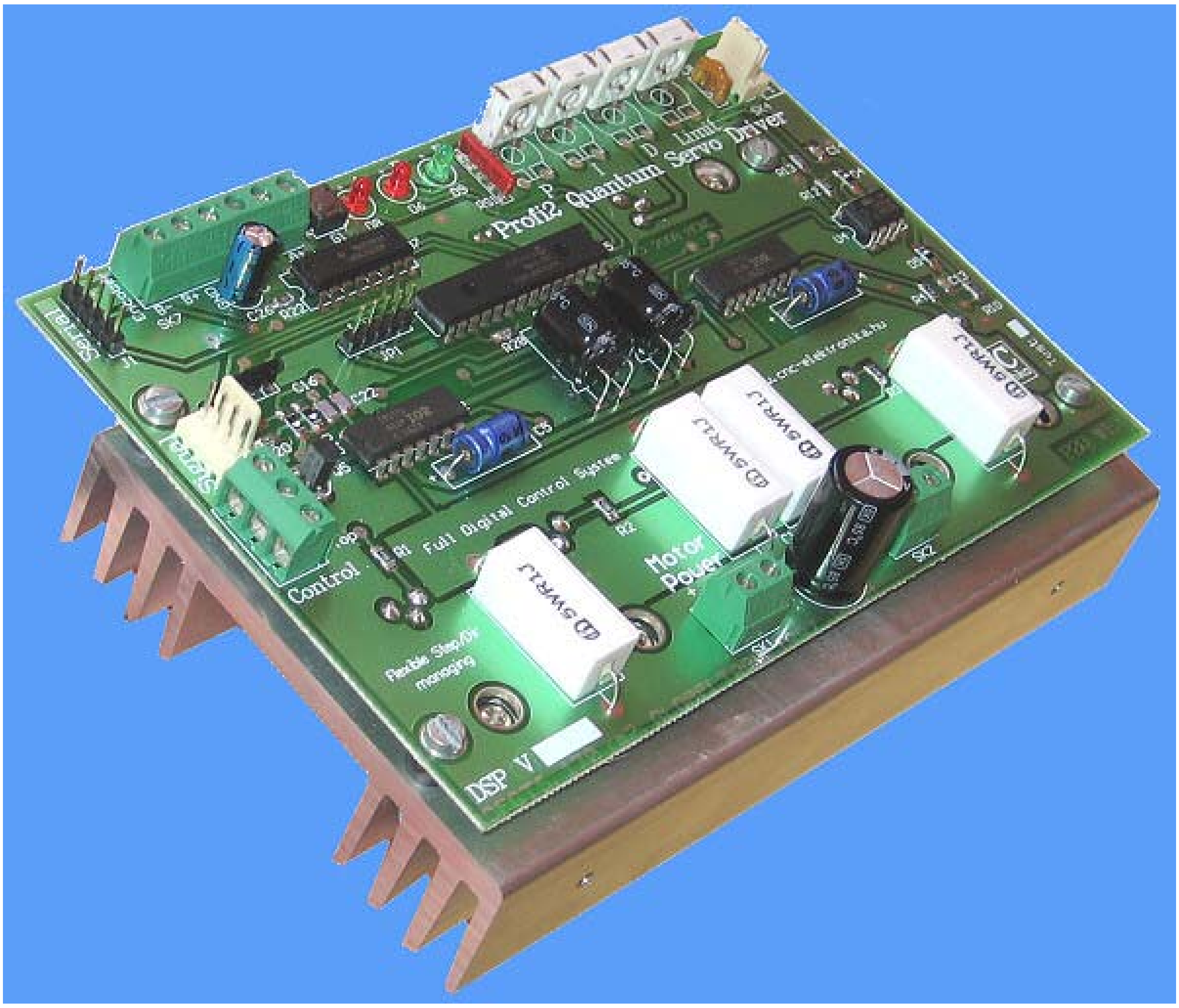
Profi2 Quantum DC Servo Controller

(Digital servo controller for DC motors with carbon brushes)



Order number: #171

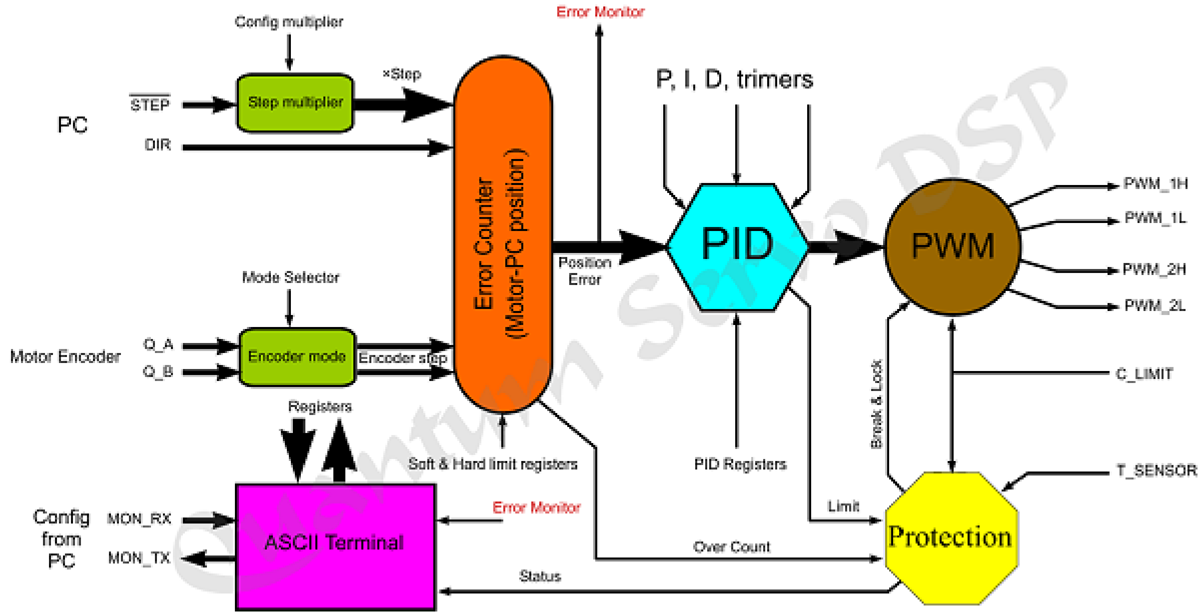
Profi2Q CNC Digital Servo Controller is capable to control DC servo motors with carbon brushes. It is suitable for both hobby-type and half-professional CNC applications. P2Q use QDSP IC, is a circuit, which is a high-speed, flexible, easy to use device, based upon dsPIC30F4012 microcontroller, for building servo controllers. The field of its application is first of all moving controllers of CNC-s, or performing any kind of regulation task demanding high precision and speed. During its the most optimal fit to the popular Mach CNC control programmes was a key issue.

Main features (V1.6.0):

- Step/Dir-system motor stepping inputs,
- Motor peak current limit 0.1- 26A,
- Continuous Power: 400W, max. 90V DC,
- Two-channel, symetric and assymetric incremental encoder inputs,
- Encoder processing: 2×, 4× modes,
- Programmable Encoder Digital Interference Filter (EDIF),
- Step signal multiplicator: 1× - 10× (step-multiplicator),
- Protection against motor overload: 1s - 7s (in a programmable way),
- Protection against overload of the controller (with readable temperature),
- Programmable integration time (95uS - 475 uS),
- Serial fine tuning (handling of the internal registers),
- Online error-level monitor (with ASCII or binary communication),
- Online PWM limit monitor in ASCII form,
- Error-level peakindicator (with ASCII 3s datalogger),
- Full PID motorcontroller algorhytm,
- Analogue P, I, D parameter-adjustment by potentiometer trimmers,
- Reduction of motor vibration,
- DSP performance: 120MHz, 30 MIPS, 16bit CPU, 40bit ALU,
- Full H-bridge control (with PWM and motor-brake modes),
- 16 bit PWM,
- Current limiting input,
- Adjustable Soft Error Limit buffer (1 - 200 Steps),
- Adjustable Hard Error Limit buffer (1 - 30000 Steps),
- Bandwith values:
  Encoder signal frequency: max. 6MHz,
  Step signal frequency: max. 1 MHz,
- Double Status signals by LEDs,
- Thermometer sensore,
- Error indication output (Fault),
- Emergency stop input (Stop),
- Numerous writeable and readable configuration registers,
- Firmware upgrade possiblity through ICSP,
- installed cooling,
- 2-sided, partly SMD mounted PCB.

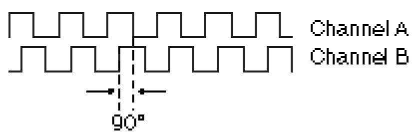
Please visit www.quantumservo.com !

Profi2Q CNC Servo Controller performs the servo control of DC motors with carbon brushes by the means of a 2-channel incremental encoder (symmetric or assymetric type). Because of the encoder-feedback a closed-loop position regulation is realised.
Unlike stepping motor controls, here a regulation takes place, - therefore in case of correct asdjustments - no steploss may occure. The control electronics uses a lot more information, therefore a more intelligent drive-method can be realized. The control (PID) forces the motor into the intended position (because of the encoder the control always has exact information), and if it is not possible (e.g. because of getting stuck), then this can be signalled to the PC, so the user can be notified about the error, and he can prevent the error even during work.

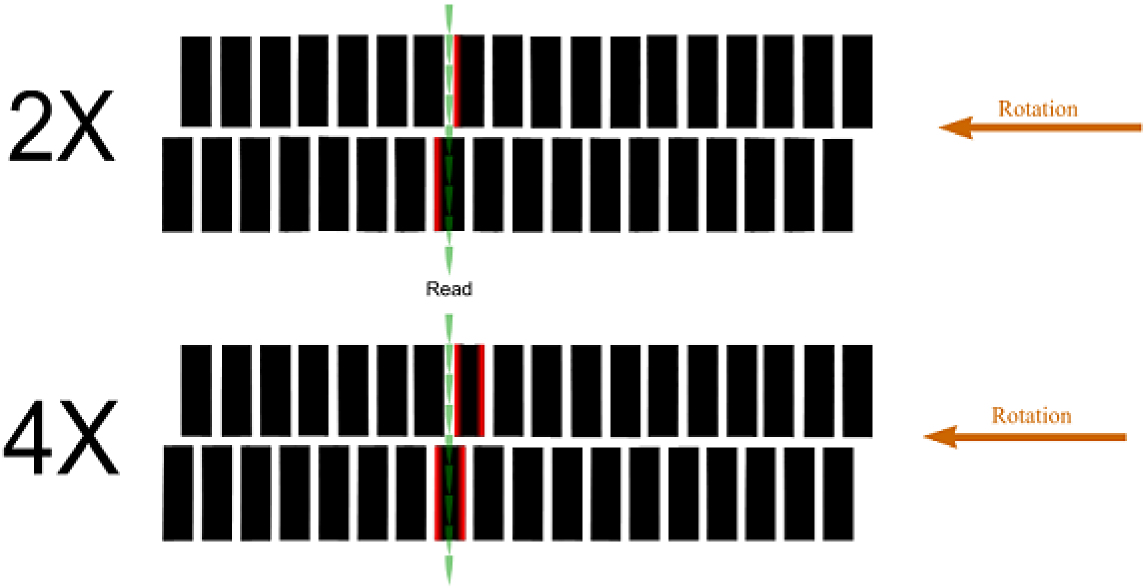


The computer makes the motor step through the Step/Dir inputs of P2Q. The Step signal is featured with negative logic (makes the motor step at falling edge). At each Step edge the QDSP makes its internal error counter step into the direction according to the Dír signal. The measure of the step is also influenced by the Step multiplier register. By this register the incoming Step pulses can be multiplied (1× -10×). It is needed so that motors equipped with high-resolution encoders can also be driven at reasonable revolving number even by CNC softwares able to output relatively low stepping frequencies. The step-multiplying reduces the resolution of the CNC machine, but it raises the available max. revolution number in return. The high encoder resolution ↔ max. speed conflict can be brought into an equilibrium state by this..

The mechanical fed-up is realised by the signals of the encoder mounted onto the motor. The encoder is realised by a light-passing disc, which contains dark dashes in two lines. The 2 lines are shifted to each-other. By the means of 2 optical photo-electric cells the two lines are read separately and the readouts are transformed into logical signals. By the phase position of the 2 signals the direction of the steps can be stated and the measure of the movement can be calculated from the number of steps.



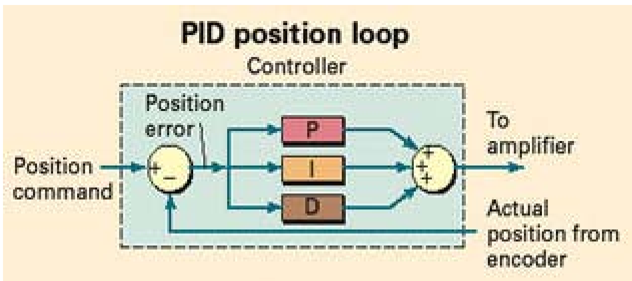
The P2Q can process the Encoder signals in 2 mode: 2× and 4× mode. These two modes influence the resolution that can be achieved by the same encoder.



In 2× mode the P2Q handles only the entering edge of the dashes (marked by red). In this case the base resolution of the encoder (PPR) is doubled.
In 4× mode the P2Q processes each edge of the dashes. In this case the base resolution of the encoder is quadruopled.

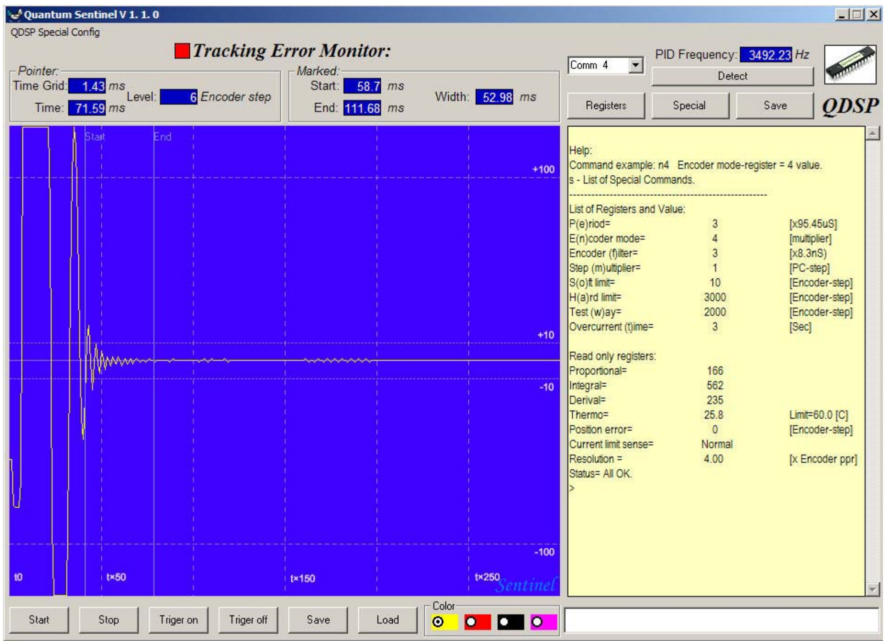
Recommended settings:
In case of 200-1000 PPR, 4×-mode,
above this range 2×-mode is preferred.

In a positionerror-free position the difference between the two signals is 0 (the dirrerence-counter stands at 0). The error signal comes from the difference of the two signals (counters) and their direction. This error signal can be read through the serial port (Serial). The error signal is the starting base for the complicated PID algorithm. The PID prepares the direction and PWM data for the bridge-controller.



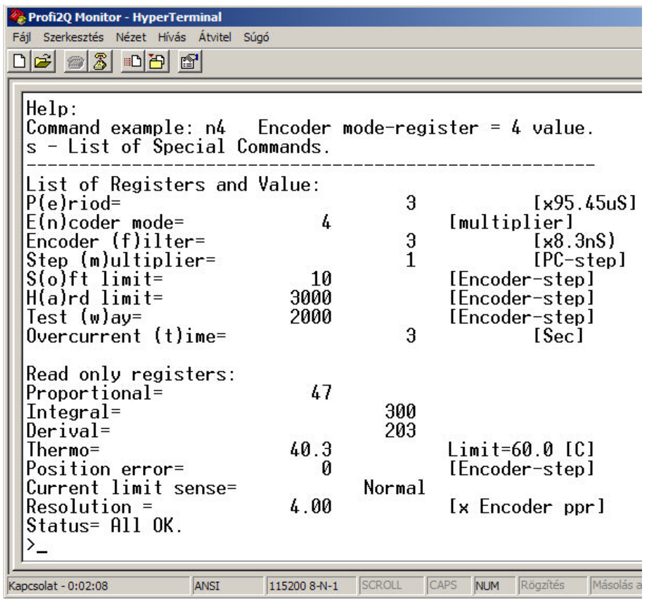
The adjustment of the more complex drive-method (PID) is more complicated that that of the stepping motor controller. During adjustment of the PID the tuning of the Controller to the unit of the given motor + mechanics takes place (a little bit even to the settings of the CNC control programme).
In case of these controllers the adjustment of the PID is supported by additional electronics and by special software, we can provide a portable, handheld, spectacular device. This can be purchased as an option. This device is Profi2Q Servo Monitor, which stores and presents the transients of the servo controller like a digital storage oscilloscope.

(Profi2Q Servo Monitor adapter, RS232C)



(P2Q Sentinel)

OR



(Usage through Hyperterminal)

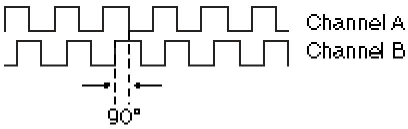
Applicable servo motors:

The motors intended to use must meet the following requirements:
must operate with a DC voltage lower than 90V,
must be a type with carbon brushes,
the nominal current consumption must lower than 26A,
the motor must be a servo-characteristic type (all the types equipped with an encoder meet this requirement),

In case of types without encoder the following should be checked:
Rotating their axis, it must rotate smoothly, without jerking. The types which jump into the positions are not suitable.

Requirements of Encoders:

They must have 2 two-phase, so-called incremental-type channels (channel A and B).



(incremental channels with a phase-shift of 90 degrees)

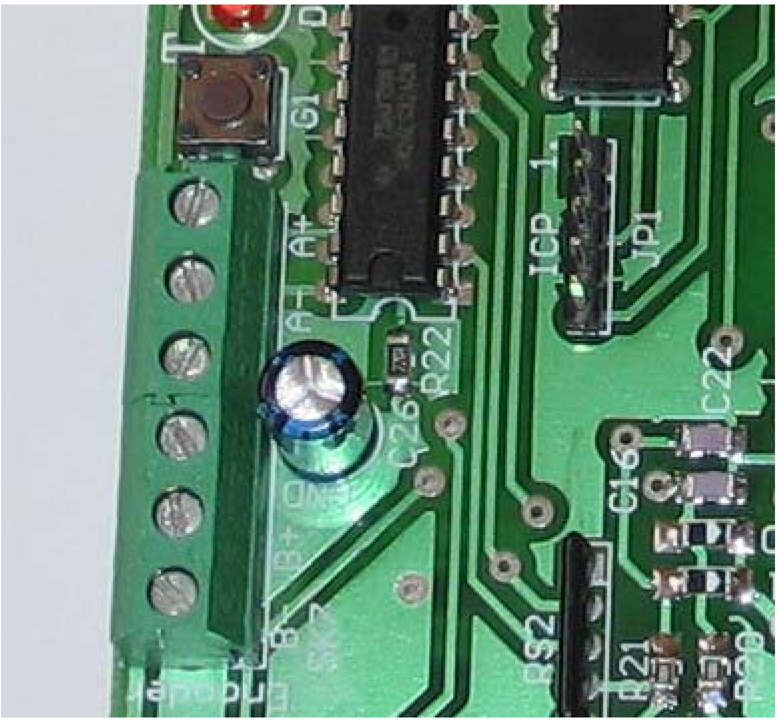
Between the square-wave signals of the 2 or 4 channels (A+, A-, B+, B- symmetrical or A, B assymetrical), - which are generated continuously during rotation of the axis, - there is a phase-shift of 90 degrees. From the relation of the 2 signals the rotating direction can be determined, from the number of pulses, the extent of the swing can be determined.
Many encoder have besides that plus channels (e.g. index), these are not used by the controller (they do not have to be connected).

If use only assymetrical encoder, then wired A+ and B+.

The electric signal levels of the channels must also be matched to the inputs of the controller. There are 2 types of the allowed signal levels:

1. TTL signal levels (with a signal level of +5V),
2. analogue, open collector trtansistor (OC*) outputs (the controller contains the internal 2k2 pull-up resistors and other signal forming parts).

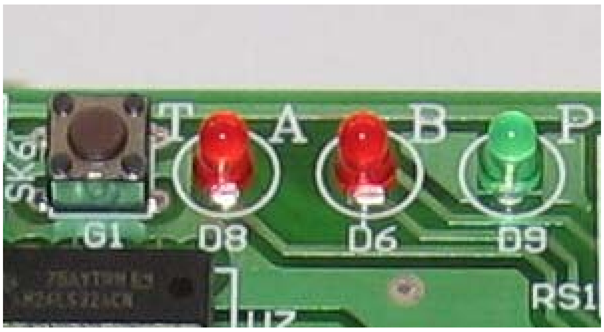
** OC= open collector (transistor output)*



(encoder inputs)

The resolution of the servo motor will be determined jointly by the resolution of the encoder and DSP setting of the controller. This resolution can be further modified by other mechanical gearing of the CNC machine and the programmable resolution (which is the smallest programmable displacement) of the machine will be determined by all the above mentioned things.

The two-level protection system of P2Q:



(LEDs)

1. Independent protection systems. In case of their operation they make the motor stop by motorbrake and prohibit DSP. They give LED ("A" and "B") indication, as well as text messages in the „Status" register. Their operation can only be stopped by restarting DSP. Each independent protection system generates an error signal on the FAULT output. By this signal the CNC control-software running on the PC (e.g. Mach3) can also be stopped.

- Overrun protection of Hard limit (Error*) register (its size can be adjusted):
If the error signal (Error*) exceeds the adjusted value, the DSP will stop the motor by motorbrake and prohibits its further operation.
It performs first of all protection against reverse encoder connection and seizure of the motor.

** Error register = error-level register, which measures the deviation between the required and actual mechanical positions in terms of Encoder steps. If there is no deviation, then its value is 0.*

- Overload-protection of the motor:
If the current-limiting of the motor is continually operating and its operating time exceeds the value of "Overcurrent time" register, then the protection stops the motor and prohibits its further operation.

- Overload-protection of the controller:
The temperature of the heatsink is continually measured by a thermo sensor and about at 60/80/100 °C it prohibits the further operation of DSP. It can be adjusted by Service code.

- Stop input active (low level). If it operates, it willmake the DSP prohibit.

2. Protection through the PC. This cannot stop the Controller in itself, it generates only an error level on the FAULT output. If this output is connected to one of the inputs of the PC and the controlling software is properly configured then this signal is able to stop the operation without pulse-loss. In certain conditions the work can be continued witout producing wastes after fixing the error.

- Overrun of the Soft limit (Error*) register. It also produces a signal on the "A" LED as long as this state remains. This signal is first of all to check whether the trace tracking is geometrically true. It continually monitores the synchronism of the motor and the CNC software. When this becomes bad, it stops operation and gives a signal. The Fault indication can be prohibited by service code.

- Motor Peak-current limiting:
The DSP continually checks the status of motor current, and if its level is high, the protection limits the PWM outputs. The fact of limiting is indicated by lighting the "B" LED. This signal has no influence to the FAULT output.

LED signals and Fault output table :

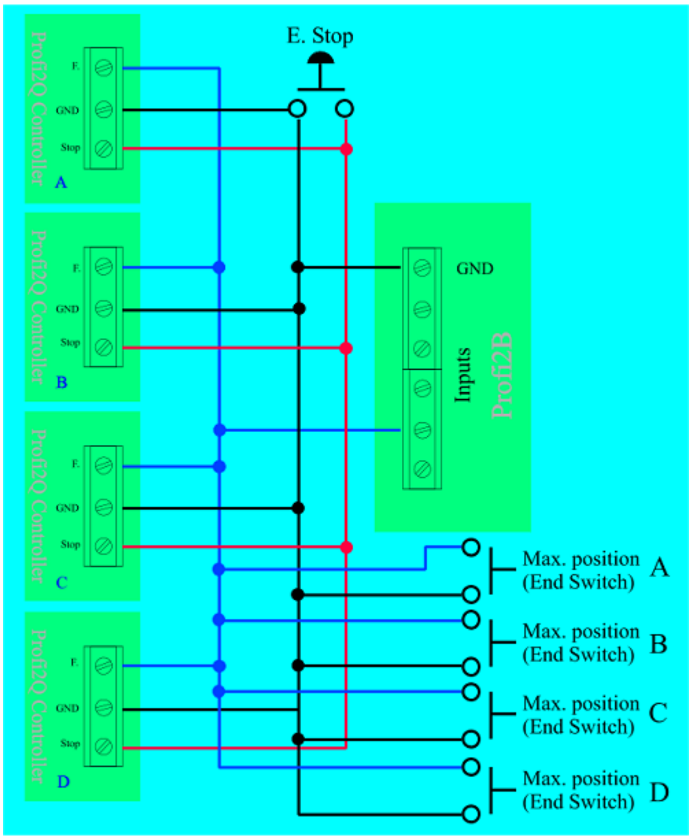
Error	**LED_A**	**LED_B**	**FAULT**	**Motorbrake**	**Status register**
Current limit:	-	X	-	-	-
Soft limit:	X	-	-/X	-	-
Hard limit:	X	-	X	X	Message
Motor Overload:	-	X	X	X	Message
Thermal protection:	-	X	X	X	Message
Stop:	t-1*	t-1*	X	X	Message

They stop P2Q and only RESET can clear this state.

(Fault, Stop ports)

The Controller has an emergency-stop function, which can be activated by a push-button located between Stop and GND pins. When this is activated, the Controller stops the motor by emergency brake and prohibits its further operation, as well as an error signal is produced on the Error output. To resume this situation, the system must be restarted or press more 3s of "T" button.
It is important to know, that emergency-stop always operates immediately in any kind of conditions, while the Stop comand issued on the PC might as well affect after several seconds because of the pulse buffer of the Controller. The Controller got into oscillation because of wrong setting (PID) can only be stopped by emergency-stop or by turning-off.

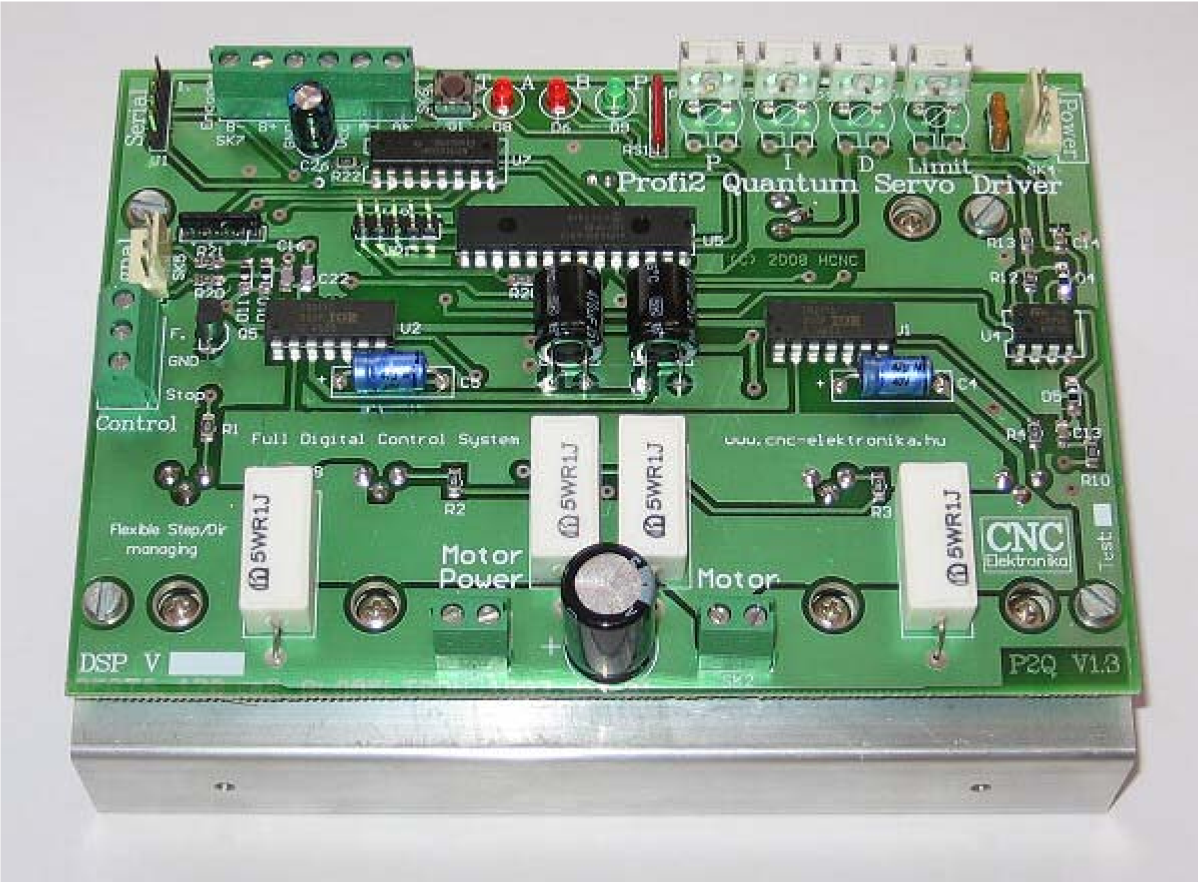
In full build-up, the protection must be wired in the following way:



(integrated protection + end-position inputs)

The above figure showsw a 4-axis Serevo Controller, which occupies only 1 input on the Profi2B base card, yet both the Error signal and all the 4 pieces maximum end-position switch will be processed. When they work Mach3 will be stopped by E-stop (in case of suitable configuration). The circuit diagram contains the external E-stop push-button, which will stop Mach3 if it is properly configured (the signal of E-Stop appears on the Error output of the Controller). When the external E-Stop is operated, the stop without pulse-loss is not guaranteed (the determination of 0 point will be necessary posteriorly). The above presented figure does not show the end-position switches of the other end of the axes (or the Home switches), they also must be taken care of (see at Profi2B or Profi2C description)

Electric connections, wiring:



All the wires should shielded mounted.
The high-current wires (connection of motor and its power supply) and the inputs of the encoder are on a screwed terminal. The cross-section of the wires is maximum 1.5mm^2. All the high-current wires should be shielded twisted pairs. For this purpose the socalled industrial 4 - 20 mA signal cable, which is a 4-wire (2 twisted pairs) shielded with a cross section of 0.5 mm^2, is very well suited (available in special electric shops).

The wiring of the Encoder must be done using shielded cables by all means. Care must be taken of using the possible shortest wiring and placing the wires far from high-current wires. The shielding must be connected to the GND terminal located on the Encoder input terminal of the Controller. The shileding (and the GND terminal) must not be connected to the metall case of the CNC machine.
The metall case of the CNC machine must be connected to the protective ground of the

current outlet.
If power supply must be provided for the Encoder, the the power supply voltage (if there isn't inside) must be filtered by a capacitor of at least 10 uF next to the Encoder (the capacitor must be connected to Vcc and GND lines).
Care must be taken of the right connection of the motor power supply. In case of wrong (reverse) connection, the Controller goes wrong.
The high-current witing must be placed as fas as possible from the Controller.

Connections:

Power Supply and Motor:

The motor power supply is connected to the Controller through SK1 terminal. Take care of the right polarity. Shilded wires must be applied

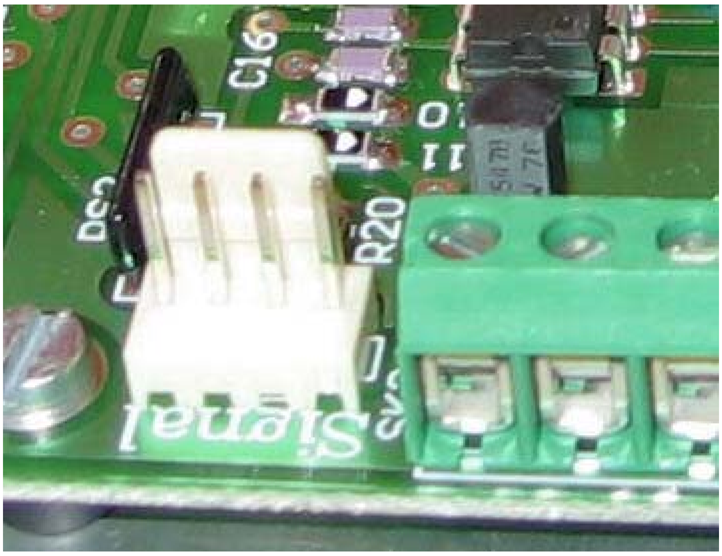
(Power Supply and Motor)

The outlet terminals of the DC motor must be connected to the SK2. Polarity does need to be taken care of, the rotating direction can be chaged within the CNC control programme. When selecton the cross section of the wiring, the nominal current of the motor must be taken into account. Shielded wires must be used.

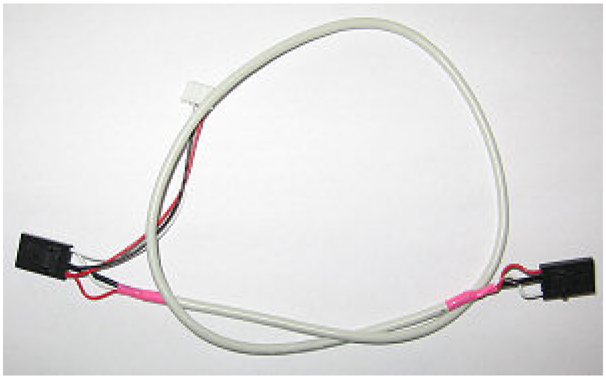
Digital Power and Signal connection:

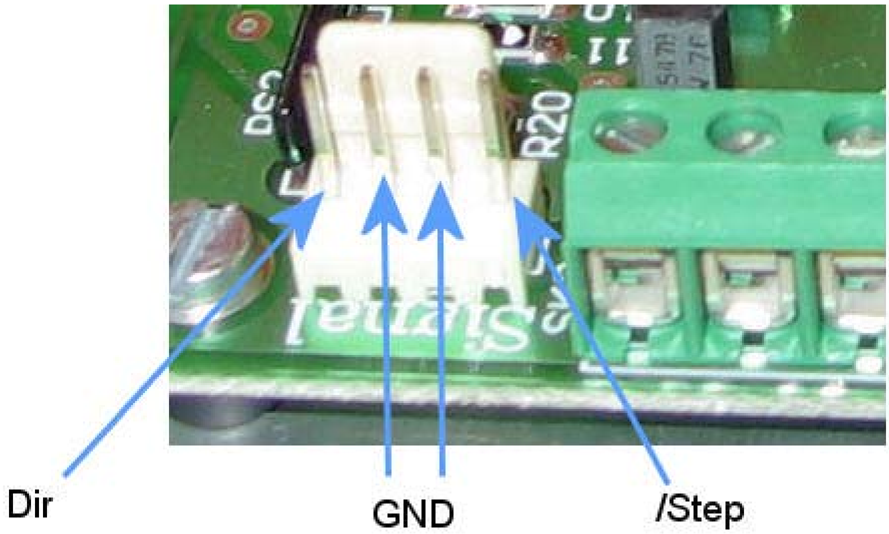
The digital power supply and signal connections are lines of pins. The pin-line connections are ed using standard internal PC (CD-ROM - motherboard), audio (shielded) cables. The usage of sush (shielded) cables, with wide black connector at both ends is strongly recommended. The connectors are positioned, reverse connection is not possible.

(digital power)

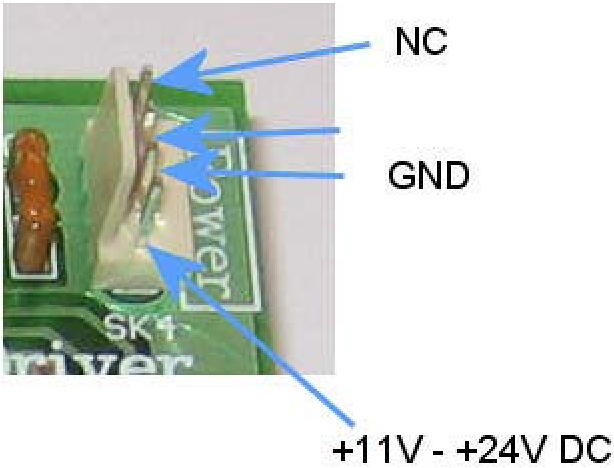


(Step/Dir signal)


(CD-ROM audio cabel)



(Signal [TTL])



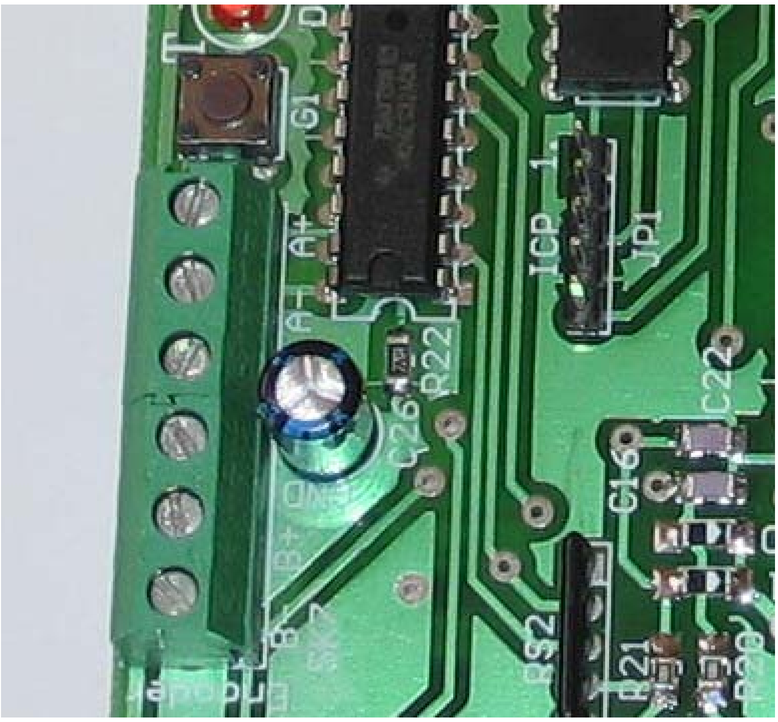
(digital power supply)

Exchanging the 2 wires may lead to damages.
The wires should not touch the heat sink (danger of melting).

Letter, A - D must be attached to the 4 pieces of Profi2Q Controllers, and the letter attached to the controller should be written onto it by an alcoholic makrker. Later, based upon this marking the bit allocation table - controller assgination can be performed.

Connection and testing of the Encoder:

The connection of the Encoder is realised through the SK7 + SK6 terminals. On the terminal the connections of Vcc and GND also can be found (if they were needed by the encoder).



(Encoder)

The encoder must be connected with shielded wiring by all means.

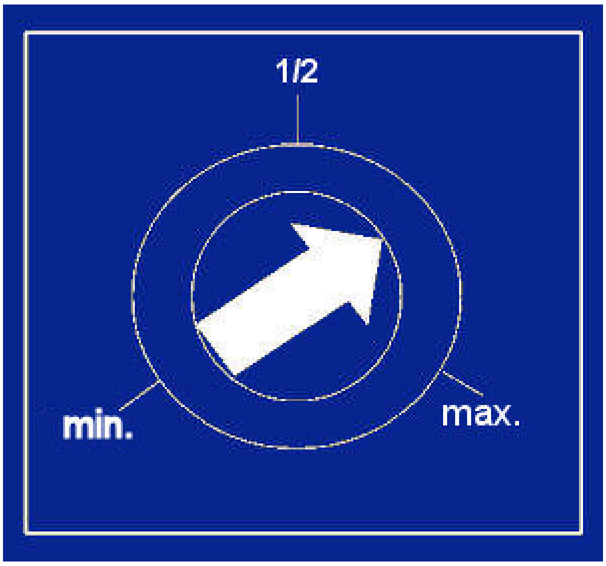
Care must be taken of the polarity of the encoder power supply, in case of revewrse connection it may go wrong.

Exchanging the channel A+ (A-) and B+ (B-) of the Encoder does not cause any failure, but it leads to abnormal operation of the Controller. Whe they are exchanged, the Controller will start the motor at maximum speed toward one direction, because the feed-back will operate reversely.

If this might happen, the Controller would stop motor in 3s and would prohibit its further operation.

Checking the connections:

Turn the all potentiometer trimmer of the completely wired Controller into approximately 1/3 position.



(potentiometer trimmers)

Turn on P2B and the motor power supply.
gently move the motor-shaft by hand.

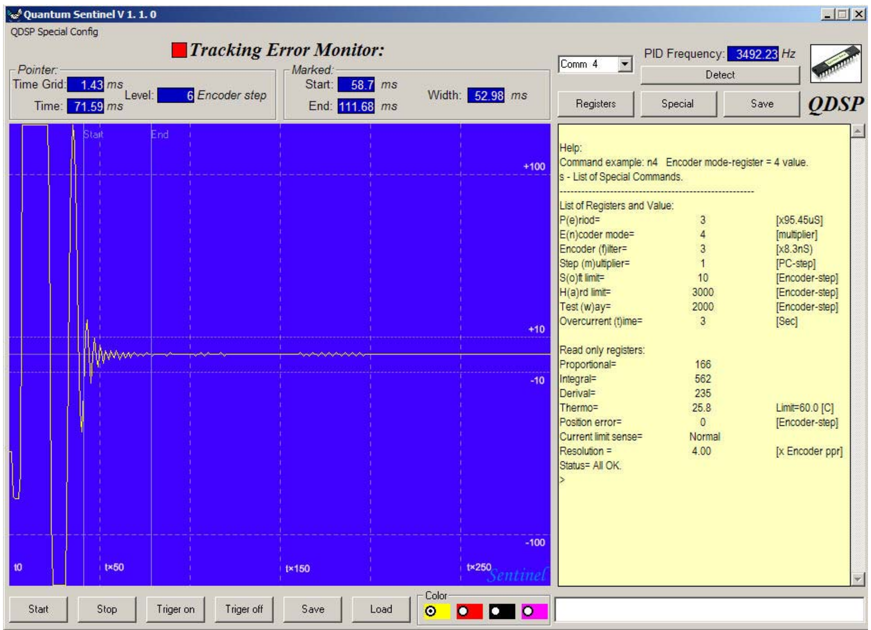
If the motor suddenly starts (at a great speed), the the connection is reverse.
Turn off the Controller.

If the motor dos not spin, then the connection is correct.

In case of reverse connection either the line A and B should be exchanged, or the excitation lines of the motor (SK2) should be exchanged.

Setup Registers:

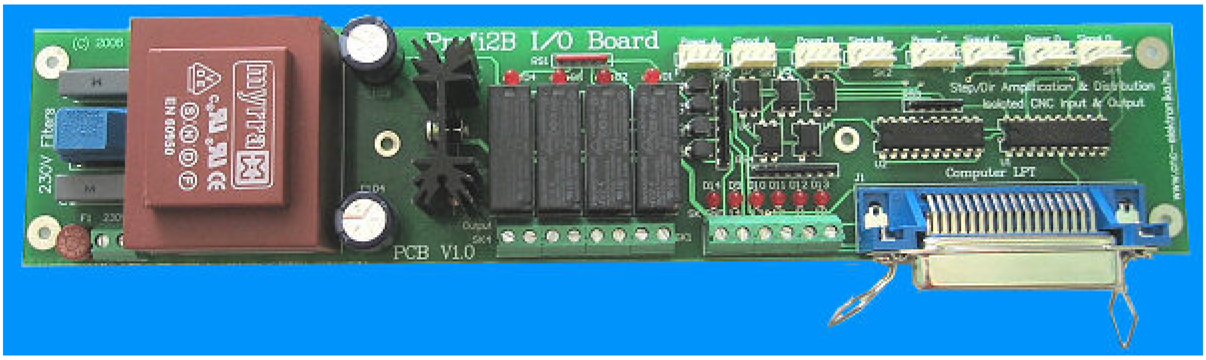
Please see all information in www.quantumservo.com webpage (QDSP)!



(Sentinel)

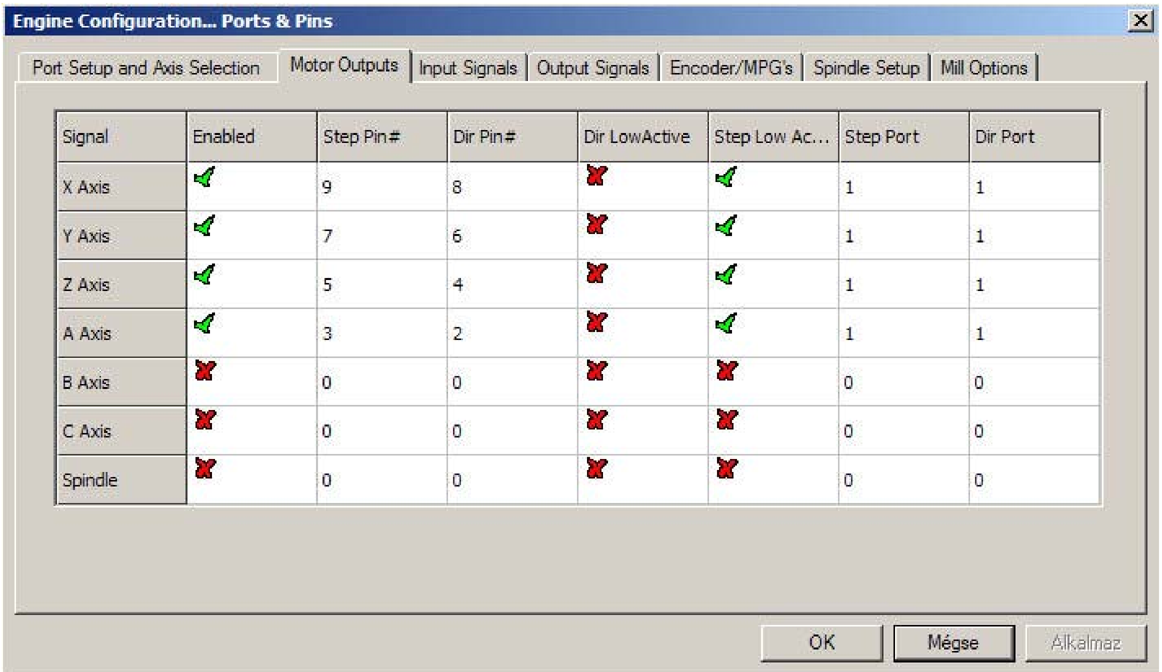
Software setting-up:

The setting-up of the software is basically the same as that of written about Profi2B or Profi2C base card Detailed setting-up information can be found here , please read it carefully.



(Profi2 B I/O board)

The following adjustment has a great importance:



Engine Configuration... Ports & Pins

Port Setup and Axis Selection | Motor Outputs | Input Signals | Output Signals | Encoder/MPG's | Spindle Setup | Mill Options

Signal	Enabled	Step Pin#	Dir Pin#	Dir LowActive	Step Low Ac...	Step Port	Dir Port
X Axis	✓	9	8	✗	✓	1	1
Y Axis	✓	7	6	✗	✓	1	1
Z Axis	✓	5	4	✗	✓	1	1
A Axis	✓	3	2	✗	✓	1	1
B Axis	✗	0	0	✗	✗	0	0
C Axis	✗	0	0	✗	✗	0	0
Spindle	✗	0	0	✗	✗	0	0

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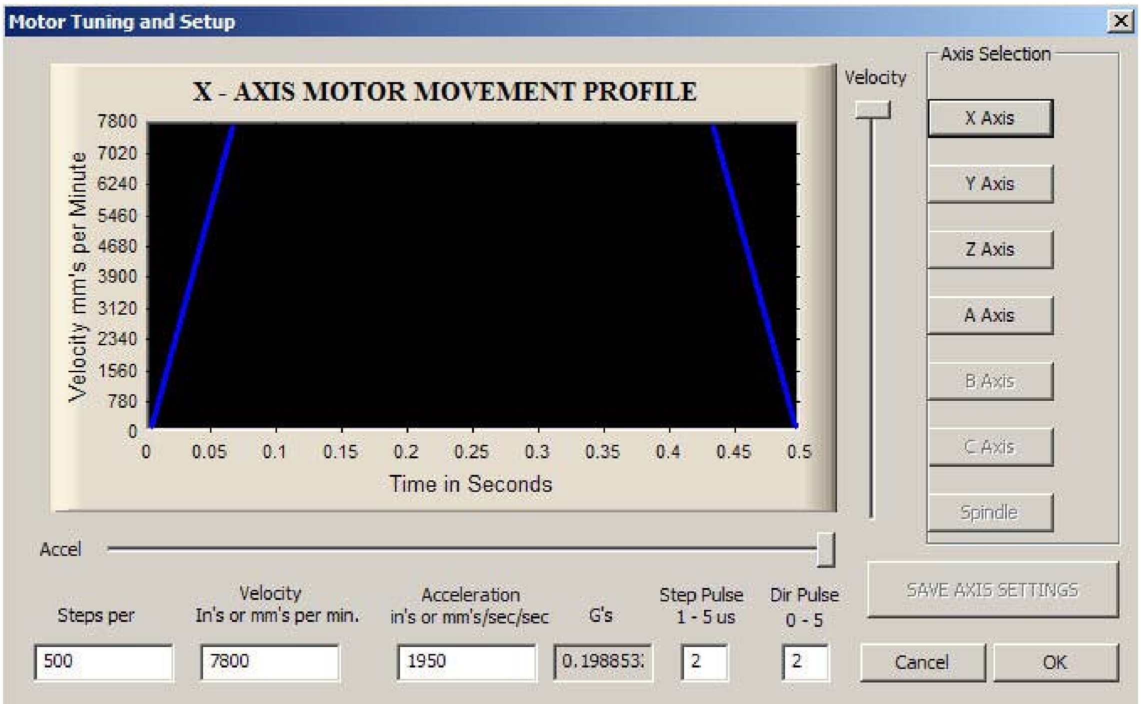
(Step/Dir and Step Low Active setup)

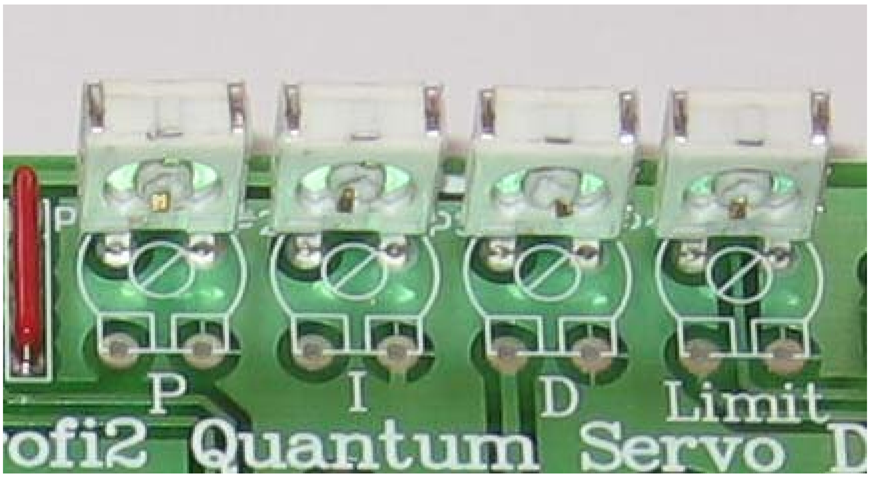
It is important that the Step Low Active signal should be set at P2Q Controller.



(Step Pulse and dir Pulse = 2 !)

Adjustment of PID regulation:

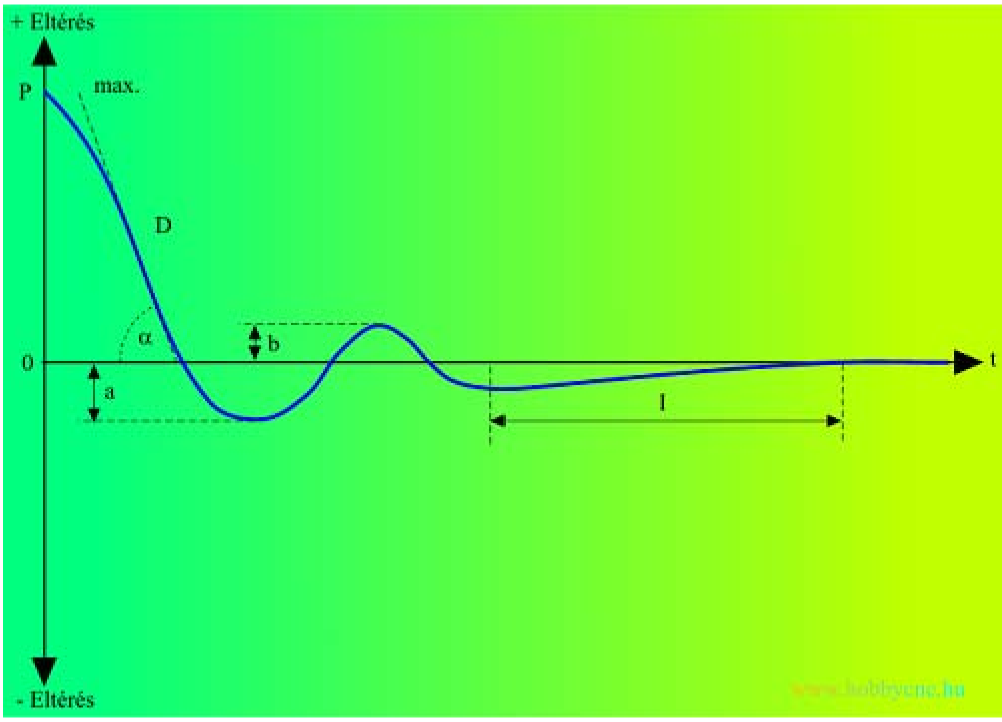
The full movement control of the motor is performed by the PID regulator, with the help of complicated mathematic procedures. The regulation works wth 3 parameters adjustable by the user. The 3 parameters are marked as P, I ,D parameters, a separate potentiometer trimmer belongs to each of them.



(P I D and Current Limit)

The amplification of these regulation parameters can be adjusted by these potentiometer trimmers.

All setup information found in www.quantumservo.com webpage (QDSP)!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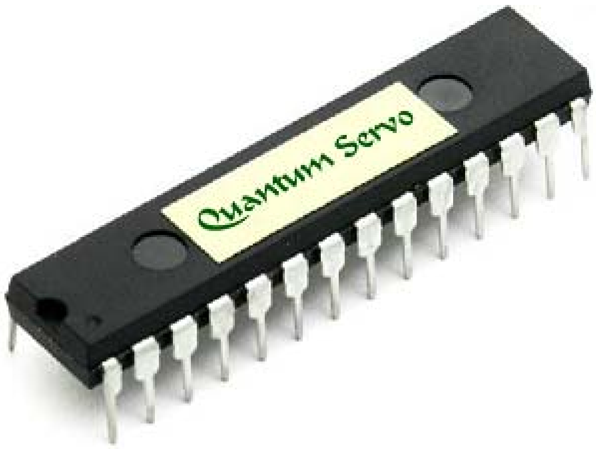
Quantum Szervo DSP Chip

(QDSP)



QDSP IC is a circuit, which is a high-speed, flexible, easy to use device, based upon dsPIC30F4012 microcontroller, for building servo controllers. Using this device, CNC position servos suitable for driving DC motors with brushes can be built with relative low number of additional circuits.
The field of its application is first of all moving controllers of CNC-s, or performing any kind of regulation task demanding high precision and speed. The possible highest execution speed, job integration and the ease of use were the most important viewpoints during its development.

Main features (V1.6.0):

- Step/Dir-system motor stepping inputs,
- Two-channel, incremental encoder inputs,
- Encoder processing: 2×, 4× modes,
- Programmable Encoder Digital Interference Filter (EDF),
- Step signal multiplicator: 1× - 10× (step-multiplicator),
- Protection against motor overload: 1s - 7s (in a programmable way),
- Protection against overload of the controller (with readable temperature),
- Programmable integration time (95uS - 475 uS),
- Serial fine tuning (handling of the internal registers),
- Online error-level monitor (with ASCII or binary communication),
- Online PWM limit monitor in ASCII form,
- Error-level peakindicator (with ASCII 3s datalogger),
- Full PID motorcontroller algorhytm,
- Analogue P, I, D parameter-adjustment by potentiometer trimmers,
- Reduction of motor vibration,
- DSP performance: 120MHz, 30 MIPS, 16bit CPU, 40bit ALU,
- Full H-bridge control (with PWM and motor-brake modes),
- 16 bit PWM,
- Current limiting input,
- Adjustable Soft Error Limit buffer (1 - 200 Steps),
- Adjustable Hard Error Limit buffer (1 - 30000 Steps),

- Bandwith values:
  Encoder signal frequency: max. 6MHz,
  Step signal frequency: max. 1 MHz,
- Double Status signals by LEDs,
- Thermometer sensore input,
- Error indication output (Fault),
- Emergency stop input (Stop), chain error handling,
- Numerous writeable and readable configuration registers,
- Firmware upgrade possiblity through ICSP,

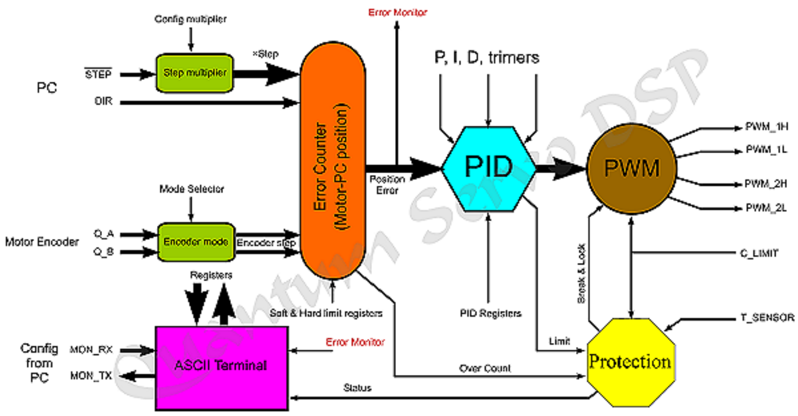
This QDSP IC can also be used in independent developments or the PCBs of the Servo controllers found on the WEB page can be assembled at home too. Ready-made, tested controllers are also available, so there is a wide range of possiblities to use this IC, - from building them in kit form up to ready-made CNC Servo controllers.

Firmware V1.6.0

Declaration of Comformity :
The present document is not the description of complete CNC Controller and contains only the description of the controlling DSP chip. It cannot be regarded as a reference manual for the exact rebuilding of the device. The author does not take the responsibility for any damage caused by this missinterpetation. The control circuit (DSP) mut not be used in vehicles, medical equippment and in any other devices, which - in case of missfunction may become more increasingly dangerous for human body. Present documentation is for people who have the necessary skills. It does not contain the detailed security prescriptions and that of the interference protection, therefore everyone may use it only at his own peril.

Internal build-up and operation:

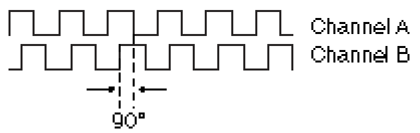
The software running at full speed in the dsPIC30F4012 microcontroller performs the position movements required by the PC, utilising the most support given by the hardware. The movements are realised by a DC motor with brushes and by an incrementing 2-channel encoder fed-up (closed loop positioning). The movements of the motor are signalled by the encoder back to the DSP, which compares this to the value required by the PC and continually correct this if there is any deviation between them.



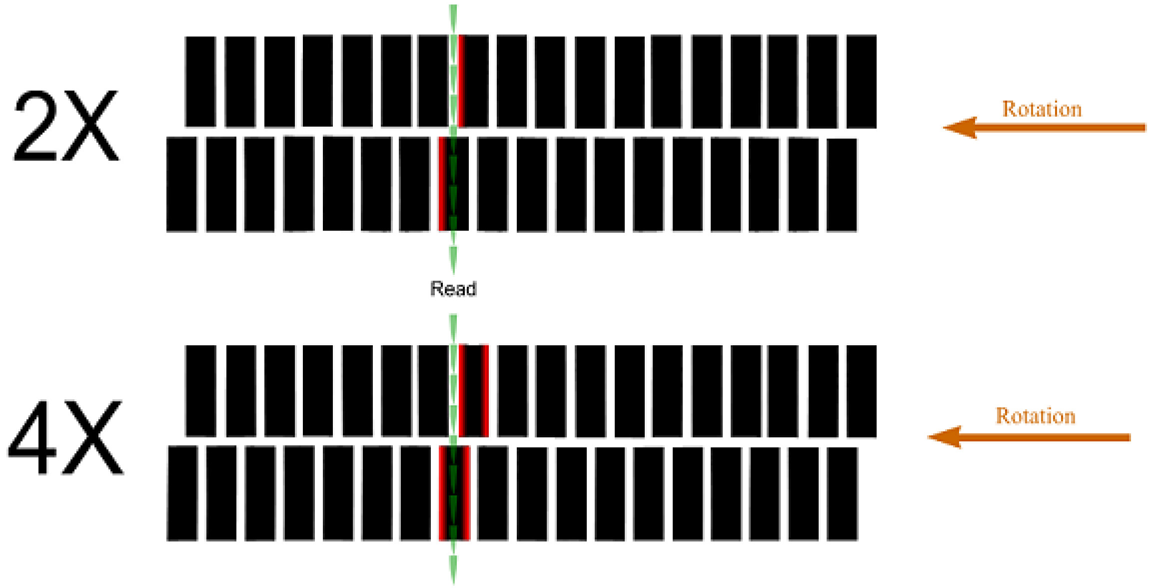
The computer makes the motor step through the Step/Dir inputs of DSP. The Step signal is featured with negative logic (makes the motor step at falling edge). At each Step edge the

DSP makes its internal error counter step into the direction according to the Dír signal. The measure of the step is also influenced by the Step multiplier register. By this register the incoming Step pulses can be multiplied (1× -10×). It is needed so that motors equipped with high-resolution encoders can also be driven at reasonable revolving number even by CNC softwares able to output relatively low stepping frequencies. The step-multiplying reduces the resolution of the CNC machine, but it raises the available max. revolution number in return. The high encoder resolution ↔ max. speed conflict can be brought into an equilibrium state by this..

The mechanical fed-up is realised by the signals of the encoder mounted onto the motor. The encoder is realised by a light-passing disc, which contains dark dashes in two lines. The 2 lines are shifted to each-other. By the means of 2 optical photo-electric cells the two lines are read separately and the readouts are transformed into logical signals. By the phase position of the 2 signals the direction of the steps can be stated and the measure of the movement can be calculated from the number of steps.



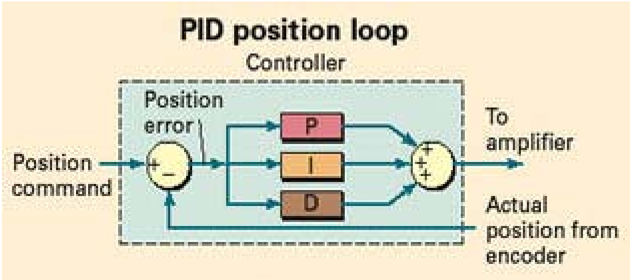
The DSP can process the Encoder signals in 2 mode: 2× and 4× mode. These two modes influence the resolution that can be achieved by the same encoder.



In 2× mode the DSP handles only the entering edge of the dashes (marked by red). In this case the base resolution of the encoder (PPR) is doubled.
In 4× mode the DSP processes each edge of the dashes. In this case the base resolution of the encoder is quadruopled.

Recommended settings:
In case of 200-1000 PPR, 4×-mode,
above this range 2×-mode is preferred.

In a positionerror-free position the difference between the two signals is 0 (the dirrerence-counter stands at 0). The error signal comes from the difference of the two signals (counters) and their direction. This error signal can be read through the serial port (MON_ ports). The error signal is the starting base for the complicated PID algorithm. The PID prepares the direction and PWM data for the bridge-controller.

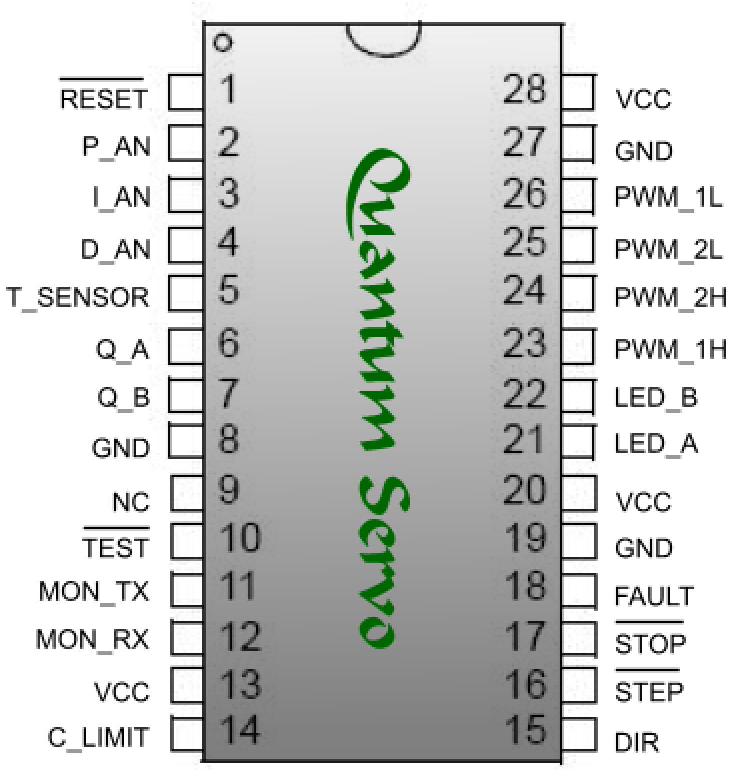


The external current-limiting signal can prohibit the PWM data. This signal is the base for several kinds of protection. The PWM generator controls the bridge outputs (PWM_..). Each branch of the „H" bridge is separately controled by the DSP, so in case of normal motor movements PWM regulation, while at emergency stop (see protection), motorbrake mode is realised.

A two-level protection system has been built-up, which protects both the motor and the CNC machine equipped with the DSP. In some cases the protection gives only a signal, in other casesn the DSP is blocked and only the Reset clears this state. Each protection operation sends a message text through the Status register, so the cause of any blow-off can alway be traced exactly. The two LED outputs (LED_A and LED_B) gives information about the current state. Its detailed description can be read at the protection system.

The serial output (MON_RX and MON_TX) is for configuration of the internal registers and monitoring of the Online error-level. Because of its standard RS232 ASCII or binary communication any kind of (independently from the operation system) terminal program can be used. In case of Windows the built-in Hyperterminal or the **Quantum Sentinel** developed for QDSP is recommended. In case of USB-RS232C converter the communication through USB port is also possible.

Pin assignment of QDSP :



1. - RESET
TTL input with negative logic. At low level it sets DSP into base (default) position. External reset circuit is not necessary, it has an internal one. At high level DSP runs its internal software (normal state).

2., 3., 4., - (P, I, D)_AN
Analogue inputs. The voltage levels between 0 – VCC determine the gain of the P. I. D. branches. It is used for setting up the PID parameters.

5. – T_SENSOR
Analogue input. It receives a voltage level between 0 – VCC, linearly increasing with the temperature , which is proportional to the temperature of heat sink. Its current value can be read out through the serial port. It is the base signal for the internal overload protection.

6. – Q_A
TTL input. It is the input of the „A” channel of the Incremental Encoder.

14. – C_LIMIT
TTL input. Current-limiting input. At high level it prohibits the PWM outputs.

15. – DIR
TTL input. It determines the direction of the motor rotation.

16. – STEP
TTL input with negative logic. It makes the motor (and the internal error register) step at falling egde.

17. – STOP
TTL input with negative logic. At falling edge it prohibits the operation of DSP and generates the motorbrake operation.

7. – Q_B
TTL input. It is the input of the „B" channel of the Incremental Encoder.

8., 19., 27. – GND
Logical grounding point (negatíve).

9. – NC
Not connected.

10. – TEST
TTL input with negatíve logic. It is the input of the Test button (stress button). In case of level changes from High_to_Low_to_High „Test way" it performs as many unit jumps on the motor as the register content.

11. – MON_TX
TTL output. Data output of the serial port for monitor programmes.

12. – MON_RX
TTL input. Data input of the serial port for monitor programmes.

13., 20., 28. – VCC

18. – FAULT
TTL output. Its high level signals the operation of the protection.

21. – LED_A
TTL output with negatíve logic. It is a status indicator, the output of the „A" LED driver.

22. – LED_B
TTL output with negatíve logic. It is a staus indicator, the output of the „B" LED driver.

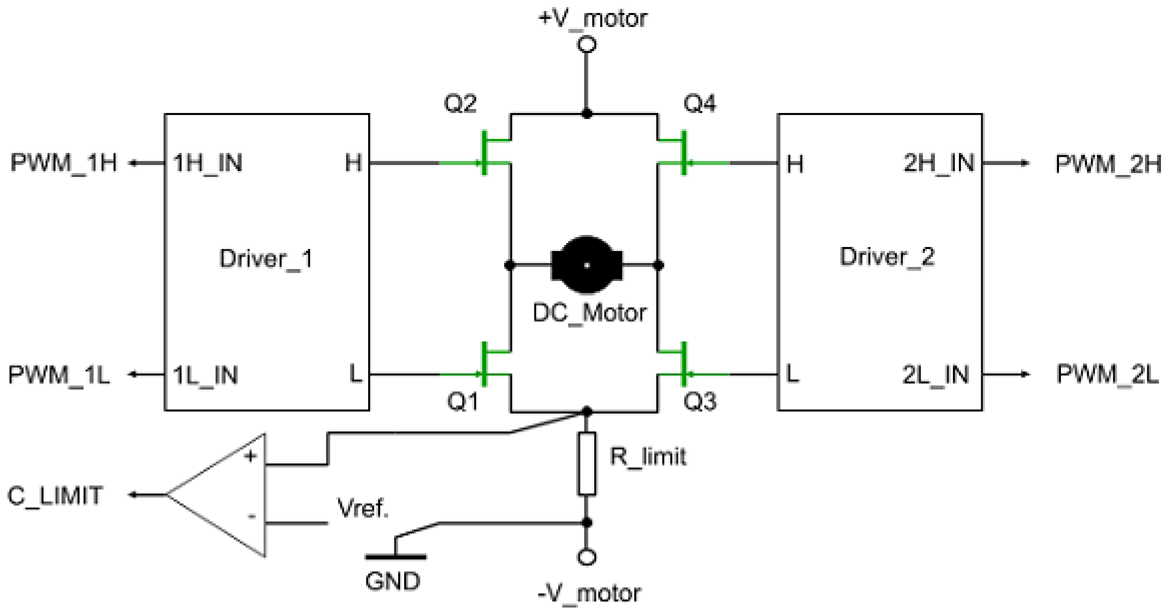
23. – PWM_1H
TTL output. It makes the upper FET of the left-side bridge-controller operate in PWM mode.

24. – PWM_2H
TTL output. It makes the upper FET of the right-side bridge-controller operate in PWM mode.

25. – PWM_2L
TTL output. It makes the lower FET of the right-side bridge-controller operate in PWM and motorbrake modes.

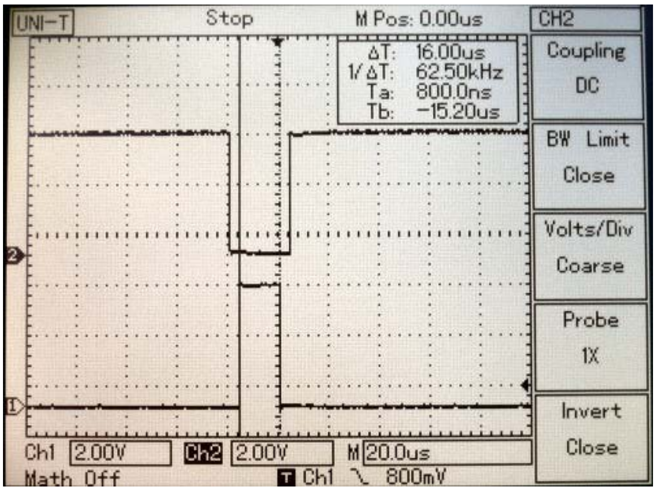
26. – PWM_1L
TTL output. It makes the lower FET of the left-side bridge-controller operate in PWM and motorbrake modes.

Bridge control:



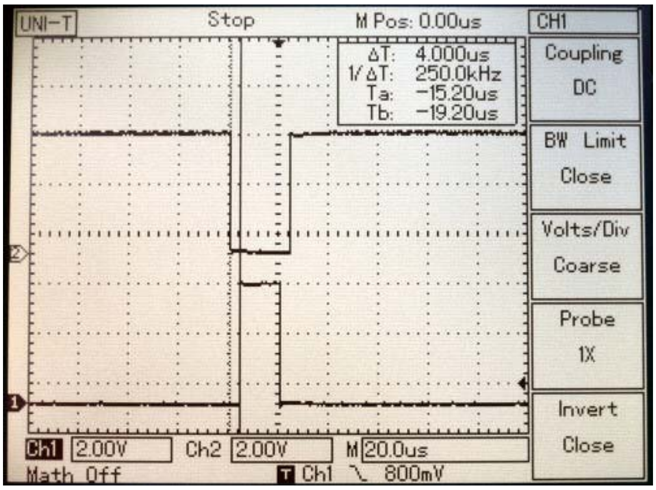
The outputs of the bridge control were designed using the IR2112 driver circuit. The Firmware contains an internal „Dead time" generator, which is 4µS. During normal operation the FETs are diagonally controlled. The lower FETs are excited in PWM mode, while the upper ones are excited in static mode. In motorbrake mode the lower FETs are static controlled. The Gate charging capacitors of the upper FETs are kept alive by a 2-second refreshing alogorithm (switchable). A charging capacitor of 47uF is recommended. The charging diode should be BAV21 or a faster type (<100nS). The charging time is 16µS.
The TTL level signal necessary for the overcurrent limiting must be provided by a comparator circuit.
In case of overcurrent limiting all the PWM outputs go into 0 level.

p100 test command (100% PWM into forward direction):



(charging cycle)

1CH = 2L, 2CH = 2H, ΔT= charging time (16µS), charging period=2s.



(dead time)

1CH = 2L, 2CH = 2H, ΔT= dead time (4µS), symmetric.

Description of connections:

(P; I; D)_AN inputs:
Recommended value for potentiometer trimmer 1kOhm (connected between GND and VCC).

T_SENSOR input:
Applicable thermosensor: from the series 640, 4k7 NTK tightly mounted to the heatsink. It must be connected between the input and VCC. It is necessary to connect between the input and GND a resistor of 1kOhm and a capacitor of 100nF in parallel connected.

STEP/DIR inputs:
The STEP signal has negative logic, it makes the internal counter step at falling edge. The DIR signal must be stable 100 nS before the STEP performs stepping. The minimum length of STEP pulse is 5nS.

TEST input:
This input has two jobs.
1. At the level change series of High_LOw_High it will perform unit jump with the size prescribed by the „Test way” register (in terms of Encoder steps). For pulling up to VCC the input, a resistor of 3k Ohm is recommended. It can be directly connected to the push-button (contact bounce-free by software).
2. If it is pushed and hold pushed for 2s, the DSP will restart (reset). The fact of restart is indicated by "flashing " of the two LED outputs too.

STOP input:
It performs an emergency function. It is not contact bounce-free, it has negative logic, it is a TTL input. It causes DSP to prohibit the motor and to switch it into the motorbrake mode as well as it put the FAULT output to high-level. Only Reset can clear this state.

FAULT output:
It is an error-indicating output. It is made to operate by the STOP input and the internal protection system. It is recommended to drive it by an open collector transistor, so that logical OR relation can be formed with the other axes and also with the PC.

LED_A and LED_B outputs:
TTL ouputs with negative logic, they can be applied even to direct drive of LEDs (the LED+ its rersistor must be connected between VCC and the ouputs). They are summarised status-indicating LEDs (Status). In case of operation of the protection the reason can be read out from the read-only „Status” register in text form.

The two-level protection system of DSP:

1. Independent protection systems. In case of their operation they make the motor stop by motorbrake and prohibit DSP. They give LED ("A" and "B") indication, as well as text messages in the „Status” register. Their operation can only be stopped by restarting DSP. Each independent protection system generates an error signal on the FAULT output. By this signal the CNC control-software running on the PC (e.g. Mach3) can also be stopped.

- Overrun protection of Hard limit (Error*) register (its size can be adjusted):
If the error signal (Error*) exceeds the adjusted value, the DSP will stop the motor by motorbrake and prohibits its further operation.
It performs first of all protection against reverse encoder connection and seizure of the motor.

** Error register = error-level register, which measures the deviation between the required and actual mechanical positions in terms of Encoder steps. If there is no deviation, then its value is 0.*

- Overload-protection of the motor:
If the current-limiting of the motor is continually operating and its operating time exceeds the value of "Overcurrent time" register, then the protection stops the motor and prohibits its further operation.

- Overload-protection of the controller:
The temperature of the heatsink is continually measured by a thermo sensor and about at 60/80/100 °C it prohibits the further operation of DSP. It can be adjusted by Service code.

- Stop input active (low level). If it operates, it willmake the DSP prohibit.

2. Protection through the PC. This cannot stop the Controller in itself, it generates only an error level on the FAULT output. If this output is connected to one of the inputs of the PC and the controlling software is properly configured then this signal is able to stop the operation without pulse-loss. In certain conditions the work can be continued witout producing wastes after fixing the error.

- Overrun of the Soft limit (Error*) register. It also produces a signal on the "A" LED as long as this state remains. This signal is first of all to check whether the trace tracking is geometrically true. It continually monitores the synchronism of the motor and the CNC software. When this becomes bad, it stops operation and gives a signal. The Fault indication can be prohibited by service code.

- Motor Peak-current limiting:
The DSP continually checks the status of C_LIMIT input, and if its level is high, the protection limits the PWM outputs. The fact of limiting is indicated by lighting the "B" LED. This signal has no influence to the FAULT output.

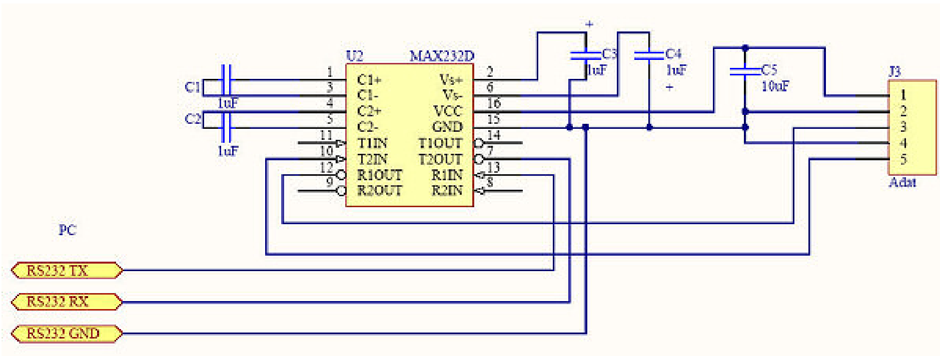
LED signals and Fault output table:

Error	LED_A	LED_B	FAULT	Motorbrake	Status register
Current limit:	-	X	-	-	-
Soft limit:	X	-	-/X	-	-
Hard limit:	X	-	X	X	Message
Motor Overload:	-	X	X	X	Message
Thermal protection:	-	X	X	X	Message
Stop:	t-1*	t-1*	X	X	Message

They stop DSP and only RESET can clear this state.

** t-1 hold the previus state.*

MON_TX and MON_RX ports:
For RS232C connection the base schenatic of MAX232 IC is recommended. Its data transmission speed is 115200,8,N,1 without transmission control in ASCII mode. with a USB converter it can also be used with a USB port. Terminal software: any standard ASCII Terminal programme (e.g. Hyperterminal of the Windows or the much more developed Quantum Sentinel).



J3: 1=Vcc; 2=GND; 3=MON_RX; 4=GND; 5=MON_TX

Communication with the QDSP:

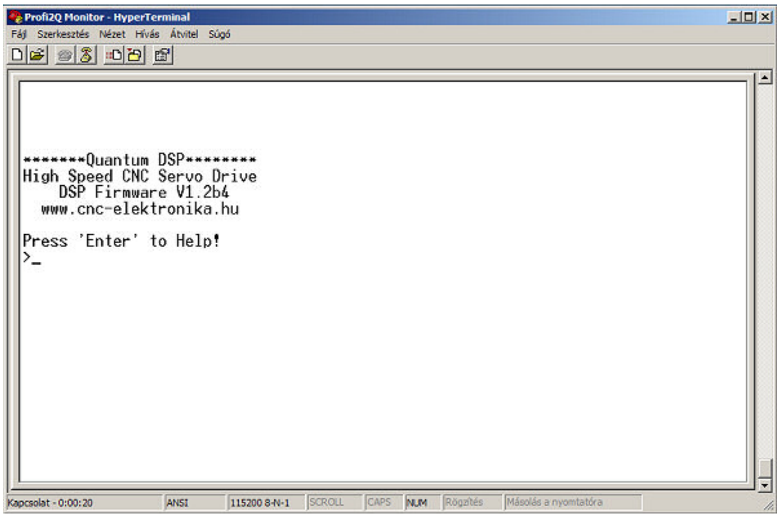
The adjustment of the DSP is performed most through its P-I-D _AN analogue inputs with the help of potentiometer trimmers. For the other setting up registers and for the complitated functions serial communication is needed. This communication happens through the MON_RX (receive) és MON_TX (transmit) pins in serial form (115200 bit/sec, 8-bit data, without parity and with 1 stop bit). Its connection to the PC can be realised through an RS232C port (see above) or by an RS232C-USB converter through the USB port.

The software necessary for the setting-up may be a simple terminal programme (e.g. Hyperterminal of the Windows or the much more developed Quantum Sentinel).
With the help of standard ASCII communication the setting-up and the error analysis can be performed under any kind of operation system (DOS, Linux, etc.) using a simple terminal programme. In Windows environment the use of the more developed Quantum Sentinel

programme is recommended. The resource demand of Sentinel is substantially larger than that of more simple terminal programmes, therefore it is recommended to run it on a separate PC (e.g. on a laptop). If it is required to run the software on the same PC, then the use of Hyperterminal is recommended.

Usage through Hyperterminal:

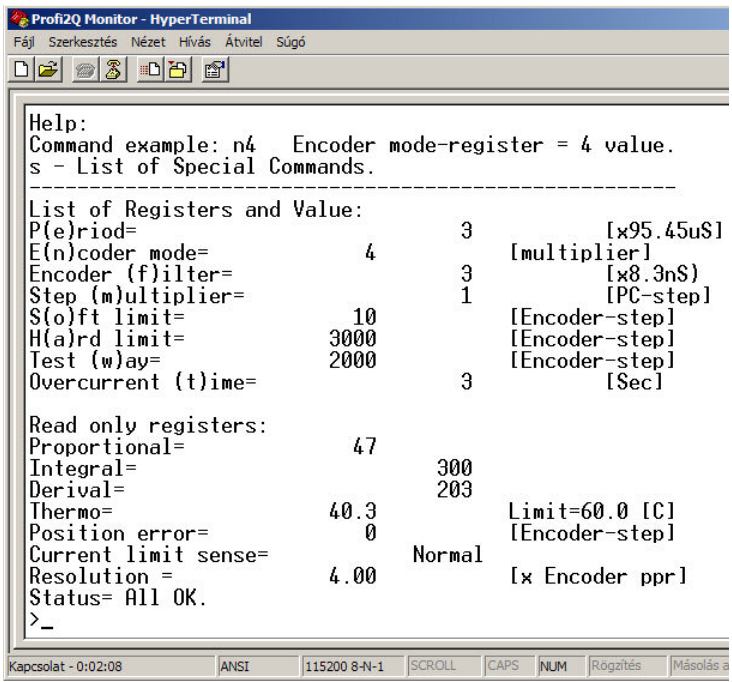
After having set-up the communication successfully, if the Terminal is started earlier than the Controller, the following introducing text is displayed following switching on the Controller:



(introducing screen)

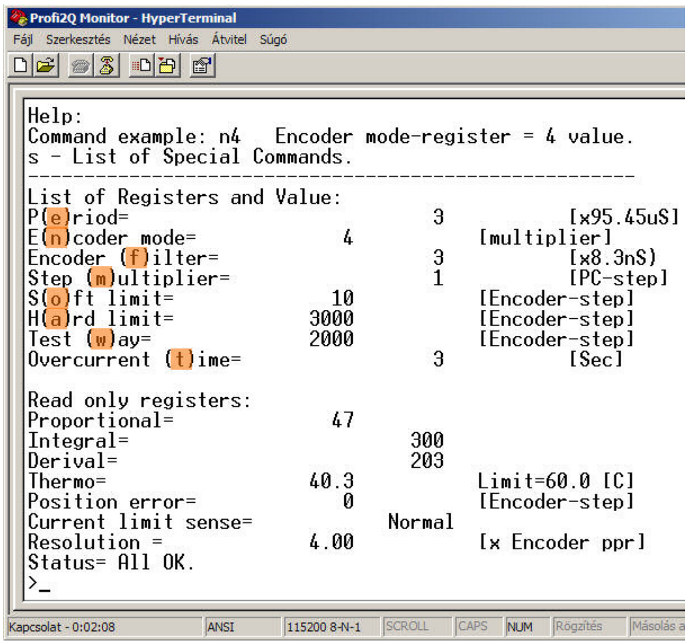
The version of the burnt-in DSP Firmware can be read out.
If the DSP is switched on before the connection has been established, then this screen is not displayed (empty), but pressing once the ENTER key the registers will be listed.

After pressing the ENTER key a detailed help is displayed:



(querry of the actual state)

Here the most important registers and their values are listed. The letters in brackets in the names of the writeable registers are commands by which the values of the registers can be changed.



(writeable registers)

An example:

m5 (+ENTER)

sets the „Step multiplier” register to 5. Doing so, the Step signal coming from the PC will be multiplied by 5.

If you wish to know the current values at any time, then push only an ENTER.
If incorrect values have been inputted, then the Controller indicates this by an error message and gives the applicable range of values at the same time. Changing some values the Controller must be restarted, this is also signalled by a message.

In the lower part (Read only regiszters) only read-only registers can be found. These registers inform the user about the current status of the Controller and their value cannot be changed. Their meaning can be found in the later parts.

The list of special commands can be accessed by s (+ENTER) command.

Registers and their configuration:

Writeable-readable registers:

The read-out of the registers can be done by pressing simply the ENTER key.
The values of the registers can be modified by typing in the revelant "letter+new value". E.g.: f4 sets the digital filter of the Encoder to the value of 4. Changing some registers requires the restart of the DSP, and it is also indicated by a message. Their measuring units (interpretation) are indicated by square brackets [...].

Changing some registers is recommended only for experts (this is indicated by red colour).
Modifying the registers during operation is NOT RECOMMENDED.

Registers and their jobs:

e - Frequency of PID evaluation (its period) register. The real speed is: the value of the register multiplied by 95.45uS. Its reciprocal value is the frequency of PID (its base value is 1/(3×95.45us)=3492.22 Hz). The DSP could be adjusted to the time-constant of the motor. Its range is: 1 - 5.
Attention! Changing this value might cause the PID components necessary to be retuned.

n - Encoder usage mode. Two modes are possible: 2×-mode and 4×-mode. The base division of the encoder is doubled (2×) or quadroupled (4×) (e.g. from an encoder with the base division of 500 PPR an encoder with the resolution of 2000 will be in 4×-mode). Changing this value will influence the resolution of the CNC machine and its end-speed. Its range is: 2; 4.
Attention! Changing this value might cause the PID components necessary to be retuned.

f - Value of the encoder digital noise filter (EDF). It is the input noise filter of the encoder, which is responsible for the non-skidding handling. In case of noisy, poorer quality encoder or its dashes, its value must be increased, but it reduces the band-width of the encoder. Only the signal-change exceeding the time of the filter is taken as stabilised encoder-change by the system, changes with shorter time are not taken into account (noise-filtering). Its range is: 1 - 7.
Attention! At a value of 7 the input bandwidth of the Encoder is reduced to 75 kHz.

m - Step-signal multiplier. It multiplies the Step (stepping) signals coming from the PC. With its help, the maximum speed of the CNC controller software can be increased and so it can be optimalised to the system. Chaging the value will influence the resolution and end-speed of the CNC machine. Its range is: 1 - 10.

o - "Soft" error-limit register. If the position error is greater than the value of the register, then the FAULT output of the DSP FAULT will actíve (it is programmable) and the "A" LED will light up. If the FAULT output is connected to the one the inputs of P2B card and the software is properly configured, then this signal will stop the operation of the CNC machine without position skidding (an error which can be corrected). Its value must be lower than the value of „Hard” limit register. Its range is: 1 - 200.

a - "Hard" error-limit register. Its operation is the same as that of the "Soft limit" register, but the later stops the DSP (with motorbrake) and this can only be cleared by restarting the DSP. Its value must be higher than the value of the Soft limit register. Its range is: 1 - 30000.

w - Length of the move caused by the active state of TEST input. The safe length of movement, which the controller performs by pressing the "stress-button" can be adjusted by that (aoviding collision), Its value must be lower than that of the "Hard" error-limit register. Its range is: 1 - 2999

t - Time-limit of the overload. If the current limiting continually remains longer than the value of this register, then the DSP stops and switches off the motor (overload-protection) and it generates FAULT signal. Only by restarting the DSP will clear this state. Its range: 1 - 7.

i - Trigger-level of the binary error-level monitoring, in absolute value (it is used by Sentinel). Its range is: 1 - 100.

l - Measure of the reduction of the motor flickering. Its range: 0 - 4.

Read-only registers:

Proportional, Integral, Derival - values of the potentiometer trimmers belonging to them (P_AN, I_AN, D_AN inputs).

Thermo - the temperature of the sensor (heatsink). Its limiting value may be one of three given values (60, 80, 100 [°C]).

Position error - the value of the current mechanical deviation at the time of read-out.

Current limit sense - the current status of a current-limiting at the time of read-out.

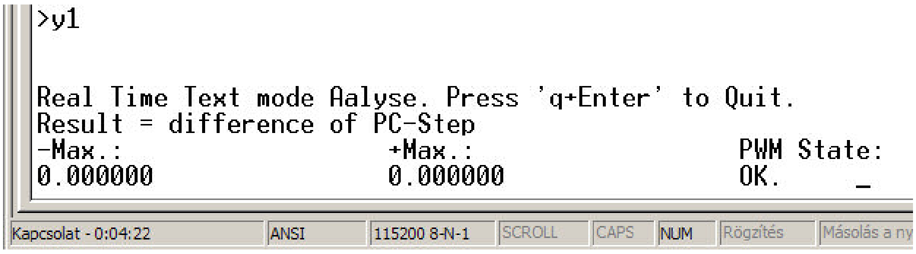
Resolution - the multiplier of the resultant resolution from the current configuration (the current resolution[PPR]= Resolution × base resolution of the Encoder[CRP]).

Status - the current status of the DSP and the things to be done and errors.

Special commands:

s - Lists the special commands.

y1 - starts the real-time position-error monitoring. To quit from that press q + ENTER. The display is a ± direction peak-indicator, with a display time-constant of 3s. Its measuring unit is: PC-Step.



(ASCII mode error-level analysis)

PWM State = The state of PWM duty cycle. In case of OK its value is < 100%, in case of Max. is 100%. More information about the quality of the drive.

p - (directed) duty cycle of the PWM motor excitation using a given value. For fault finding and test purpose. Its range is: 0 ... +-100 [%]

J – (Capital letter J) Service codes. For fault finding and for special configuration purpose (Fuses).

C1 – (Capital letter C) clears all the changes of the register content and and set everything to its default value (reset).

u – It lists the status of the Fuses.

r - P trimmer preamplification. Adjustable trimmer area.

x- D trimmer preamplification. Adjustable trimmer area.

Service codes (Fuses) (J-switches):

1100 : Sends out the value of the current PID periode in ASCII chars (Sentinel),
1028 : AC mode (bridge refresh off),
1027 : DC mode (bridge refresh on),
1026 : Soft limit without FAULT indication (default state),
1025 : Soft limit with FAULT indication,
1024 : blocking of the temporary motor overload-protection,
1023 : setting the temperature protection of the Controller to 60°C (default state),
1022 : setting the temperature protection of the Controller to 80°C,
1021 : setting the temperature protection of the Controller to 100°C,
1002 : Triger mode off (Sentinel),
1001 : Triger mode on (Sentinel),
1000 : Starting of a binary error-level data-stream (Sentinel). To stop it preess q + ENTER.

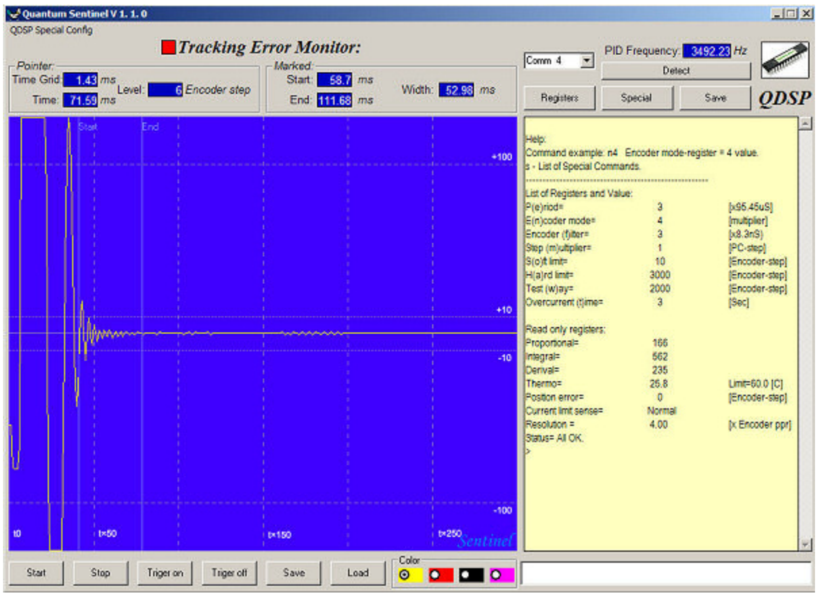
8 bit (0-255) error-level data. 128 means 0 error (-range <128< +range).
To start it from an external software programme use J1000+CR ASCII data.

Fuses which are stored in the internal EEprom:

1026 or 1025,
1023 or 1022 or 1021,
1001 or 1002.

Quantum Sentinel

(Graphic servo error-level monitor and configuration programme)



Quantum Sentinel is a graphic error-level display, analysing and configuration programme developed for QDSP. It contains both the graphic display for transients and the ASCII configuration terminal programme. With its aid full extent PID adjustment and contoller configuration can be realized.

After installing and starting the programme, the port number of the connected serial data-interface must be inputted (Comm X). The programme will accept only existing free port numbers.
The main screen is divided for two parts:

- On the left side the graphic oscillographcan be found, which presents the error-level as the function of time (transients).
- On the right side the text-based configuration part can be found.

Beside these a menu-line with special functions can also be found on the top.

Left-side field:

Time is assigned to the horizontal axe, while the ± error-level is assigned to the vertical one. It presents the mechanical deviation compared to that of the ideal one (which is intended by the PC) as the function of the time. „The overshot ” forming during changing direction and the true track-following on the smooth sections can be studied with its help.

The measurement is triggerable (it can be started above a given error-level). The trigger level can be given with the value of the „i” register (in absolute Encoder Step units). If the trigger-

monitoring is switched on, then the transient presentaion will start at t0 position of the horizontal axe. The time scale increases from the left to the right.
Taking the mouse to the figure, the current time and error-level data on the spot of the mouse pointer can be read in the Pointer filed. With the help of the left mouse button a time marker can be set and pressing this button again the closing marker can be set. The time interval between the markers can be read in the Marked field. This makes the possibility to measure the width of the treansients (in the time).
The makers can be deleted by the right mouse button.

The LED on the top signals the status of the Tracking Error Monitor. Its colour is green, when the praphic presentation is on and red when it is off.

The software keys of the graphic presentaion are on the buttom of the screen.
The monitoring can be started by **Start**, and it can be stopped by **Stop**. To change trigger mode and to start monitoring at the same time can be realized by **Trigger on** and **Trigger off** keys (through the Fuses). The **Save** key will save the current transient screen in BMP file-format. By the **Load** key a previously saved tarnsient srceen can be loaded, and this may also be the background for the next tarnsient for comparison purposes.

By **colour keys** the colour of the drawing can be changed. It is worth using this feature if the next transient is going to be presented on a screen previously loaded.

Right-side field:

This is the configuration side of QDSP. The registers and fuses can be adjusted and querried through this field.

Comm The serial communication port must be assigned in the pull-down menu.

A **Detect** key querries the PID frequency (time data) of QDSP and sets the display above it and the time axe of the graphic presentation.

The **Registers** key lists the registers and their current values.

The **Special** key lists the special commands and registers of DSP.

The **Save** key saves the content of the window in txt format.

The most buttom window is the field for inputting commands. The modifying commands can be inputted here (e.g.: n4+ENTER). Typing only an empty ENTER in the line has the same effect as the Registers key has. If the generated list does not fit to the field displaying it, a side bar will appear, by which the screen can be scrolled (it is useful to use this for the display of full configuration of QDSP and for saving it).

QDSP Special Configuration menu:

State of Fuses:

It lists the current content of the Fuses . It is the same as the 'u' command.

Thermo protection on 60°C, 80°C, 100°C:

Sets the heat-protection to 60, 80 or 100°C.

Motor protection off (Temporaly):

It temporarily makes the overload-protection of the motor inefficient (for testing purpose).

Soft limit with Fault signal:

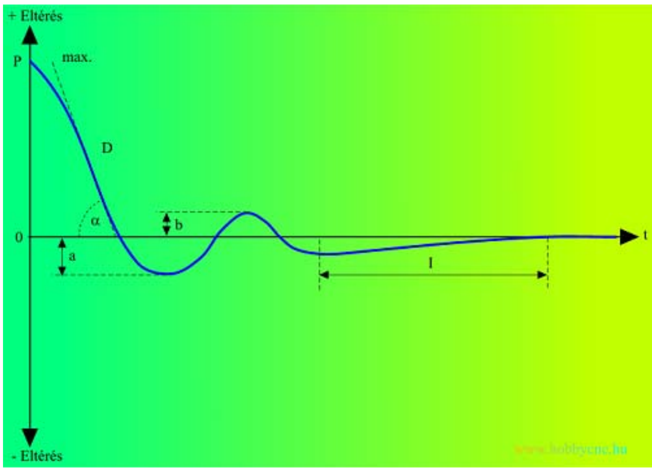
If the Error-level exceeds the content of the Soft limit register, Fault signal will be generated in the output.

Soft limit without Fault signal:

No Fault signal will be generated if the Error-level exceeds the content of the Soft limit register.

PID adjustment

(tuning the servo controller with the motor)



Theory:

The operation of servo controls totally differs from that of stepping motor controls. As the principles and the processes taking place are rather complicated, therefore only a brief description can be given here (at user level).

Fitting the Encoder:

DC motors do not have a predetermined stepping position as the stepping motors, so this function is totally realized by the control, with the help of an encoder mounted to the motor. This means continual and dynamic holding in position (if it is moved out from there, it will stand back).

The resolution of the motor is basically determined by the encoder, though it can be modified upward and downward by the control in some extent.

DSP is able to use the Encoder in 2 modes:

It uses the base resolution of the encoder (the number of its lines) - in 2× (duobling) mode doubling it,

- in 4× (quadroupling) mode quadroupling it.

The 4× mode is preferred and recommended so that the more precise position following could be realized. In case of very high Encoder base resolution (>2000) the 2× mode is recommended.

Beside that DSP is able to multiply the Step signal through its („Step multiplier") register, in an extent of 1× - 10×.

It is necessary because of the CNC softwares, as the softwares are able to output (usually through the LPT port) Step signals only with limited frequencies. It would result in too low maximum revolution number in case of high-resolution Encoders.

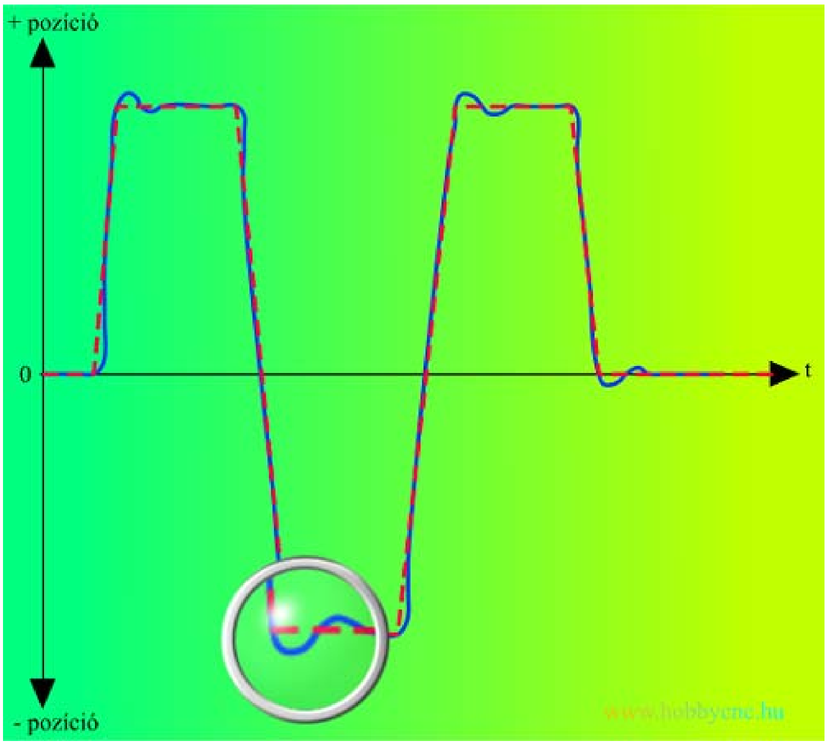
The maximum revolution number available can be calculated by the following formula:

$$f_{max.}=((F_{Kerner}\times \text{Step multiplier})/(E_{resolution}\times E_{mode}))\times 60 \quad \text{[rev./minute]}$$

$f_{max.}$=the maximum revolution number available [1/min],
F_{Kerner}= is the maximum stepping frequency of the CNC software programme [Hz],
Step multiplier= is the value of the internal Step multiplying register of DSP,
$E_{resolution}$= is the base resolution of the encoder [the number of its lines, PPR],
E_{mode}= is the value of the DSP „Encoder mode” internal register [2 or 4],
×60 = changing to minute.

Important!
As the feedback of the whole system is realized through the Encoder, its resolution influences all the other dynamic parameters (overshot, liability to swing, etc.) too. It is recommended to use the possible highest resolution, so that the possible best controlling ability could be reached.

Position-true following; swings; PID:
In a Step/Dir system the control will follow the moving commands with some time-delay, as it does not know in advance where to go. This delay is extremely small and negligible in case of smooth and uniform movements. In case of sudden and big changes of speed (e.g. changing direction) this delay is bigger, might even be substantial. The source of this delay are inertia of the mechanical parts (torques) and the response time of the motor+elektronics.

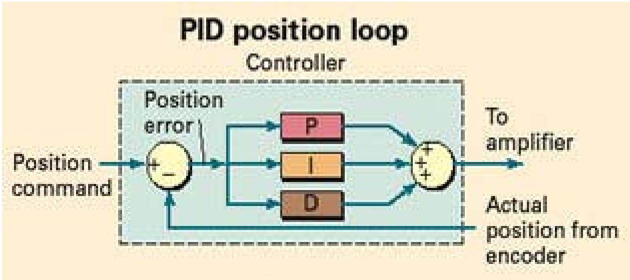


(rough sketch of the moving track)

The figure above shows the rough sketch of the deviation of the moving track. The dashed red line represent the moving track to be realized (with direction changes without accelerations and retardation), the blue line represent the real mechanical track. It can be seen that the control can follow the commands only with some swings and deviations at the points of direction changing. The so-called PID control procedure has been developed to solve this problem. This procedure is realized in the DSP internal software.

PID:
The PID control tries to hold the mechanical part in the track to be realized. This is realized by the motor excitation calculated from the resultant of three main components. The PID shortening comes from the initials of these components.

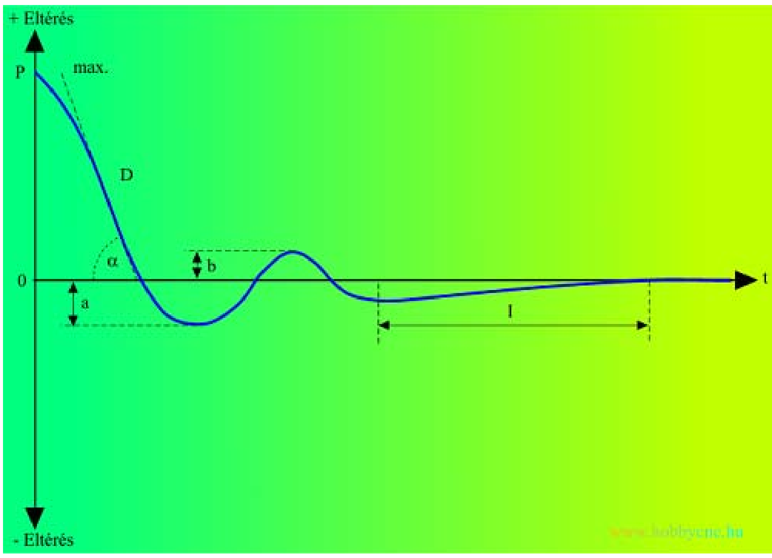
P = Proportional (proportional component);
I = Integral (error-integrating component);
D = Derival (component reacting to the fast changes).



P = proportional component. It raises the motor excitation proportionally to the deviation between the current and the intented positions. Its extent influences the motor dynamics (with how much force it should react to the increasing errors).

I = error-summing component. It amplifies the small remaining position errors, by summing them up, and it will set the motor to the intended position. It is for eliminating of small errors. its response time is relatively long.

D = fast response component. Its task is the fast response to the fast, sudden changes, excitation with extra dynamics. It will increase or decrease the excitation proportional to the speed of chages, intensifying by this the reaction of the motor or its swing-dumping (negative reaction). It is reponsible first of all for the swing-dumping (stability) of the system. It operates only when the speed changes and its effect is proportional to the chnages.



(transient curve)

The curve above shows a mechanical response to a track demanding a fast, sudden (pulse-like) position-change (mechanical setting-up). It represents a motor approachiung 0 point at a great speed, the mechanical parts will stop with swings and will set to the 0 point in the end. The interventions of the PID controller can be well observed.

P gives the base excitation, which increases proportionally to the extent of the deviation (this is the base torque for the motor). D gives the maximum angle of incidence (dumping), which is reponsible for the dumping of swings. The greater the angle is (the smaller the effect of D component), the more and greater overshots (a+b) can be measured, and the more time is needed for the system to to return to normal. The component I is responsible to fix remaining position-error (amplifying them after a time so much that it will set the motor to the position intended). It has a great importance in realizing the position-true moving

The effect of the PID components:

- P component: by increasing it the track-true moving of the motor will be better, the torque of the motor will increase.
- Low P component : great position-deviation errors, slow response, weak motor.
- High P component: over-reacting, swinging system (oscillation), jerking motor, liability to swing after direction changes.

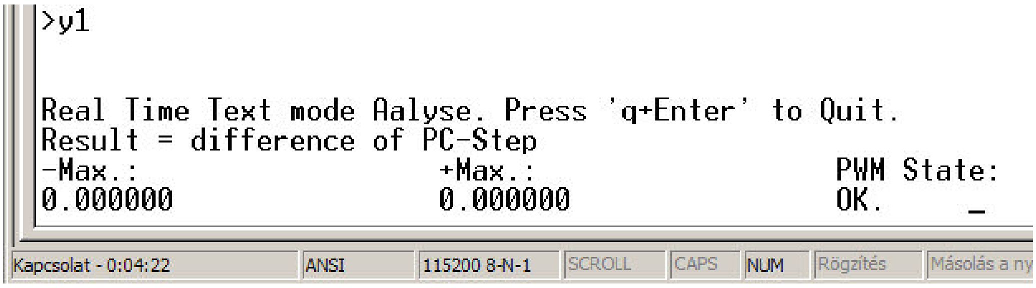
- By raising component I the position following will be better, the system will keep the 0 error-level harder. In case of position-following error the system will faster and more rigorously stand to position.
- Low I component: the remaining error will not be eliminated (not track-true position following, developing remaining errors after direction changes).
- High I component: swinging, oscillating mechanics (overcompensation), strong jerking, swinging motor. Strong oscillation, which cannot be dumped.

- By raising component D, the accelerations will be more dynamic, the retardations will be realized with higher dumping. The stability of the system increases (swing dumping), the response time will increase too.
- Low D component: oscillating (swinging) system, swings, which will be dumped only slowly or not at all will be dumped after direction changes.
- High D component: overdumped, rigid motor-drive (srong warming-up in the motor and slow response, grouchy motor-voices).

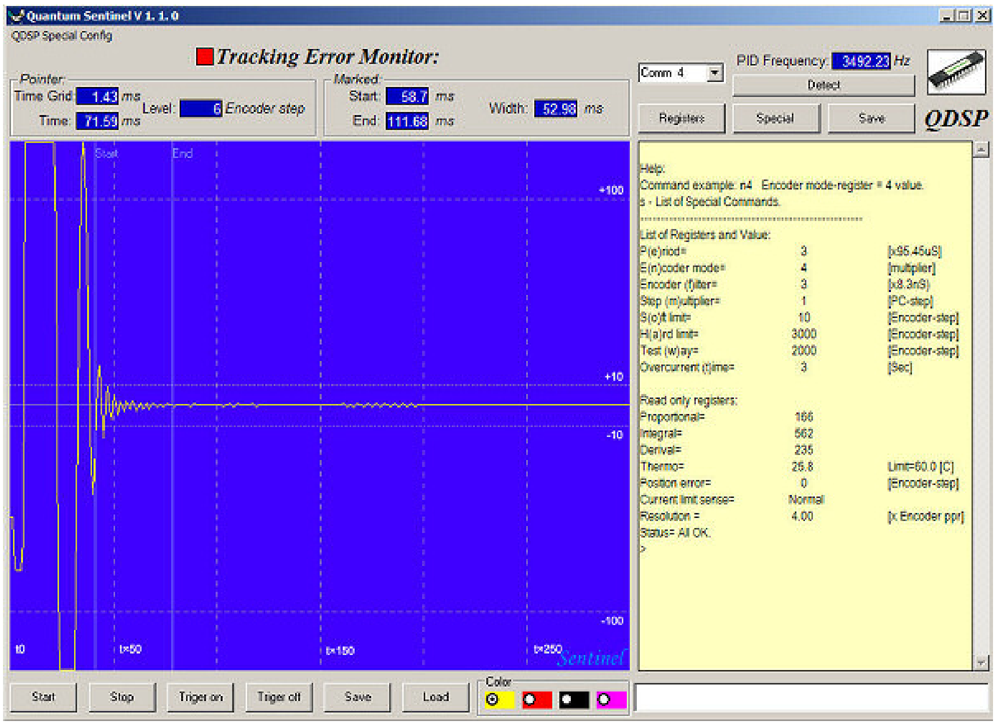
Whe the motor is adjusted, all the three component must be adjusted at the same time. The quality of the control is determined by all the three components, therefore there are several sets of the values of the three componets, which result in good control.

Tuning of PID control:

As the phenomena cannot be followed by eye at all, threfore the built-in serial monitor (together with Quantum Sentinel or Hyperterminal) must be used for the exact adjustment of the controller.
It is worth studying this by all means, therefore before tuning please read carefully their description.



(non-graphic error-level analysis by the means of Hyperterminal)



(graphic analysis by the means of Quantum Sentinel)

The PID controller must always be adjusted together with complete mechanic unit (together with its braking resistance and its mass), possibly using the CNC control programme intended to apply (e.g. Mach3) (with the speed and acceleration intended to use). Running the monitor and Mach3 at the same time, the adjustment must be performed on each axis proceeding axis by axis.
The basic knowlidge of Mach3 CNC control programme is necessary for the adjustment.

Before adjustment Mach3 must be configured, as well as the base resolution of the CNC machine and its speed and acceleration values must be set-up. As for as the acceleration values the data of the motor must also be taken into account, because greater acceleration than the motor is capable (taking into account the gear ratio) will result in untrue error-levels. It is worth testing the acceleration values proceeding from the lower values to the higher values.
During the adjustment the mechanic parts will perform jumbled movements, and measuring these movements with the help of the monitor, the adjustment can be performed. The aim is that the mechanical parts could follow the moving track intended by the PC with the possible lowest error.
The moving track will be realized by a simple G-code programme, which must be loaded to Mach3 and it must be made to run with different speed and acceleration values.

Movement generating small programme (G-code):

```
G90G80G49
F2000
G1 X0.0000 Y0.0000 Z0.0000 A0.0000
M98 P1234 L50
G1 X0.0000 Y0.0000 Z0.0000 A0.0000
M5M30
O1234
G1 X0.0000 Y0.0000 Z0.0000 A0.0000
G1 X700.0000 Y00.0000 Z0.0000 A0.0000
M99
```

In the F line of the programme (here F2000) the programme moves the given axis (here axis X) at a determined speed (here 2000 mm/minute) 50×, between 0 and 700 mm, up to one end and back (performing cyclic subroutine calls). The marked lines need to be edited in the course of the test from time to time. The line F (here F2000) needs to be edited if the speed is intended to increase (in mm/minute unit), the line G1 X700.0000 ... needs to be edited if the other axes are intended to move (e.g. for axis Z the line G1 is X00.0000 Y00.0000 Z700.0000 A0.0000). If the value of the move is not suitable (here 700mm), it can be overwritten with any value (in mm units).

The Mach3 provides a screen for editing the programme (by using the notebook of Windows).

The process of the adjustment:

Important!
Before beginning the test, make sure whether the encoder is properly connected. In case of reverse (channel A and B) connection the motor will run to one direction at full speed. The connection can be checked with disconnected motor switching it on and trying to move out its shaft from position, the motor must not accelerate its spinning. In case of reverse connection exchange the two ends of the motor wire.

1. Set up the internal registers (Encoder mode and Step multiplier registers). This will also determine the extent of the available resolution, which must be set-up in Mach3 (see the formula above), referring to the given axis. In case of changing the Encoder mode, the controller must be restarted.

2. The current limit must be adjusted to the maximum allowed peak-current of the motor. (Limit potentiometer trimmer).

3. Do not connect the protection output for the time of the adjustment (FAULT output).

4. The resolution of the axes, their speed values and the acceleration values must be set-up in Mach3 (the initial value of the speed should be minimum 15000 mm/minute, the initial value for the acceleration should be 100 mm/s^2). The acceleration values and those of the maximum speed will be necessary changed in the course of the adjustment.

5. The G-code must be loaded into Mach3 and the move for the axis going to be tested must be set-up by editing this code (e.g. if axis Y is going to be tested, then the co-ordinate must point to the value of 700.0000 and the others must point to 00.0000)

6. The 3 PID potentiometer trimmers must be adjusted to minimum (the slides must be set to towards GND). Then raise the slides of the potentiometer trimmer of P and D up to about 1/3 of the total length.

7. All the shafts of the machine must be adjusted to the middle position and make sure there is a track-length of 700 mm to both directions (if the track available is not so long, then the extent of the move in the test G-code must be reduced).

8. Start the programmes and the test. Observe the move and should the system swing heavily, adjust component P.

9. With the help of the Monitor programme measure in continual mode the lags (delays) and by adjusting component P set-up a delay between 0 - 10 Step (measuring it in the smooth section).

10. If the mechanic parts swing heavily at direction changing, then raise component D until the process becomes controllable (too strong is not at all ideal).

11. By raising gently component I adjust the system so that the controller could reduce the error 0 - 3 steps during smooth movements (with slight swing at near 0). Be careful, because too high I component may result in heavy swings. Should this happen, switch off the motor, take back component I and then continue tuning the system.

12. At this Mach set-up (with low acceleration values) a well-adjusted controller will work at each point (even during direction changes) with 0 error (max. ±3 Steps). The tuning must be done (by P-I-D adjustments) until this state is reached. If the mechanical parts get stuck, run untrue, then a little bigger error is also acceptible.

13. The error must be checked at several speed values (e.g. at 10, 100, 500, 1000, 3000, 4000 mm/minute, etc.). When increasing the speed the error may increase a little temporarily at the time of direction change, but the controller must fix it quickly (it can be mended by raising component P or component I). In case of increasing swing, component D can also be increased (but the system must be checked at lower speed values too).

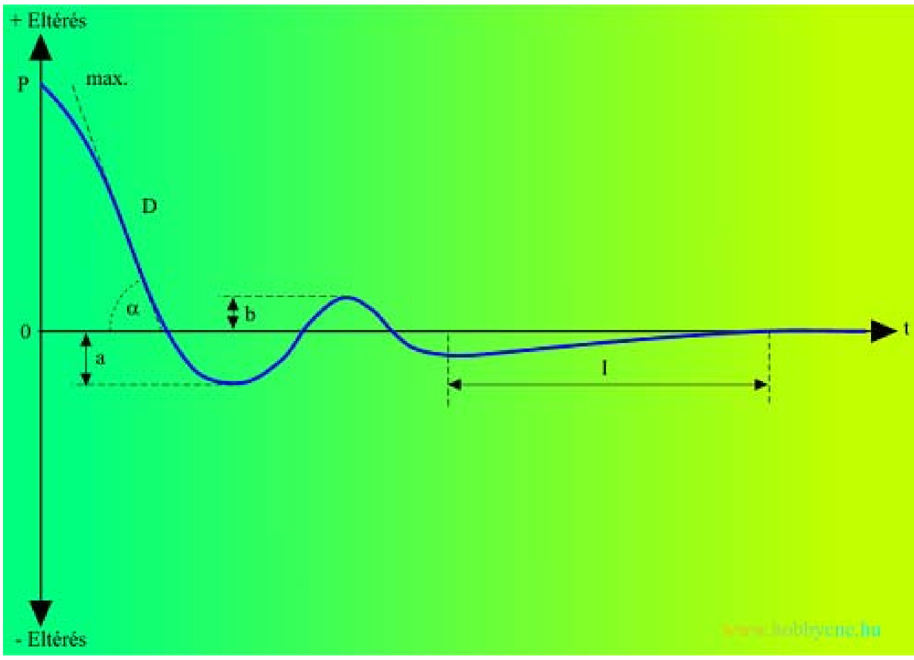
14. None of the 3 items must be overfed. The slide of the potentiometer trimmers must be stopped just at the right position, where the error is just eliminated. Othrwise the adjustment will result in an overreacting control.

15. If everything is all right, the value of the motor acceleration of Mach3 may be raised and the error peaks developing at changes must be checked.

16. The best set-up value for the acceleration is where the controller is able to produce an error of (max. ±3 Steps) at near 0 even during braking and acceleration too. If this value has been found, then our system will be able to work with this acceleration value. In fast operating mode a short (pulse-like) error-signal is allowed even with a Step value of 50. If component I can even compensate this error in the linear part, this acceleration value can also

be used (only in fast operating mode). The error-level can usually be adjusted between ± 3 Steps.

17. Stress Test:
To perform this test, Mach3 must be stopped and Test button of the controller must be pressed. The test is OK, if the motor jumps and stand to the test without oscillations. In case of remaining oscillation either component I and or component P must be reduced, or component D must be increased. If it was necessary to adjust any of them, then it is necessary to check the system at the above-written speed values.



(test with the Test button)

For this test the graphic display of Quantum Sentinel in Triger on mode is ideal.

18. Holding in position test:
With Mach3 stopped, observing the Monitor the error-signal must be between 0 (+-1). Then hold on the shaft of the motor with your hand and try to move it out. The motor must force back the shaft to the 0 position up to the force of its torque. This can also be traced on the data of the Monitor. The strength of position-holding can be increased mainly by raising component I, in a little extent by raising component P. If any of the three component was adjusted, the system must be checked in moving state too.
In case of a motor vibrating and emitting grouchy voices at standing position, the value of Antitremb(l)e register must be raised so that this state could be eliminated. It is recommended to apply a low value (1 - 2) in this register, so that the best position-holding could be achieved.

19. If acceptable values have been measured at each point, the adjustment is successful.

Further tips:

So that more precise adjustment could be realized, the use of Quantum Sentinel software is recommended (in Triger off mode). Because of the resouce-demand of the programme the use

of an external PC is necessary (otherwise the pulses of Mach3 will be incorrect).
If the speed set-up at G-code is higher than the axis speed set-up in Mach3, the programme will cut down the motor (in this case the maximum speed of the axis at the Mach3 motor tuning must be raised).
A motor being in swing cannot be stopped by the end-position-switch, because the switch operates through the PC.
By bulding-in Stop, the controller can be stopped in any condition. After being stopped, the controller will work only after it has been restarted.
The Step pulses of poorer quality CNC softwares (e.g. KCam4) are not smooth enough. These can generate swings in the course of servo movements. Their use is not recommended.
If the swings developing at direction changes can no longer be further reduced, then lower acceleration values must be applied (at motor tuning set-up of Mach3).