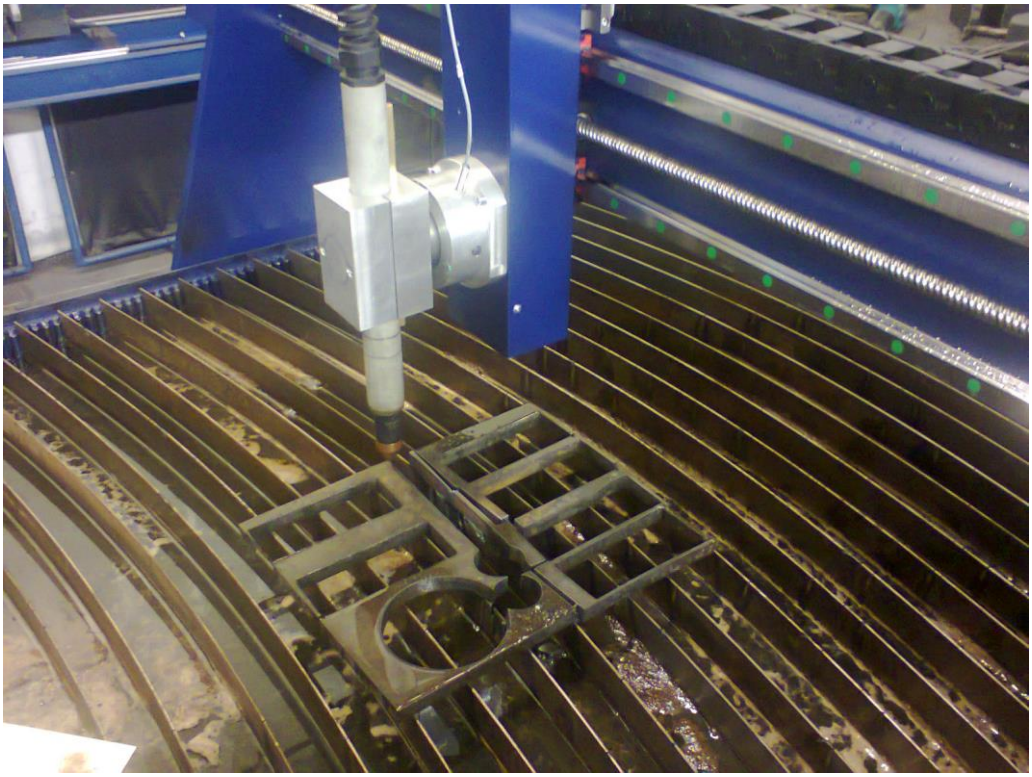
USBCNC PLASMA CONTROL with iCNC600 or External device (Proma)

PLASMA USERMANUAL



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Document History

Version	Date	Author	Comment
0.1	15-01-2012	B. Eding	Initial version for the iCNC600 CPU
1.1	16-08-2017	B. Eding	Added possibility to use PROMA device with all CPU5 variants
1.2	17-02-2018	B. Eding	Updated cutting sequence chapter 1.3
1.3	2-4-2018	B. Eding	Update control parameters chapter 2.4.5.

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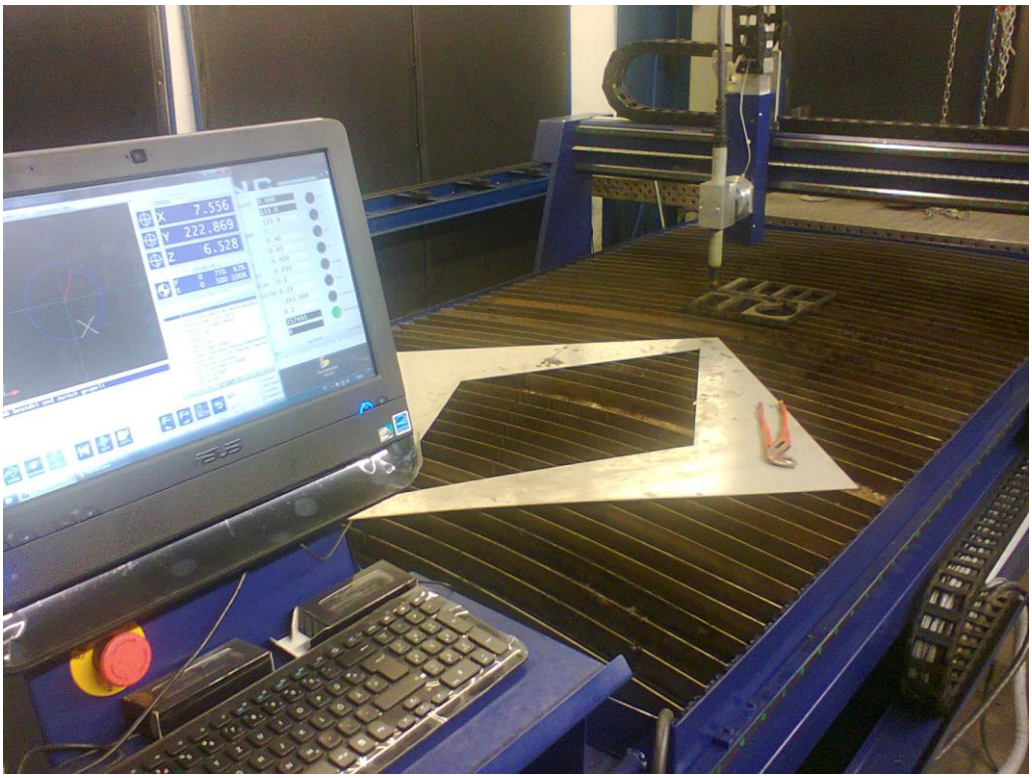
1 Introduction

1.1 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

THC	Torch Height Control
CNC	Computerized Numerical Control
CPU	Central Processor Unit, a PCB board with a Processor on it, the signals to the machine are connected to this board.
DXF	Drawing Exchange Format) is a CAD data file format developed by Autodesk
FIFO	First In First Out Buffer
HPGL	Hewlet Packard Graphical Language
GUI/UI	Graphical User Interface
INTERPRETER	A software function that is able to read a text file and execute the commands contained therein.
JOBFILE	A *job* is the text file (G code) that will be executed by the interpreter.
GUI	Graphical User Interface.
PWM	Pulse Width Modulation
G-Code	CNC specific language to control the movements and IO of a milling machine.
LAF	Look Ahead Feed, advanced motion algorithm that ensures minimal machining time.

1.2 CONTEXT AND SCOPE



http://www.maschinen-werkzeuge.com/

Hyperterm powermax 105

1.3 THE CUTTING SEQUENCE.

```
1.   G0 Z20 ;Go to safe height.

2.   M20 in the g-code or switch THC on in the UI before start.

3.   G0 X.. Y.. to Move to start position for pierce/cut.

4.   Optionally, use a touch sequence to set Z position:
     g91 g38.2 F100 Z-40 ;Move 40mm incremental down touch the plate
     g90 G0 Z#5063       ;Little up to exact touch point
     G92 Z0              ;Set Z zero at is plate height


5.   G0 Z6          ;To piercing height
     M3             ;Switch plasma on.
6.   G4 P2          ;Delay pierce delay [2 seconds] to allow piercing.
7.   G1 F100 Z4     ;to Move Z down (torch) to cutting height.
8.   G1/G2/G3 F..  ;make the cut.

     After MEAS DELAY, the THC is started automatically.
     Voltage Set point for THC is either automatic of given in the
     GUI.

9.   M5 at the end of a cut, to switch the plasma off.

10.  G0 Z20 ;Go to safe height for next cut and repeat 3 (optionally
     4. and 5. 6. 7. Until all cuts are completed.

11.  M21 ;THC Off, can also be done in the UI.
     M30 ;PLASMA off
```

Do not use this sequence unthinkingly, know what you are doing!

1.4 EDING CNC SUPPORTS 2 TYPES OF THC

EdingCNC supports 2 types of THC, 1. Integrated Fully proportional (iCNC600 only and 2. External Z-Up Z-Down using a device like PROMA Compact THC 150. (All CPU's).

2 Integrated Torch Height Control (iCNC600)

Fully integrated proportional THC control with adaptive Z axis velocity by measuring the PLASMA ARC voltage and a software PID control algorithm which moves the Z to keep the measured voltage Equal to the given set-point. This gives the best dynamics.
It is possible only by our iCNC600 board because this has an isolated analog input that is fully adjustable.

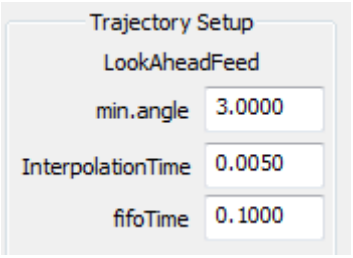
2.1 INTERFACE ICNC600 – PLASMA SYSTEM

ICNC600 Connection	Plasma Source connection e.g. Hyperterm
Analog in 5 (J9 Pin 7)	Connect to output of 1:50 voltage divider
GND (J9 Pin 8)	Idem (GND)
TOOL OUT 24V (J11 Pin 1)	Connect to PLASMA ON Relay coil
TOOL OUT GND (J11 Pin 2)	GND
AUX IN 1 24V (J5 pin 3)	Plasma is on feedback from plasma equipment.
AUX IN 1 GND (J5 Pin 5)	GND

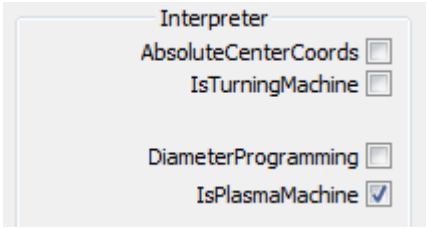
Note that the analog input of the iCNC600 CPU is in the range of 0-10V, the plasma Arc voltage however is much higher and can be up to 300V and during ignition even above 1000V.
Therefore an 1:50 voltage divider special made for Plasma equipment is required. It can usually be obtained from the Plasma equipment supplier, or is already integrated in the Plasma equipment.

The plasma is on is an output from the plasma source to an input of the CPU indicating that the plasma is ON. This input is optional.

2.2 PARAMETERS IN THE SETUP



First Setup Page



2nd Setup Page

Type of Machine set to Plasma Machine.
fifoTime changed from 0.25 to 0.1 for better dynamic, requires a Faster PC, minimum Duo Core and > 2GHz processor.

2.3 PARAMETERS INSIDE CNC.INI FILE

Plasma configuration parameters in the cnc.ini file can be entered if the software is not running. It can be done using the Windows Notepad editor, or the external Notepad++ which is Free to down.

The first alinea of settings is for external control with a PROMA like device. For the integrated control leave `useExternalUpDownControl = 0`

```
[PLASMA]
;Set next parameters if an external controller is used with up/down
outputs
useExternalUpDownControl = 0
externalUpDownVelocity = 0.000000
;Select the inputs to be used for up/down control below, 1-8:AUX1-
AUX8, 51-56:HOME1 - HOME 6
plasmaExternalZDownInputPortID = 0
plasmaExternalZUPInputPortID = 0

;Next parameters are used for both external THC and Internal THC
plasmaIsOnInputPortID = 0
zMax = 0.000000
zMin = -140.000000
controlDelay = 0.100000
cornerFeedFactor = 0.250000
allowTHCWithoutPlasmaMachine = 0
allowTHCWithoutM3M4 = 0

;Next parameters are used only for Internal THC
plasmaAnalogInputPortID = 5
adcOffset = 60.000000
adcMulFactor = 0.140000
defaultSetPointVoltage = 135.000000
KPUp = 0.600000
KPDown = 0.600000
KD = 0.050000
deadBand = 0.500000
filterTime = 0.050000
holeDetectVoltage = 25.000000
holeDetectTime = 0.100000
measuredIsSetpoint = 0
```

The **adcOffset** and **adcMulfactor** determine the relationship between the input voltage read by the processor and the arc voltage. The **adcOffset** value of 60 resembles the arc voltage where the analog input read is zero. The **adcMulFactor** is calculated by dividing the range through 1000, in this case, the range 60-200 = 140, so the **adcMulFcator** = 140/1000 = 0.14.

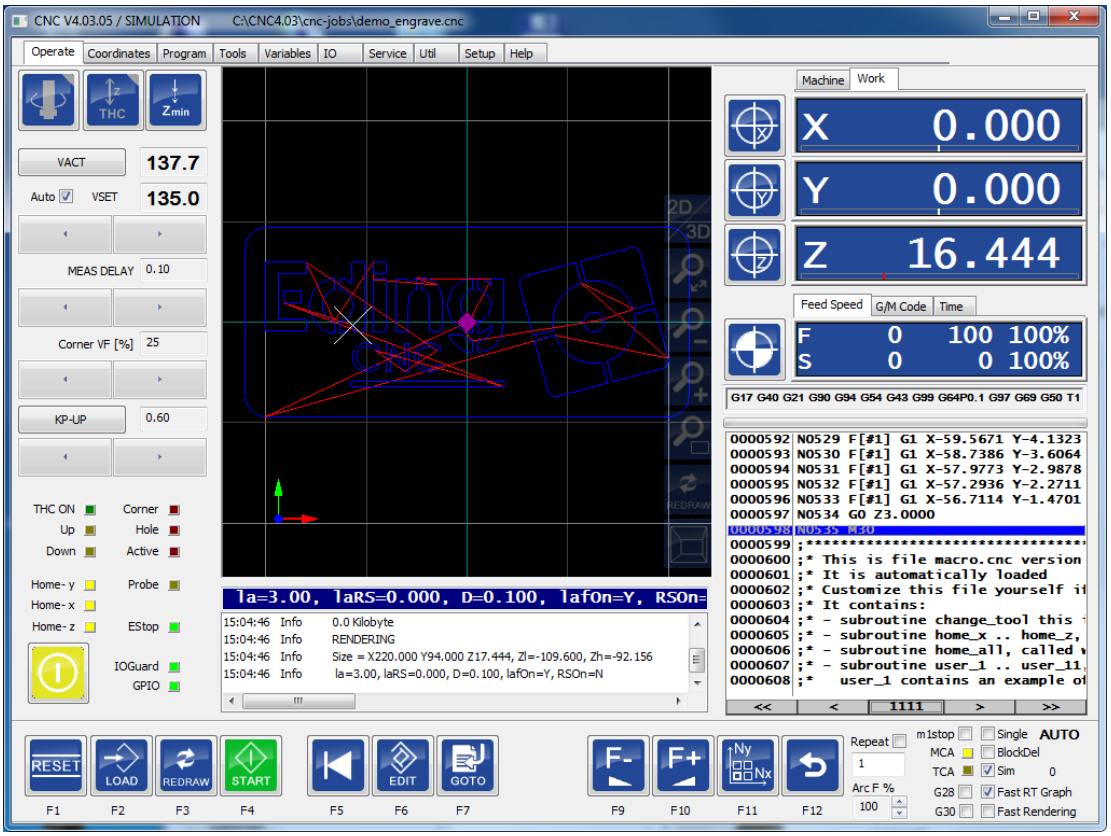
This sets ARC voltage working range between 60Volt and 200 Volt

See also the iCNC600 user manual for setting up the ADC input if changes are wanted.

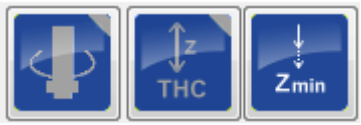
Other parameters that influence the dynamic of the THC is the FIFO time, it is standard set on 250 in the setup. By lowering this value, the dynamic behavior is improved. This requires A fast PC
The value can usually be lowered to 0.1 Sec without problems. If the error FIFO UNDERRUN occurs or COMMUNICATION LOST error, the FIFO time is set too low. So some experimenting here is needed.

2.4 PLASMA USER INTERFACE

When plasma machine is set, a different left panel is shown, see below:



2.4.1 At the top we see 3 buttons:



- Spindle ON/OFF (PLASMA) : Switches the plasma ON/OFF
- THC ON/OFF, switches the THC system ON/OFF.
- Define Z min, takes current Z position and define that as minimum for the THC, THC will not go lower. It is displayed also in the Z readout gauge in RED.

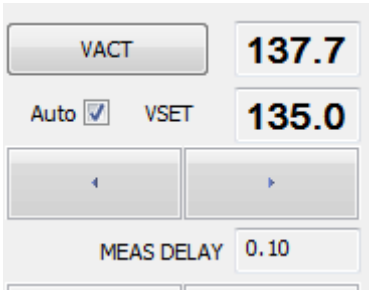
2.4.2 The LEDs

THC ON : LED is ON when THC function is on.
UP: Z is moving UP
Down: Z is moving down
Corner: Corner protect active
Hole: Hole Detect active
Active: On when control is active

The THC is active when several conditions are met:

- THC function is switch on
- Spindle (PLASMA) is ON
- Move is G1, G2, G3 without Z
- Corner protect is not active
- Hole detect is not active.

2.4.3 VACT and VSET:

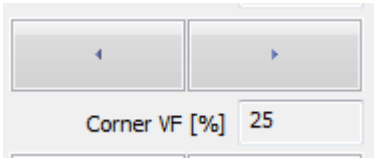


By Pressing the button shown VACT here, following variables of the controller can be shown:

- **VACT**: Actual plasma voltage
- **VDIFF**: Difference between Actual
- **CTROUT**: Output of the THC controller the speed for the Z axis.

- **Auto**, when switched on a measurement will take place at the beginning off the cutting sequence. After the **MEAS DELAY** time, the voltage is measured and set at set point. This is performed once for a job. So the user does not need to enter a Voltage set point, only set correct Z height
- **VSET** shows the actual Voltage set point for the THC controller.
- **MEAS delay**: Sets the delay for automatic measurement and control on. When a cutting move starts, this delay is used before the controller is switched on and the measurement is taken.

2.4.4 Corner protection



The Corner VF setting is needed to prevent the torch from diving down at corners.
At corners the actual Feed becomes lower, because of this the Plasma voltage gets higher and the THC will start moving the Z DOWN. This is not wanted. So when the Feed is lower than specified percentage here, the THC control will temporarily be disabled, the Z axis will remain at same height.

2.4.5 Controller parameter settings and tuning guidelines

The THC is in fact a standard PID controller, we have removed the because it is not useful in the application. Remaining is PD proportional and Differential.
With these parameters we control the behavior of the controller.

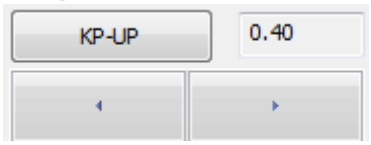
For tuning the parameters KP and KD use a test cutting movement of a bended piece of material about 200 mm in length. Use realistic bends and start wit a low FEED for testing, e.g. F1500. Perform the cutting and check the Z axis behavior, adjust parameters and repeat this until satisfied.

Basic Control Theory and PID tuning skills are required here.
If you don't have these skills, educate yourself. A good starting point for the theory is:
https://en.wikipedia.org/wiki/PID_controller

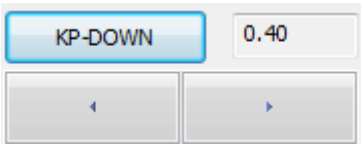
Default parameters

FIFO TIME	KP (UP/DOWN)	KD	DEAD-BAND	FILTER-TIME	HOLE D. V	HOLE DETECT-VOLT
0.2 (standard)	0.3	0.04	0.5	0.05	25	100
0.1	0.6	0.02	0.5	0.05	25	100

2.4.5.1 KP



Press the button showing KP-UP now to go to the next parameter.

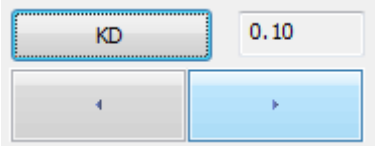


Standard the KP parameter is shown, this controls the THC control speed. When too low, the Z axis will follow too slow. When too high, the Z axis will start oscillating.
Find the optimal value where there is just no oscillation.

There are 2 KP values, one for moving UP and one for moving down. We have made this because experience learns that that the behavior of the system is different moving up or down.

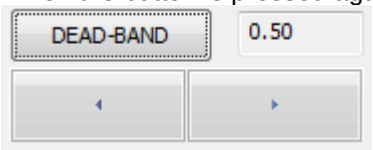
2.4.5.2 KD

When the button shown KP is pressed we will see KD, this is the differential K factor for the control loop. It makes the dynamic better, but it easily makes the control loop oscillate. Start with low values and increase very little every try.



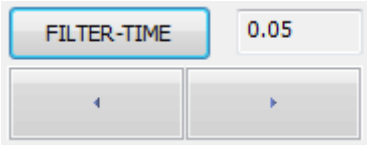
2.4.5.3 DEADBAND

When the button is pressed again we see the DEADBAND parameter.



When VACT-VSET is lower than this value, the controller does nothing, it prevents limit cycling, going up down continuously when not needed.

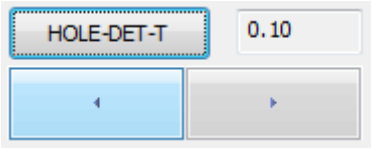
2.4.5.4 SPIKE FILTER



Next parameter is FILTER-TIME
This is the time of our spike filter, spikes are filtered as well sudden voltage increases when going over a part where there is already cut.
Suppose we are moving with F3000, and our cutting width is 2 mm.
F3000 = 50 mm/sec or 2 millimeter takes 0.40 sec. The filter time should be bigger than 0.04 to filter this spike away. Be Aware, the filter influences the control speed negatively.

2.4.5.5 HOLE DETECT

When we go over a hole or when we pass the end of the plate, then the plasma voltage will suddenly rise a lot. When we would do nothing the controller will make the Z move downwards, fast and cause collision. The prevent this we have the hole detection that needs 2 parameters.



When the voltage difference Vact - Vset is more than the HOLE-DETECT-VOLTAGE and longer than the HOLE-DETECT-TIME, the controller will stop controlling.

2.4.5.6 TRACING FOR CHECKING THE PID BEHAVIOR

For test purpose an extra parameter is added, LOG AN INPUT VAL, this value can be 0 or 1. When set to 1, the values of the analog value are logged to a file for investing. The file is made in the CNC4.01 director and gas this format: ANALOG-MM-DD-YYYY-HH-MM-SS.txt. The tracing performs its function during 1 run, then it is switched off automatically, so you need to switch it on again for every run you want to use it.
It can be easily shown with GNUPLOT, like this.

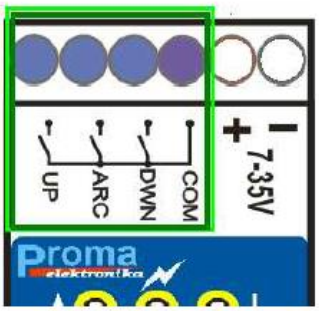
Start GNUPLOT:
In the console type e.g.

gnuplot> cd c:\CNC4.03
gnuplot> 'ANALOG-30-1-2017--21-3-32.txt' u 1:2 w l
It means to plot the data in the file of Column 1 as X and Column 2 as Y with lines connected.
This is the result of random changing the analog input:

3 External Z-UP and Z-Down Control (PROMA)

This is the **cheaper** solution and is possible will all CPU5/7 series, as example we will document the CPU5A4E in combination with the PROMA Compact 150 device.

3.1 INTERFACE CPU5A4E - PROMA DEVICE:



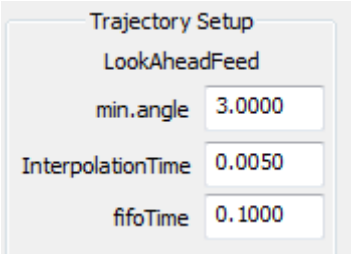
In this case the external device measures the plasma arc voltage and generates Z-UP and Z-DOWN signals to the CNC controller. Dynamics will be less than with the integrated solution because the Z speed is constant. It is still be good usable and it is the cheapest way.

The CPU5A has no free general purpose inputs, we use a little trick here that allows us to use the Home inputs.

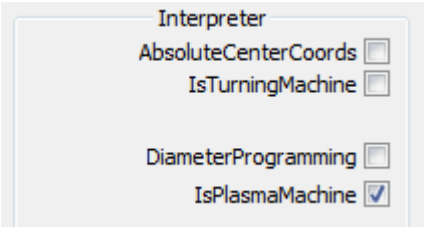
- In the set-up we set Use Only Home X for all axes. In our machine we have to connect all home switches parallel and connect them to the 1st HOME input.
- The 3 other homes for Y,Z,A are now free and we will use those for connecting Z-Up, Z-Down and PlasmaIsOn.

CPU Connection	**Plasma Source connection e.g. Hyperterm**
Z-Up, use any free input of the CPU We use HOME-2 now on CPU5A4E	Connect to UP output of the PROMA
GND	Connect to COM (Common) of PROMA
Z-Down, use any free input of the CPU We use HOME-3 now on CPU5A4E.	Connect to DWN output of the PROMA
GND	Connect to COM (Common) of PROMA
Plasma Is On, use any free input of the CPU We use HOME-4 now on CPU5A4E.	Connect to ARC output of the PROMA
GND	Connect to COM (Common) of PROMA
TOOL OUT	Connect to PLASMA ON of Plasma equipment. Check in the CPU manual how to connect a relay if a relay is needed.

3.2 PARAMETERS IN THE SETUP



First Setup Page



2nd Setup Page

Type of Machine set to Plasma Machine.
fifoTime changed from 0.25 to 0.1 for better dynamic, requires a Faster PC, minimum Duo Core and > 2GHz processor.

3.3 PARAMETERS INSIDE CNC.INI FILE

Plasma configuration parameters in the cnc.ini file can be entered if the software is not running. It can be done using the Windows Notepad editor, or the external Notepad++ which is Free to down.

The first and second alinea of settings is for external control with a PROMA like device. For the PROMA device set `useExternalUpDownControl = 1`

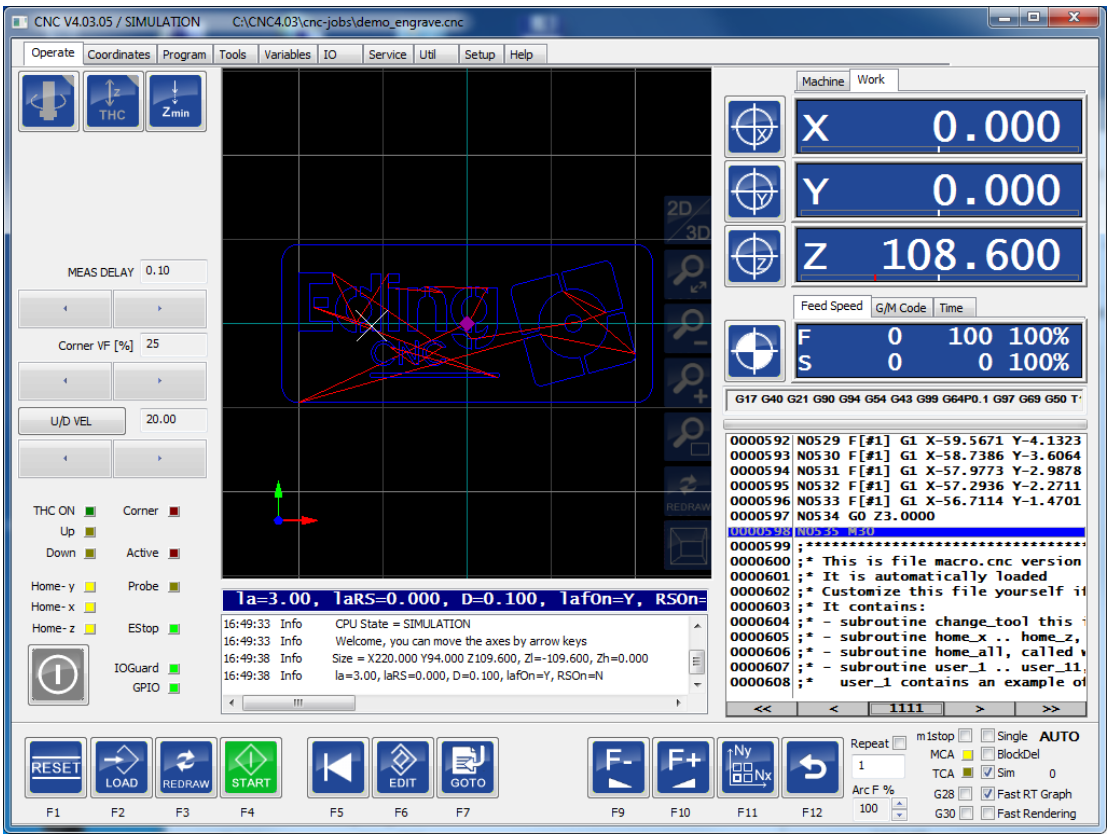
```
[PLASMA]
;Set next parameters if and external controller is used with up/down
outputs
useExternalUpDownControl = 1
externalUpDownVelocity = 20.000000
;Select the inputs to be used for up/down control below, 1-8:AUX1-
AUX8, 51-56:HOME1 - HOME 6
plasmaExternalZDownInputPortID = 52
plasmaExternalZUPInputPortID = 53

;Next parameters are used for both external THC and Internal THC
plasmaIsOnInputPortID = 54
zMax = 0.000000
zMin = -140.000000
controlDelay = 0.100000
cornerFeedFactor = 0.250000
allowTHCWithoutPlasmaMachine = 0
allowTHCWithoutM3M4 = 0
```

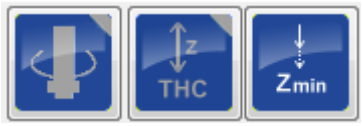
Other parameters that influence the dynamic of the THC is the FIFO time, it is standard set on 250 in the setup. By lowering this value, the dynamic behavior is improved. This requires A fast PC, minimum duo core and > 2 GHz processor.
The value can usually be lowered to 0.1 Sec without problems. If the error FIFO UNDERRUN occurs or COMMUNICATION LOST error, the FIFO time is set too low. So some experimenting here is needed.

3.4 PLASMA USER INTERFACE

When plasma machine and is set and useExternalUpDownControl = 1, a different left panel is shown, see below:



3.4.1 At the top we see 3 buttons:



- Spindle ON/OFF (PLASMA) : Switches the plasma ON/OFF
- THC ON/OFF, switches the THC system ON/OFF.
- Define Z min, takes current Z position and define that as minimum for the THC, THC will not go lower. It is displayed also in the Z readout gauge in RED.

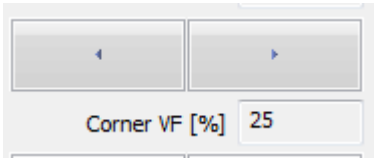
3.4.2 The LEDs

THC ON : LED is ON when THC function is on.
UP: Z is moving UP
Down: Z is moving down
Corner: Corner protect active
Active: On when control is active

The THC is active when several conditions are met:

- THC function is switch on
- Spindle (PLASMA) is ON
- Move is G1, G2, G3 without Z
- Corner protect is not active

3.4.3 Corner protection



The Corner VF setting is needed to prevent the torch from diving down at corners.
At corners the actual Feed becomes lower, because of this the Plasma voltage gets higher and the THC will start moving the Z DOWN. This is not wanted. So when the Feed is lower than specified percentage here, the THC control will temporarily be disabled, the Z axis will remain at same height.

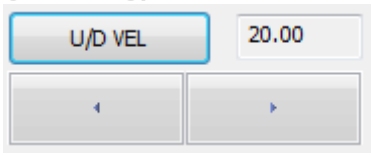
3.4.4 Controller parameter settings

There is only one parameter for this type of THC.

Default parameters

U/D VEL (UP/DOWN)
20

3.4.4.1 U/D VEL



The velocity used when the external device activates the Z-Up or Z-Down input.