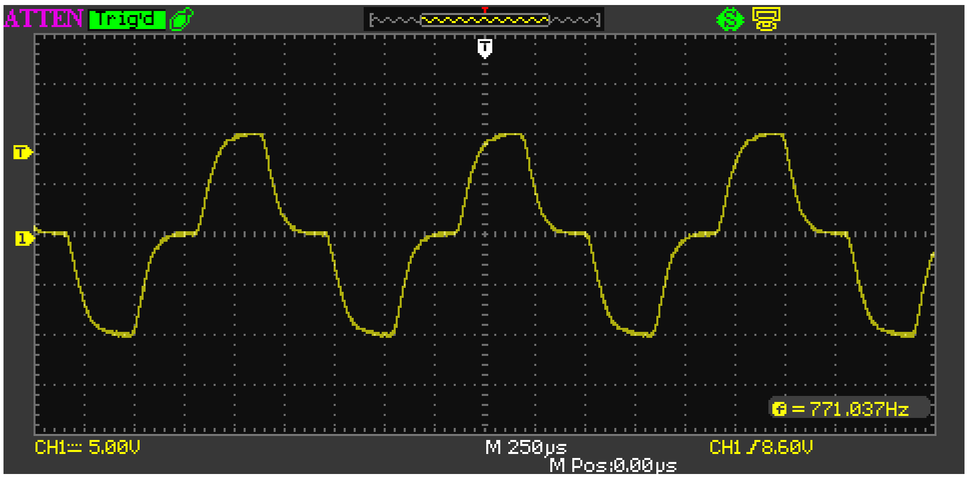
To test DAC outputs voltage range, rising/falling edges timings **DAC Test mode** is used. DAC Test mode is activated if in **Hardware→Encoders** configuration dialog, **/(2^Div)** line for **Encoder#11** column set “99” value and press “Save” button.



CNC Settings
- Axes/Motors
- Network
- Motion
- Hardware PLC
- Software PLC
- G-codes settings
- DXF import settings
- Macro List
- Macro Wizard
- Probing Wizard
- Preferences
- Screen
- Work Offsets
- Parking Coordinates
- Inputs/Outputs/Sensors
- Technology
- Camera
- 5 axes RTCP
- Panel/Pendant
- Hardware
  - Common Hardware Settings
  - Encoders
  - Analogue Closed Loop
  - Pulse-Dir Closed Loop
  - ET2/ET4
- Advanced

	Encoder#0	Encoder#1	Encoder#2	Encoder#3	Encoder#4	Encoder#5	Encoder#6	Encoder#7	Encoder#8	Encoder#9	Encoder#10	Encoder#11
ution	65536	2500	2500	2500	2500	2500	2048	2048	512	512	512	512
	2046	2046	2046	2	2046	2046						
	2045	2045	2045	1								
	2	2	2	2	2	2	2	2	2	2	2	2
	1	1	1	1	1	1	1	1	1	1	1	99
on												
otor	N/C	#0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C

In DAC Test mode all DAC outputs generate **Zero** » **MAX** » **Zero** » **MIN** sequence with frequency about 700Hz. Scope screen example is shown below.



```
Value "99" should be used for DAC test mode ONLY!
For working mode any other value from "1" to "90" should be used in
"/(2^Div)" line for "Encoder#11".
```

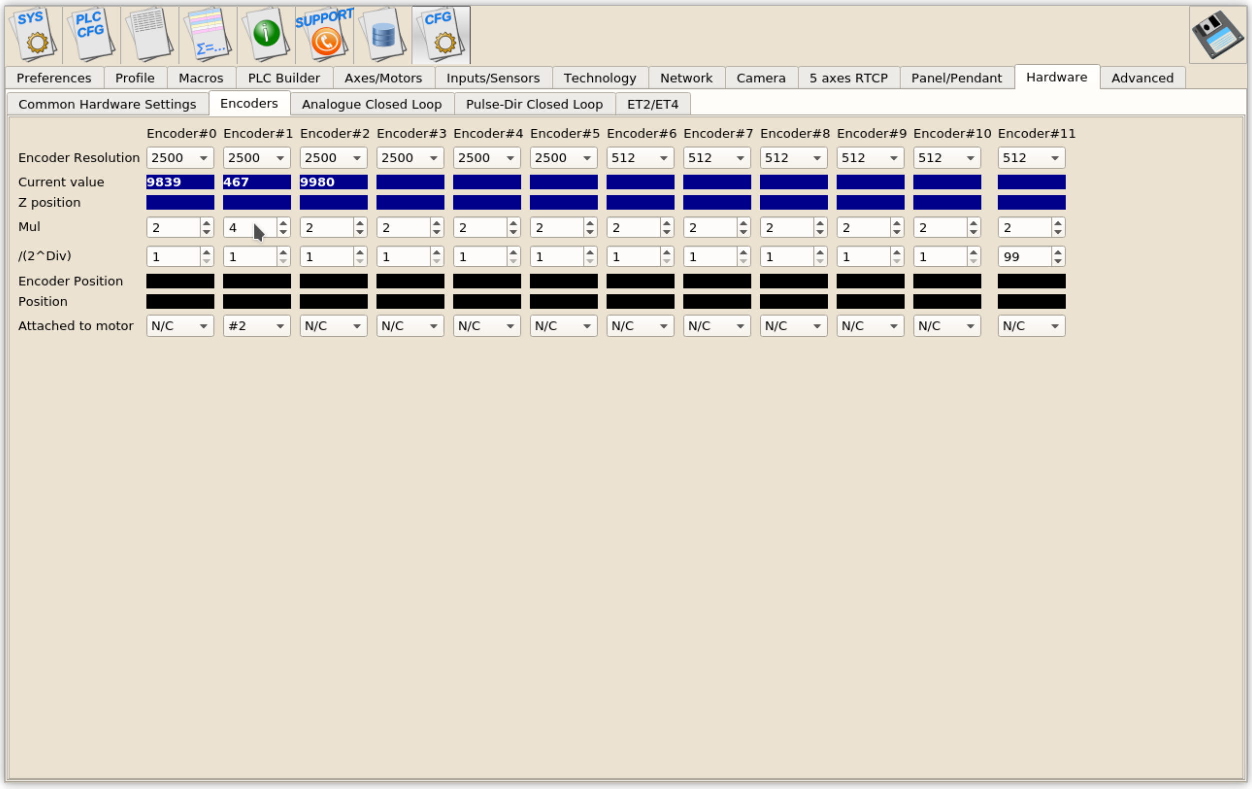
Analogue -10V..+10V/Incremental encoder closed-loop setup

1. Goto **Encoders** settings tab.
   1. Setup **Encoder resolution** for All Encoders used.
   2. Set Multiplication ratio **Mul** to "2" for all the Encoders.
   3. Set Divider **/(2^Div)** to "1" for all the Encoders. Result Ratio willl be 2/(2^1)=1
   4. Setup **Attached to motor** for all Encoders used.

Pulse-Dir/Incremental Encoder closed-loop setup

Example: Let's use Motor output #2 (configured as axis X) and Encoder #1 to build closed-loop PID control.

1. Goto **Encoders** settings tab. If rotary encoder is used as a feedback - setup **Encoder resolution** for Encoder #1. For linear encoder set resolution **2500**.

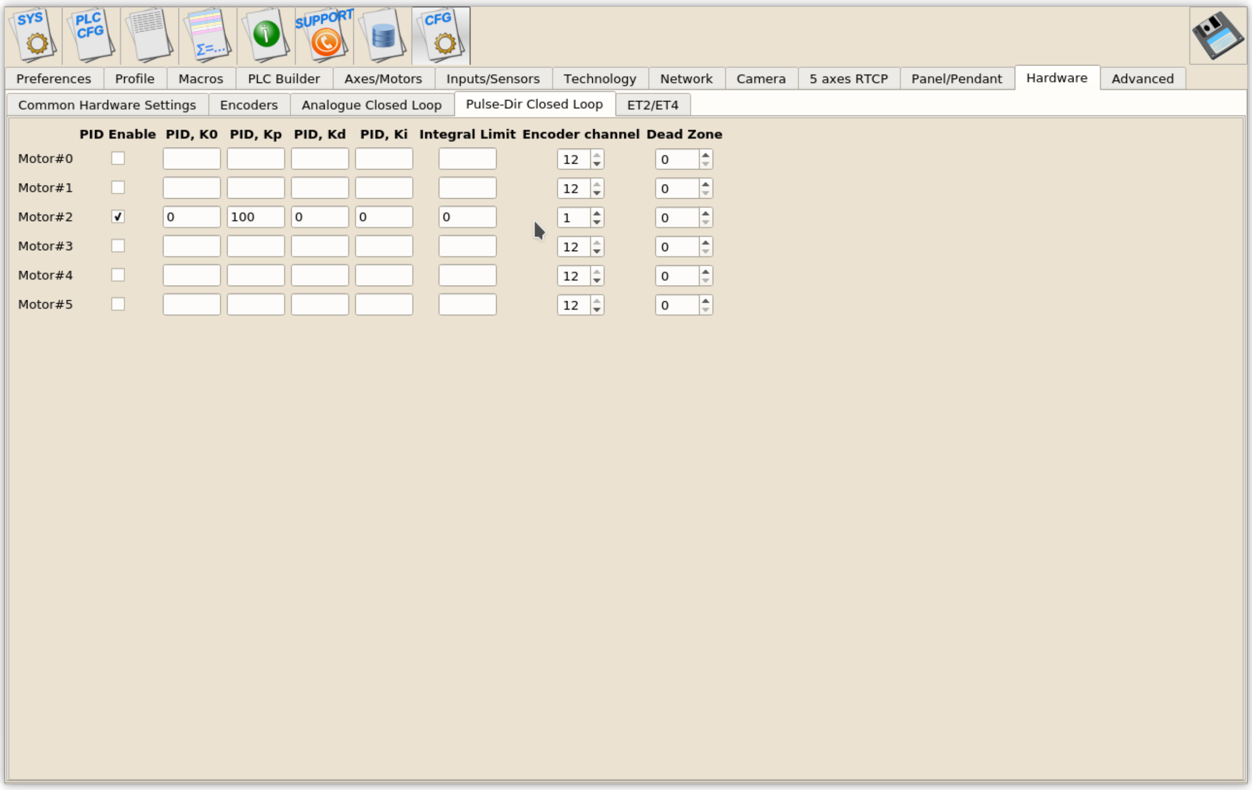


	Encoder#0	Encoder#1	Encoder#2	Encoder#3	Encoder#4	Encoder#5	Encoder#6	Encoder#7	Encoder#8	Encoder#9	Encoder#10	Encoder#11
Encoder Resolution	2500	2500	2500	2500	2500	2500	512	512	512	512	512	512
Current value	9839	467	9980									
Z position												
Mul	2	4	2	2	2	2	2	2	2	2	2	2
/(2^Div)	1	1	1	1	1	1	1	1	1	1	1	99
Encoder Position												
Position												
Attached to motor	N/C	#2	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C

2. Set **Mul** and **/(2^Div)** ratios to get result Encoder resolution equal to **Pulses-per-Unit** resolution. For example

```
Servo driver with 2500 pulses per revolution,
Electronic gears "1" and ball screw 5mm are used.
Linear encoder with 1um resolution used as a feedback.
=>((A)) Pulses per unit value is (2500*4)/5=2000 pulses per mm
Original Linear encoder resolution (1um) is 1000 pulses per mm, need to
set
multiplier to "4" and divider to "1" to get result ratio
4/(2^1)=4/2=2 and
=> result Encoder resolution is 1000* 4/(2^1)=2000 pulses per mm (which
is equal to ((A))
```

3. Set **Attached to motor** to “#2”
4. Goto **Pulse-Dir Closed Loop** ang setup PID parameters for PID attached to Motor#2.



	PID Enable	PID, K0	PID, Kp	PID, Kd	PID, Ki	Integral Limit	Encoder channel	Dead Zone
Motor#0	☐						12	0
Motor#1	☐						12	0
Motor#2	✓	0	100	0	0	0	1	0
Motor#3	☐						12	0
Motor#4	☐						12	0
Motor#5	☐						12	0

The most important parameters are

1. PID proportional ratio Kp
2. PID integral ratio Ki
3. PID integral limit. An integral value will be limited by given value.
4. Encoder channel used as PID feedback