DCS-3010
BRUSH DC MOTOR DRIVE

1. DESCRIPTION

DCS-3010 is a microcontroller PWM drive for permanent magnet DC (PMDC) motors with supply voltage up to 100 V DC and current up to 30 A. Drive is based on a 16-bit microcontroller with implemented PID control algorithm.

As the feedback of DC motor position an incremental encoder with phase-shifted square signal is used. Encoder interface enables 1x, 2x and 4x encoder resolution.

Adjustment of all parameters is performed by using the configuration software ServoTune3.

The input control interface enables control via opto-isolated lines in next modes:

- STEP/DIR/ENABLE,
- CW/CCW/ENABLE,
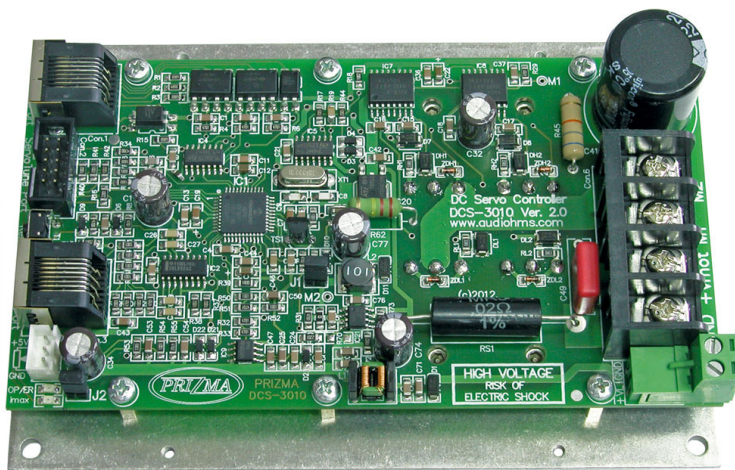- Encoder follower in 1x, 2x and 4x decoding,

as well as via analog input within the range 0–5 V with and without feedback (there is the connector on the drive for connecting an external potentiometer).

Build-in soft start enables DC motor 1s after powering on decreasing electric shock on start.

There is an opto-isolated output on drive named Track Error which is activated if adjusted value of tracking error offset is exceeded. That output can be used for activation of external circuit for DC motor emergency stop.

Drive has over-voltage and over-temperature protection.

If electric current is higher, drive can be placed on additional cooler.

APPLICATION
- CNC machines
- Coordinate tables
- Positioning
- Robots
- Education

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2. SPECIFICATIONS

Type	PWM closed loop PMDC Servo drive with PID controller algorithm
PWM frequency	10 ÷ 20 kHz, software set up
Number of axis	1
DC motor supply voltage	10 ÷ 100 V DC
DC motor current	3 ÷ 30 A max, software set up
Logic circuit power supply	18 ÷ 28 V DC / 200 mA
Input control interface	Digital control modes via opto-isolated lines STEP/DIR/ENA, CW/CCW/ENA and Encoder follower (1x, 2x and 4x) Analog 0 ÷ 5 V with and without feedback
Command line current	5 mA at 5 V
Output	Opto-isolated Track Error
Frequency of STEP command	< 600 kHz
Command line pulse width	> 0,5 µs
Feedback	Incremental encoder with phase-shifted square signal
Encoder resolution	$\times 1$, $\times 2$ and $\times 4$ multiplication, software set up
Encoder power supply	Source on drive +5 V DC / 250 mA
Parameter set up	Via IDC10 connector and programming interface (PI-RS232, IPI-USB or Bluetooth BT-PI)
Build in protections	Over-voltage and over-temperature
Dimensions (W x L x H)	154 mm x 105 mm x 45 mm
Weight	~300 g

NOTE: specifications are subject to change without notice

3. SEFETY PRECAUTION
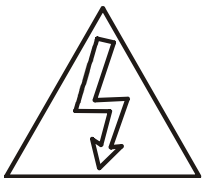
Drive installation can perform only person who has appropriate knowledge.

Supply voltages over 50 V DC can be danger of death. If supply voltage is over 50 V DC, aluminium heat sink has to be properly grounded.

Use only galvanic isolated power supply for drive DCS-3010. Opto-isolated space between input-output command lines and controller electronics on drive printed circuit board (PCB) is around 5mm.

For **stop in case of emergency** it is recommended to interrupt power line of DC motor and, if it is possible, activate motor brake.

If temperature on drive exceeds 70 $^{\circ}$C over-temperature protection will be activated. It is recommended for drive to be placed in enclosures with good cooling and to ensure additional cooling if it is needed. In case when it is used fan for cooling, recommendation is using filter for dust.

Drive should not be used in places where, in case of failure, people safety is in danger, financial losses are big, or there exist other losses.

During drive operation should be used all required precautious.

Does not exclude the possibility that this document contains errors. In addition the manufacturer assumes no responsibility for any damage caused by the use of this drive, which has occurred as a result of compliance or non-compliance with this instruction manual.
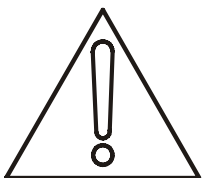
4. DRIVE OUTLOOK

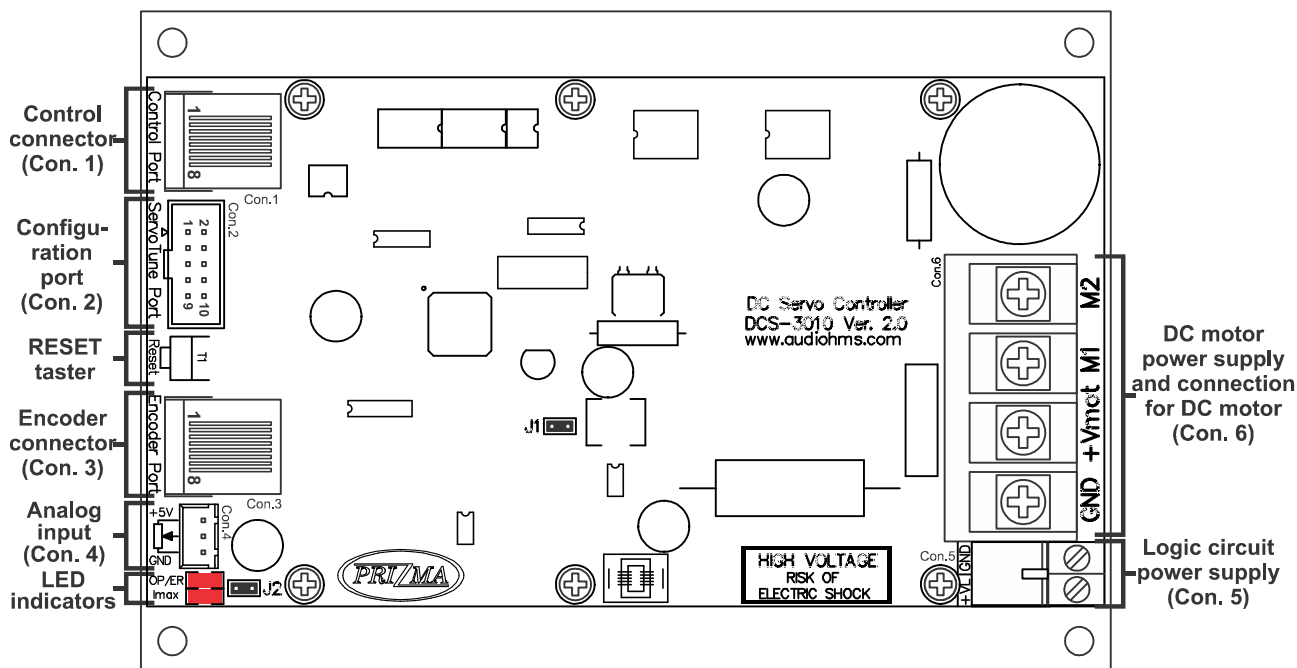Drive DCS-3010 has 6 connectors (from Con. 1 to Con. 6) as it is shown in the figure 4.1.

Figure 4.1 Connector positions on drive DCS-3010
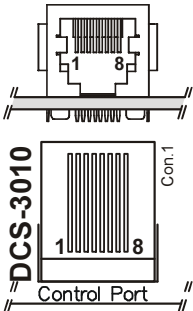
4.1 Control connector

Digital controls (STEP/DIR/ENA, CW/CCW/ENA or Encoder) are brought over the 8-pin RJ45 connector (control connector – Con. 1) as well as Track Error output. Track Error output that is activated when the tracking error exceeds the set value of the offset.

Control connector is designed so that the input-output card IO3-R2 is connected via 1-1 network cable (Ethernet cable).

Pin arrangement is presented in Table 4.1, and a schematic diagram of these pins is shown in Figure 4.2.

Tabela 4.1 Pins description of 8-pin RJ45 control connector (Con.1)

	Pin No.	Selected type of digital control			INPUT / OUTPUT
		STEP/DIR/ENABLE	CW/CCW/ENABLE	Encoder follower	
	1	STEP –	CW –	GND	Input 1
	2	STEP +	CW +	A +	
	3	DIR -	CCW -	GND	Input 2
	4	DIR +	CCW +	B +	
	5	ENABLE – (GND)			Input 3
	6	ENABLE +			
	7	Error output (emitter)			Output 1
	8	Error output (Track Error – open collector)			

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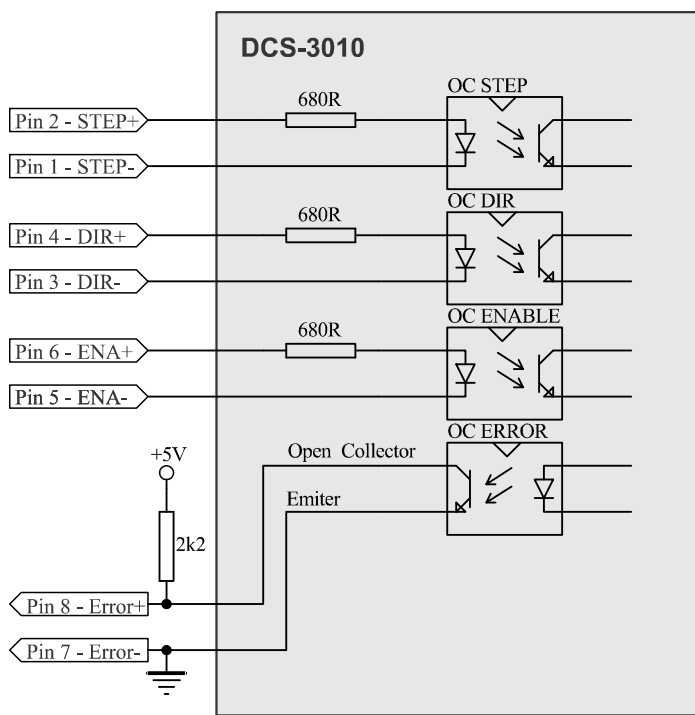Tel. +381 34 330 200, web: www.prizma.rs e-mail: prodaja@prizma.rs

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Figure 4.2 Schematic representation of opto-isolated inputs and outputs

There is a 680 Ω resistor at the optocouplers for STEP, DIR and ENABLE command, that limits the current to 5mA at the command voltage of 5V (TTL logical level).

If the logic command voltage at the entrances is higher, it should be placed additional resistors at lines 2, 4 and 6 and at connector Con.1 to ensure that the current does not exceed 5 mA.

EXAMPLE: If the drive DCS-3010 is control by using the PLC with 24VDC logic levels, it is necessary in each of the lines 2, 4 and 6 to the connector Con. 1 add the 3.9 kΩ resistor.

Here it is necessary to note that in line Track Error should be placed an external pull-up resistor.

Optoisolating distance between the input-output command lines of control connectors and control electronics on the PCB drive is approximately 5 mm.

4.2 The configuration port

Parameter setting (PID controller constants, encoder resolution, tracking error offset, etc.) is performed by using PI-RS232, IPI-USB or PI-BT interface for programming and configuration software ServoTune3.

Programming interfaces PI-RS-232, IPI-USB or PI-BT can be connected to the DC servo drive DCS-3010 via the configuration port marked as Con.2 in Figure 4.1 (10-pin IDC connector).
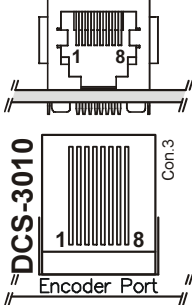
A detailed description of the setup parameters of DC servo drive DCS-3010 is given in the instructions for use the software ServoTune3.

NOTE: Configuration port ground is not galvanic separated from the drive ground. It is recommended to use insulation programming interface IPI-USB or PI-BT.

4.3 Encoder connector

For DC motor position feedback incremental encoder is used on DC servo drive DCS-3010. Encoder can be connected via encoder connector (connector Con.3 in Figure 4.1). Functions of the 8-pin RJ45 connectors are provided in Table 4.2.

Table 4.2 Description of encoder connector pins 8-pin RJ45 connector (Con.3)

	Pin No.	Name	Description	Function
	1	A+	A encoder channel (pull-up resistor 4.7 kΩ)	Encoder connection
	2	A-	A\ encoder channel	
	3	B+	B encoder channel (pull-up resistor 4.7 kΩ)	
	4	B-	B\ encoder channel	
	5	NC	-	
	6	NC	-	
	7	+Ve	Encoder power supply source 5 V / 250 mA max	
	8	GND	GND – Encoder	

Use an incremental encoder with phase-shifted square TTL outputs. It is recommended to use encoder with a minimum number of encoder pulses (lines) of 200 PPR. On the drive is the source of power supply for incremental encoder +5V / 250 mA max.

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On the DC servo drive DCS-3010 can be connected encoder with single-ended outputs (A and B, Figure 4.3) or encoder with differential (complementary) outputs (A+, A-, B+ and B- outputs, Figure 4.4). Encoder interface SED1 at the A and B inputs has pull-up resistors of 4.7 kΩ.
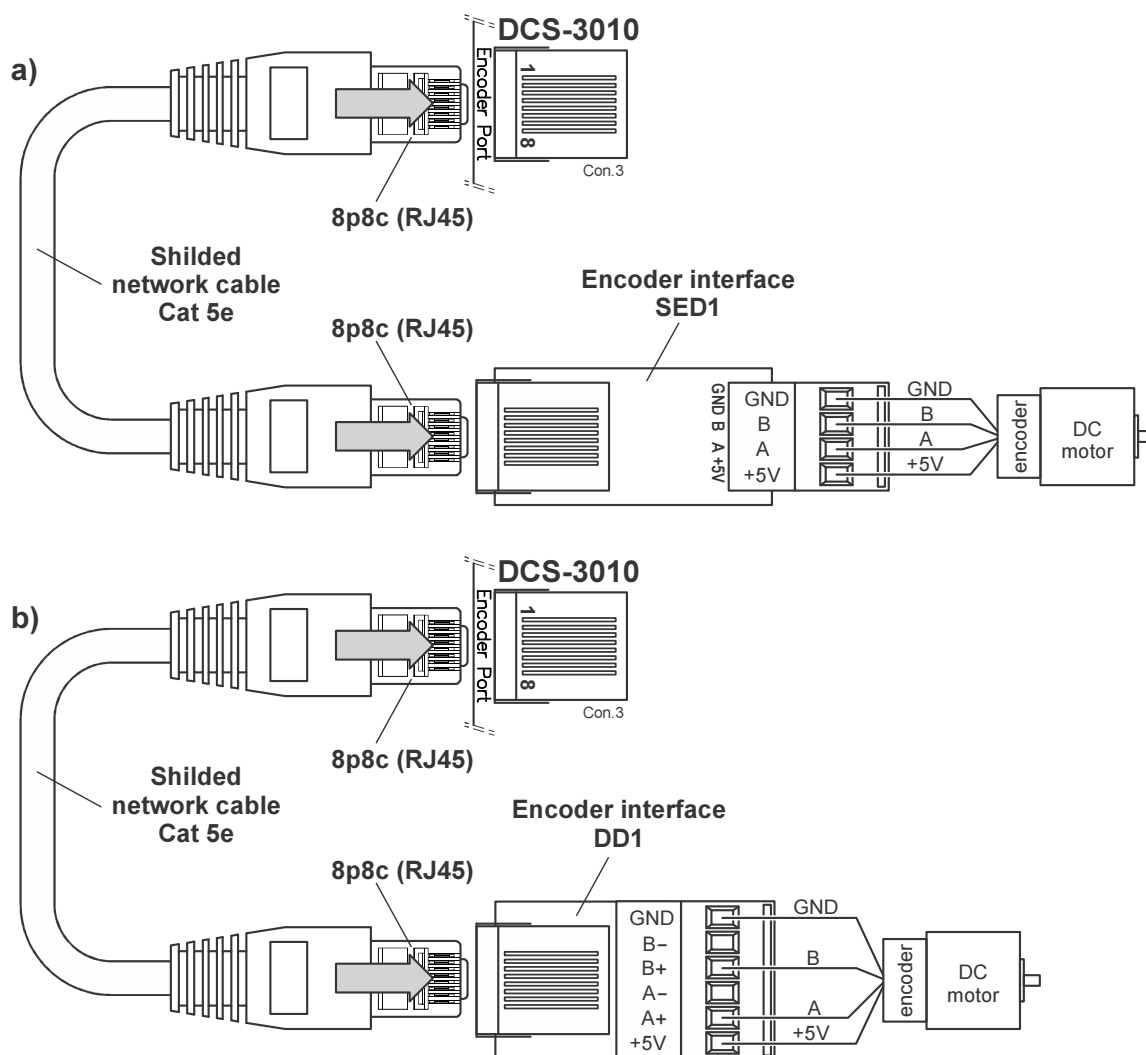

Figure 4.3 Connection of single-ended encoder with DC servo drive DCS-3010 via,
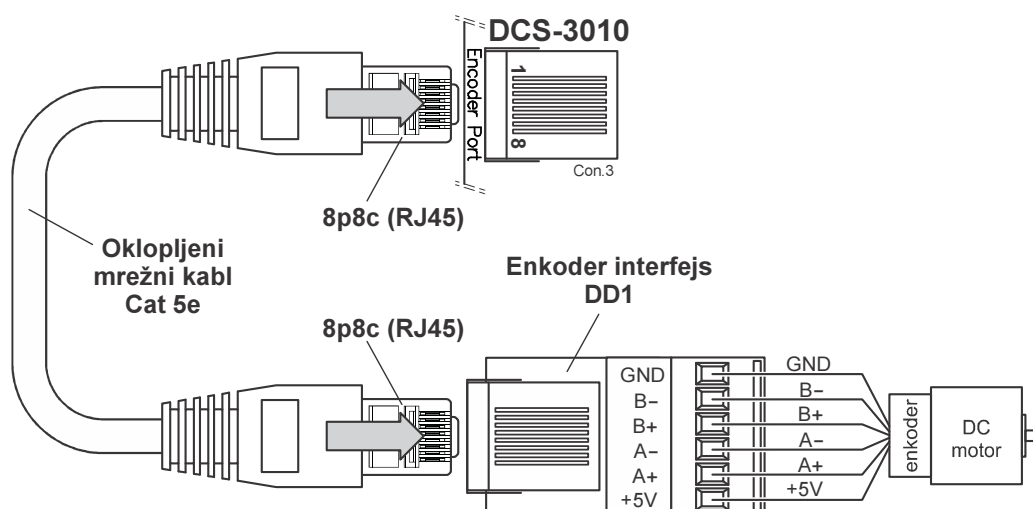a) SED1 encoder interface and b) DD1 encoder interface

Figure 4.4 Connection of encoder with differential (complementary) outputs via DD1 encoder interface on DC servo drive DCS-3010

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> **NOTE: Connection of single-ended encoder on DC servo drive DCS-3010 via DD1 encoder interface is not recommended for larger cable lengths.**

In order to reduce or eliminate the impact of high-frequency electrical noise is recommended to use shielded network cable Cat 5e for connection encoder interface SED1 or DD1 with DC servo drive.

Cable to connect the encoder should not be longer than a specific application requires.

4.4 Analog input

DC servo drive DCS-3010 has the ability to control DC motor via the reference voltage of 0÷5 V which is applied to the analog input connector (Con. 4 in Figure 4.1).

External potentiometer with nominal resistance of 1÷10 kΩ can be directly connected at the analog input connector as shown in Figure 4.5.a.

Figure 4.5.b the connection of external motion path generator. Voltage at the motion path generator output should not exceed 5 V DC.
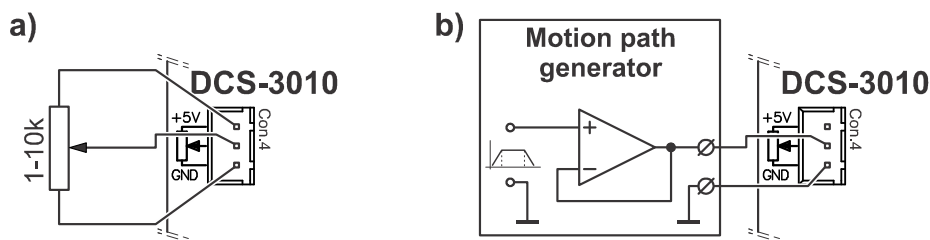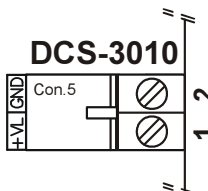

Figure 4.5 Voltage reference analog input DC servo drive DCS-3010 generated over,
a) external potentiometer and b) motion path generator

4.5 Logic circuit power supply

Logic circuit power supply of drive DCS-3010 is performed via a connector Con.5 (see Figure 4.1). Logic circuit supply voltage should be from 18÷28 V DC / 200 mA. It is not necessary that this source to be stabilized; it is enough that after rectification apply electrolytic capacitor with minimum capacitance 470 µF.
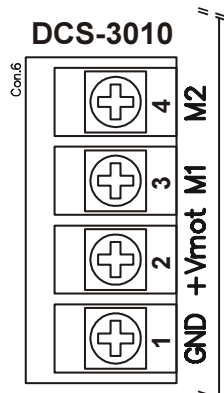
Table 4.3 Description of pins (terminals) in the 2-pin connector Con. 5

	Pin No.	Name	Description	Function
DCS-3010 Con.5	1	+VL	Power supply +18÷28V DC / 200mA	Logic circuit power supply
	2	GND	GND	

4.6 DC motor power supply and connection for DC motor

DC motor power supply and connection for DC motor is located on the connector Con. 6 (Figure 4.1).

Table 4.4 Description of pins (terminals) of connector Con. 6

	Pin No.	Name	Description	Function
DCS-3010 Con.6	1	GND	Ground	DC motor power supply
	2	+Vmot	+10÷100 V DC	
	3	M1	DC motor terminal	Connecting DC motor
	4	M2	DC motor terminal	

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DC motor power supply voltage V_{mot} should be 10÷15% higher than nominal supply voltage of DC motor, i.e.:

$$V_{mot} = 1{,}15 \cdot U_n \tag{1}$$

NOTE: Power supply voltage of DC motor V_{mot} must not exceed the maximum value of the drive DCS-3010 supply voltage.
If after connecting the DC motor to terminal M1 and M2 and after the arrival of the supply voltage, the motor starts rotating, and then stops and OP/ER LED indicator starts to flash 2 times (Tracking error indicator; see Table 6.1), it is necessary to replace motor terminals M1 and M2 (DC motor terminal M1 connect to terminal M2 and DC motor terminal M2 connect to terminal M1).

EXAMPLE:
Nominal DC motor supply voltage DC is $U_n = 48VDC$. What is the voltage required to power a DC motor?
$$V_{mot} = 1{,}15 \cdot U_n = 1{,}15 \cdot 48 = 55{,}2VDC \approx 55VDC$$

Calculating the voltage of the secondary windings of the transformer used to supply DC motor is calculated using the expression:

$$U_{sek} = 1{,}2 + \frac{V_{mot}}{1{,}41} \tag{2}$$

EXAMPLE:
For the previously calculated supply voltage of DC motor $V_{mot} = 55DVC$, secondary winding power transformer voltage is:
$$U_{sek} = 1{,}2 + \frac{V_{mot}}{1{,}41} = 1{,}2 + \frac{55}{1{,}41} = 40{,}2VAC \approx 40VAC$$

The current of transformer secondary winding depends on the characteristics of the connected DC motor and it should be 50 ÷ 100% higher than motor's nominal current. It is necessary to know that the DC motor in certain operating modes can pull much more current than it is nominal.

4.7 The connection of the breakout board IO3-R2 and connection the power supply

The recommended configuration of the breakout board IO3-R2, three DC servo drives DCS-3010 and the power supply DCS-3010, is shown in Figure 4.6.

Galvanic isolated power supply is recommended for Logic circuit power supply of each DC servo drive DCS-3010 and addition galvanic isolated power supply for the breakout board IO3-R2.

Power supply for DC motors can be carried out from one power source. It is recommended to place a slow blow fuse on supply line +Vmot for each drive DCS-3010.

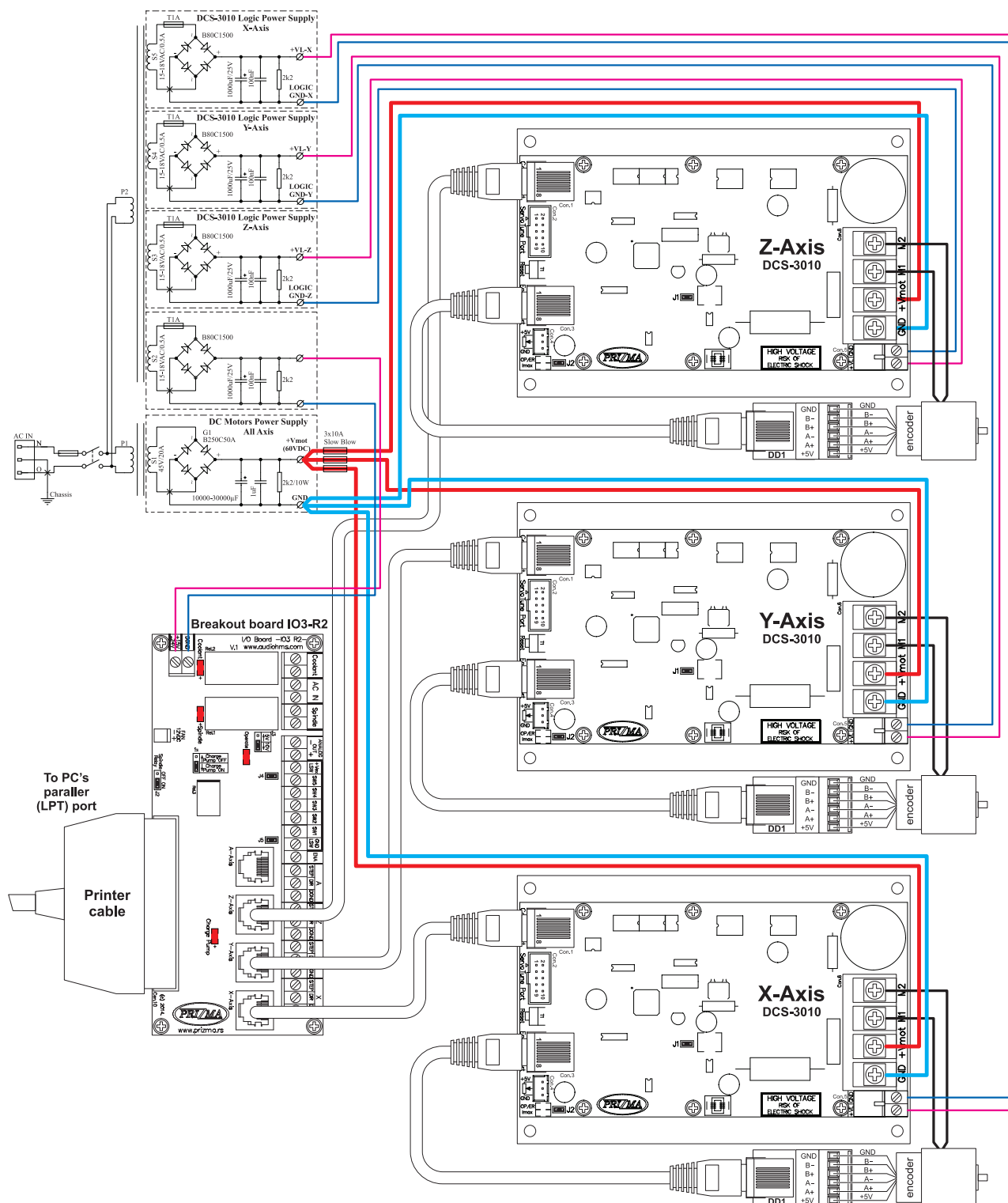**NOTE: Take care not to create a ground loop while system installation.**

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Figure 4.6 The connection of the breakout board IO3-R2 with 3 DC servo drives DCS-3010 and power supply circuit

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5. RESET BUTTON

RESET button is placed between configuration port Con.2 and connector for encoder Con.3 (see Figure 4.1). By pressing the RESET button it is possible to cancel the present error of DC servo drive.

In addition, pressing the RESET button performs the disable of output H-bridge, so it is possible to rotate the rotor of DC motor without disconnection of supply voltage.

6. LED INDICATORS

There are 2 LED indicators on the drive as follows:

- multifunctional red **OP/ER** LED indicator and
- red LED indicator **Imax** shows exceeding the maximum set current DC motor.

Table 6.1 Description of the state multifunctional **OP/ER** LED indicator

OP/ER	Description	
○	The control electronics is not under voltage	
●	Drive ready to start – ENABLE	
1 x ☀	Drive ready to start – DISABLE	
Errors	**Description**	**Action needed**
2 x ☀	Tracking error	- Increase the value of Error offset - Press the RESET button
3 x ☀	Encoder error	- Check the condition of the encoder and encoder cable - Turn off error detection of encoder - Press the RESET button
4 x ☀	Over-temperature protection is activated *	- Provide better cooling of the drive - Press the RESET button
5 x ☀	Over-voltage protection **	- Provide a source with the lower voltage for DC power supply
6 x ☀	Circuits for setting the level of the maximum current error	- Press the RESET button - Contact the authorized service
7 x ☀	Error of microcontroller	- Press the RESET button - Contact the authorized service

The limit of activation over-temperature protection is set at 70 ^{o}C.

**The limit of activation over-voltage protection is set at 120 VDC.*

WARRANTY

Manufacturer guarantees that all DC servo drives DCS-3010 will work in proper upon delivery. Before delivery all DC servo drives DCS-3010 are tested on power supply voltage with connected DC motor in range of 20÷90 VDC and output current up to 20A. Supply voltage which that exceeds the maximum allowed value, incorrectly connected power supply, incorrectly connected and defective DC servo motor, strong electromagnetic discharge (close to contactor) etc. can damage the drive.

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9. ServoTune3 – INSTRUCTIONS MANUAL

To adjust the parameters of drive DCS-3010 use the configuration software **ServoTune3** (Figure 9.1). The software consists of a single file and to install it is necessary to copy the file to the desired folder on your computer.

The configuration software ServoTune3 will works on Windows XP, Windows Vista or Windows 7 operating system.

Software ServoTune3 enables:

- Adjusting the PID controller constants,
- Adjusting the encoder resolution multiplication,
- Adjusting the steps multiplier,
- Enable/disable of drive DCS-3010,
- Setting the number of steps to capture the response of DC motor on step function and drawing diagrams of the motor position response, diagram of voltage and current change,
- Adjusting values of Tracking error offset,
- Read the current value of the position of DC servo motor,
- Recording of log file with the values of set position, current position difference and values of the DC motor electric current,
- Selection of input interface type (STEP/DIR/ENA, CW/CCW/ENA, encoder 1x, 2x or 4x or analog input with and without feedback),
- Selection of PWM frequency,
- Setting options of digital filter for encoder input,
- Setting the maximum electric current through DC motor etc.
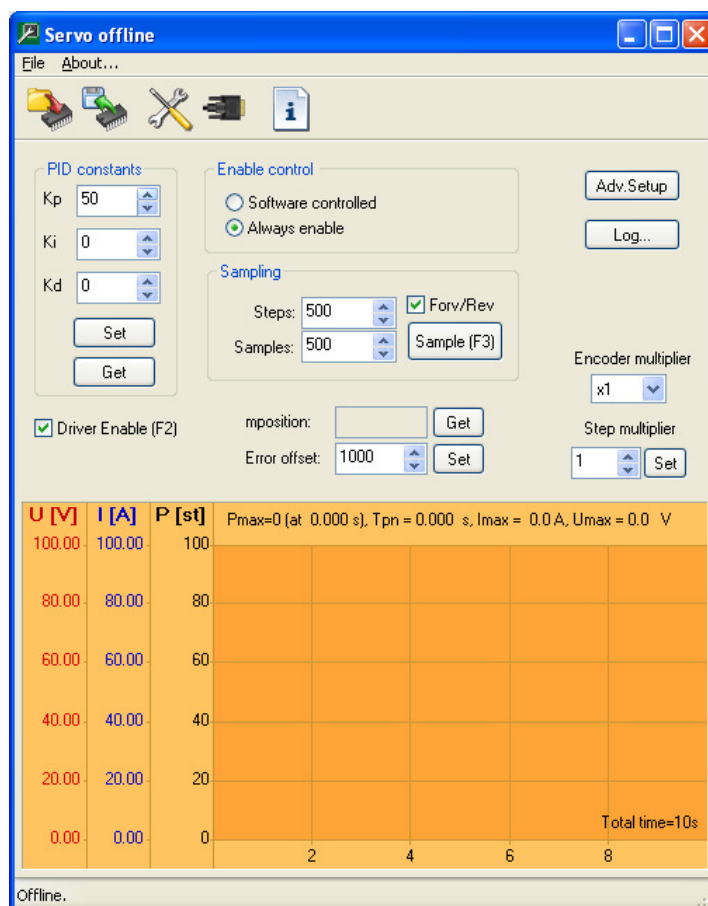
Figure 9.1 ServoTune3

NOTE: Software ServoTune3 is used for adjustment of working parameters of drive DCS-3010. This software is not appropriate to control DC motor.

9.1 COM port selection

Connection between software ServoTune3 and PC with drive DCS-3010 is achieved via programming interfaces PI-RS232, IPI-USB or PI-BT. Setting parameters for the COM port is done through dialogue from the Figure 9.2 which is accessed by selecting option **File -> Communication setup** or by pressing the icon

.

Set the serial number of the COM port that is connected to the interface for programming as well as the desired baud rate. If check box 'Save to EEPROM' is activated, selected value of baud rate will be recorded in microcontroller EEPROM.
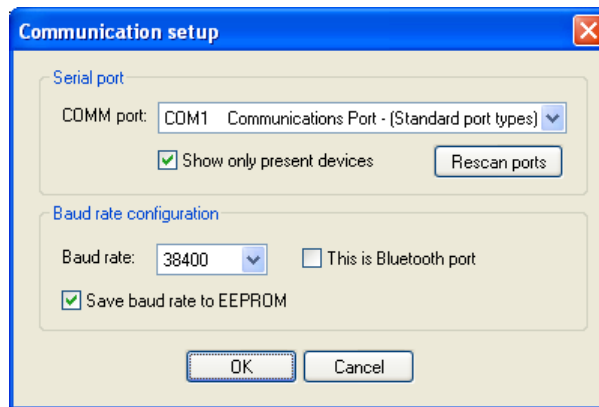
Figure 9.2 Communication setup dialog

At the ServoTune3 application top will appear label that the drive is online with version of firmware (Figure 9.3) if communication between PC and drive is established. From drive DCS-3010 all parameters will be read and printed in the appropriate fields.

Figure 9.3

In the case that communication is not achieved with the drive DCS-3010, after starting software ServoTune3 warning dialog will appear, as it is shown in Figure 9.4 and **servo offline** status in main window, as it is shown in Figure 9.1.
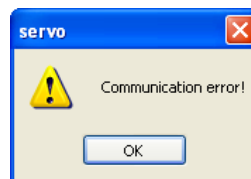
Figure 9.4 Error opening COM port

This error occurs when the parameters are not set up correctly (number of COM port and baud rate) or when the programming interface is not connected to the drive. In some cases, may occur a breakdown in communication with the drive DCS-3010 and then it is necessary shut down the ServoTune3 software, restart the drive DCS-3010 by pushing RESET button and start the ServoTune3 software again.

9.2 Setting the PID controller constants
Drive DCS-3010 is based on the 16-bit RISC microcontroller with PID control algorithm in it. Setting these constants is performed in fields that are shown in the table below.
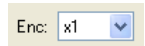
	Name	Description	Minimum	Maximum	Default
	Kp	Proportional gain constant	0	32768	50
	Ki	Integral gain constant	0	32768	0
	Kd	Derivative gain constant	0	32768	0

Pressing the button **Get** from EEPROM values for Kp, Ki and Kd will be read. To write new values in EEPROM microcontroller, it is necessary to press the **Set** button.
NOTE: During setting PID constants take all precautions as it may cause oscillation in DC servo motor – machine mechanics system.

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9.3 Setting the encoder resolution multiplication

Drive DCS-3010 has the capability of software adjustment for encoder resolution multiplication. So it is possible to encoders with relatively small number of pulses per revolution to obtain 2 or 4 times higher resolution.

	Name	Description	Values
Enc: x1	Enc	Encoder resolution multiplication	x1, x2 and x4

EXAMPLE:
Encoder with resolution 500PPR (pulses per revolution) will have:
- 500PPR for encoder multiplication 1x,
- 500PPR x 2 = 1000PPR for encoder resolution multiplication 2x and
- 500PPR x 4 = 2000PPR for encoder resolution multiplication 4x.

9.4 Setting the steps multiplication

Steps multiplicator shows how many steps do the DC servo motor for each pulse on the STEP command line. This parameter is useful in the case of using the high-resolution encoder, but STEP command generator has no possibility of generating pulses of sufficiently high frequency.
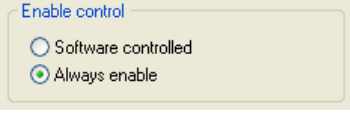
	Name	Description	Minimum	Maximum	Default
Step multiplier 1 Set	Step multiplier	Step multiplication	1	50	1

To write desire values in EEPROM microcontroller, it is necessary to press the **Set** button.
NOTE: Higher values for the step multiplier can lead to unsmooth movement, especially at low speed.
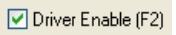
9.5 Control of enable input on drive DCS-3010

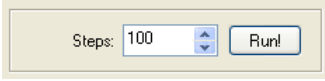Options for control of drive DCS-3010 enable input are shown in Table below.

	Name	Alternatives
Enable control ○ Software controlled ⦿ Always enable	Enable control	**Software controlled** – In this mode ENABLE input at control connector Con.1 (Figure 4.1) is activated. If there is logical unit at the ENABLE input, the drive is active and will carry out the commands that come from STEP and DIR command lines. In the case that at ENABLE input is logic zero then the drive DCS-3010 is disabled, commands STEP and DIR are not carried out and DC motor is not under voltage (this option is often used if it is necessary to manually rotate the DC motor). **Always enable** – In this mode ENABLE input at control connector Con.1 (Figure 4.1) is not activated. Drive is always activated (enabled).

From software ServoTune3 can be performed selection of ENABLE mode of drive DCS-3010 during setting parameters. The change of check box can be performed by pressing the function key F2.

	Name	Description	Options
☑ Driver Enable (F2)	Drive Enable	Drive Enable	ENABLE – selected (DC servo motor is under voltage) DISABLE – not selected (DC servo motor is not under voltage)

9.6 Record response of DC motor to the step function

In order to adjust the parameters of PID controllers easier, ServoTune3 software provides the ability to record the response of DC servo motor and attached mechanics to which is connected to a step function. In addition, it is possible to set a desired number of steps.

	Name	Description	Parameters		Min	Max
			Name	Description		
Sampling (Steps: 500, Samples: 500, Forv/Rev, Sample!)	Sampling	Recording response	Steps	Number of steps	1	32767*
			Samples	Number of read values	1	32767
Steps: 100, Run!	Steps	Performing a desired number of steps without recording the response	Steps	Number of steps	1	32767*

* Maximum value of Steps should be lower than set value of Error offset. Otherwise tracking error will appear and DC servo motor will be disabled. Cancelling of tracking error is performed by pressing the RESET button or by switching off the DCS-3010 drive power supply.

Activate the appropriate function is performed by pressing the **Sample** or **Run**.

Pressing the **Sample** button, or by pressing the function key F3, DC servo drive will handle the given number of **Steps**. By setting the check box **For/Rev** for each pressing of **Sample** button DC motor will handle a given number of step alternately in one and then the other direction of rotation.

After the execution of Sample command will be drawn diagrams of DC motor response at step function, and charts of the changes of voltage and current through the DC servo motor (Figure 9.5).
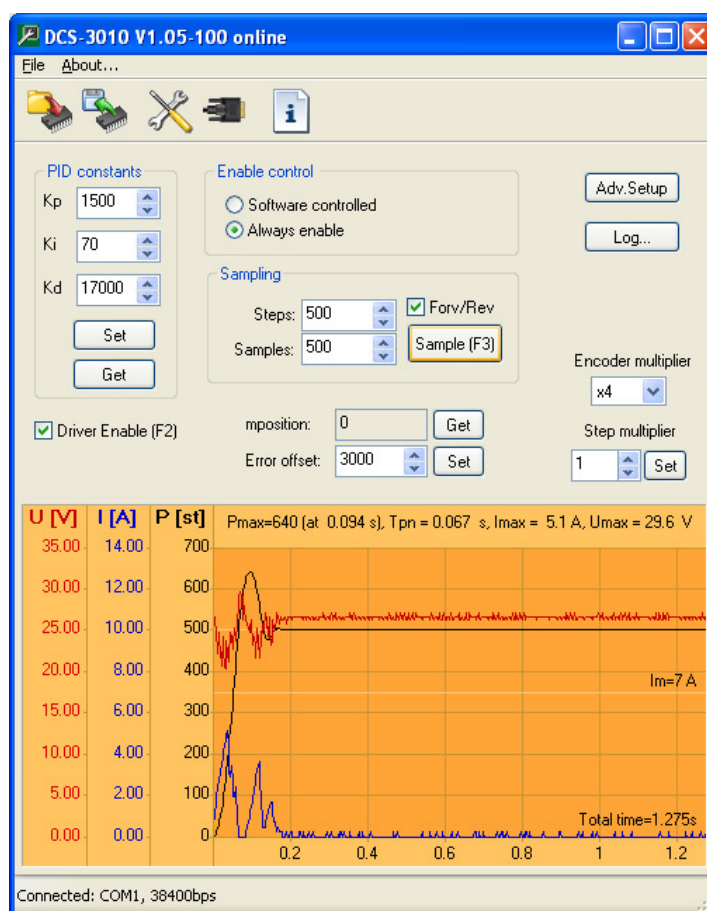

Figure 9.5

The recorded values of the DC motor position, power supply voltage and current through the DC servo motor will be saved in a file called `odziv.dat` which is located in the folder that contains software ServoTune3. The following is a small sample of the file `odziv.dat`.

```
% ****** ServoTune sampling output ********
% Date and time: 07.12.2012 07:27:39
%  Time[s]   Position Current[mA] Voltage[V]
  0.000000         0        244       26.63
  0.001500         1        488       27.12
  0.004000         9       1220       26.13
  0.006500        26       1464       24.65
  0.009000        48       1953       25.15
  0.011500        76       2441       22.19
  0.014000       111       2685       24.65
  0.016500       152       2685       23.67
  0.019000       200       3173       22.68
  0.021500       254       3417       20.71
  0.024500       315       3906       24.16
  0.027000       396       4150       22.68
  0.029500       471       4394       20.71
  0.032000       553       4638       20.21
```

The first column of the file is the time, the second column is the current position of the DC motor, the third column represents the value of the current through the DC motor in milliamps (mA) and the fourth column is the change of supply voltage DC motor in volts (V). The values from the file `odziv.dat` can easily be imported into the software for drawing diagrams (Excel, MATLAB, i.e.).

9.7 Setting values of tracking error offset

Setting of tracking error offset can be performed by entering the desired values in a field named Error offset.

	Name	Description	Minimum	Maximum	Recommendation
Error offset: 1000 [Set]	Error offset	Tracking Error offset	0	32767	bigger than 100

To save desire values of tracking error offset into EEPROM it is necessary to press the **Set** button.

If the difference of set position and the current position DC servo motor exceeds the set value of tracking error offset, Track Error output activates (to the control port), and **OP/ER** indicator will denote Additionally, DC servo motor will be DISABLED. Cancelling the tracking error offset is achieved by pressing RESET button or switching off the drive DCS-3010 power supply.

9.8 Read the current value of the DC motor position

Reading current position of DC servo motor, i.e. encoder position (**mposition**) is obtained by pressing the button **Get**.

	Name	Description
mposition: 0 [Get]	mposition	Current position of DC servo motor

9.9 Saving and loading configurations

Once adjusted configurations can be saved in a configuration file by selecting **File -> Save config...** or by

pressing the button .

Also the configuration file with all the settings can be loaded into the DC servo drive DCS-3010 by choosing

option **File -> Load config...** or by pressing button .

9.10 Advanced Setup

Pressing the button **Adv. Setup** (Figure 9.6) or icon [icon] opens dialog box with a choice of options for advanced settings (Figure 9.7).
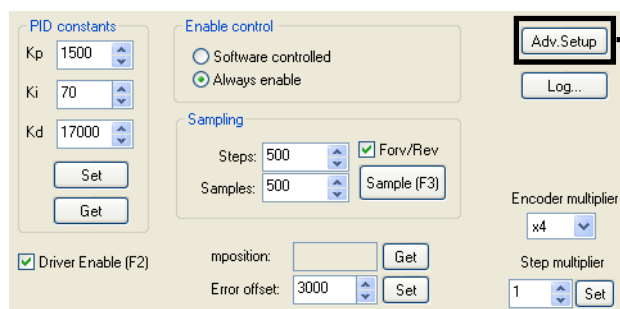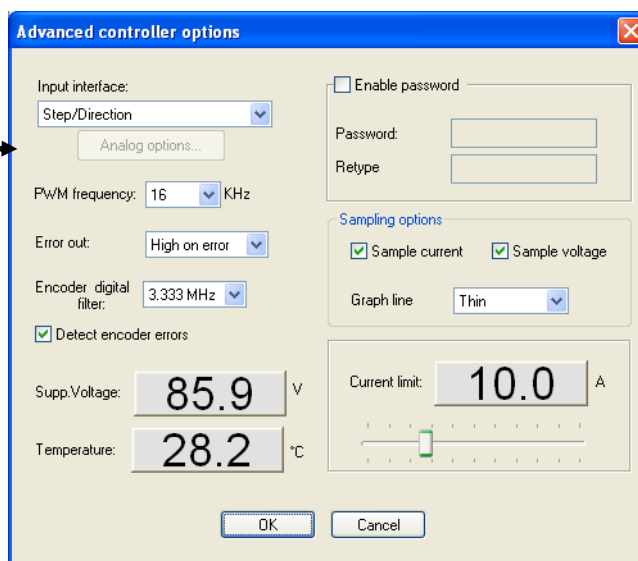

Figure 9.6

Figure 9.7

Advanced settings include the range of options:

- type of input interface,
- frequency of PWM,
- the logic level at Error output in case of error,
- digital filter for encoder,
- encoder error detection,
- password protection of parameters,
- selection of parameters that will be shown in the main diagram and
- maximum current of DC motor.

In order to accept change of any of the above values in the EEPROM microcontroller it is necessary to press the button OK (Figure 9.7).

9.10.1 Type of Input interface

Control of DC motor is carried out through three command lines. The first two command lines in this manual called STEP/DIR, while the third is ENABLE (see Figure 4.2). Optional input interface provides a choice of control modes via the above three command lines, or via the analog inputs in the following modes:

- Step/Direction i.e. STEP/DIR/ENABLE,
- StepUp/StepDown i.e. CW/CCW/ENABLE,
- Encoder x1 /ENABLE,
- Encoder x2 /ENABLE,
- Encoder x4 /ENABLE,
- Analog input with feedback (Analog with FB) and
- Analog input without feedback (Analog without FB).

NOTE: Configuration of input interface type Encoder 1x, 2x and 4x are not fully tested.

DC servo drive DCS-3010 has the ability to control DC motor via the voltage signal of 0÷5V which is applied to the analog input (Con. 4 in Figure 4.1). At the analog input can be directly connected potentiometer with nominal resistance 1÷10kΩ (Figure 4.5.a) or external motion path generator (Figure 4.5.b). Look section 4.4 of this manual.

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If you choose one of the options from the analog input, **Analog option** button will become active, and after its activation will appear one of the dialogue shown in Figure 9.8.
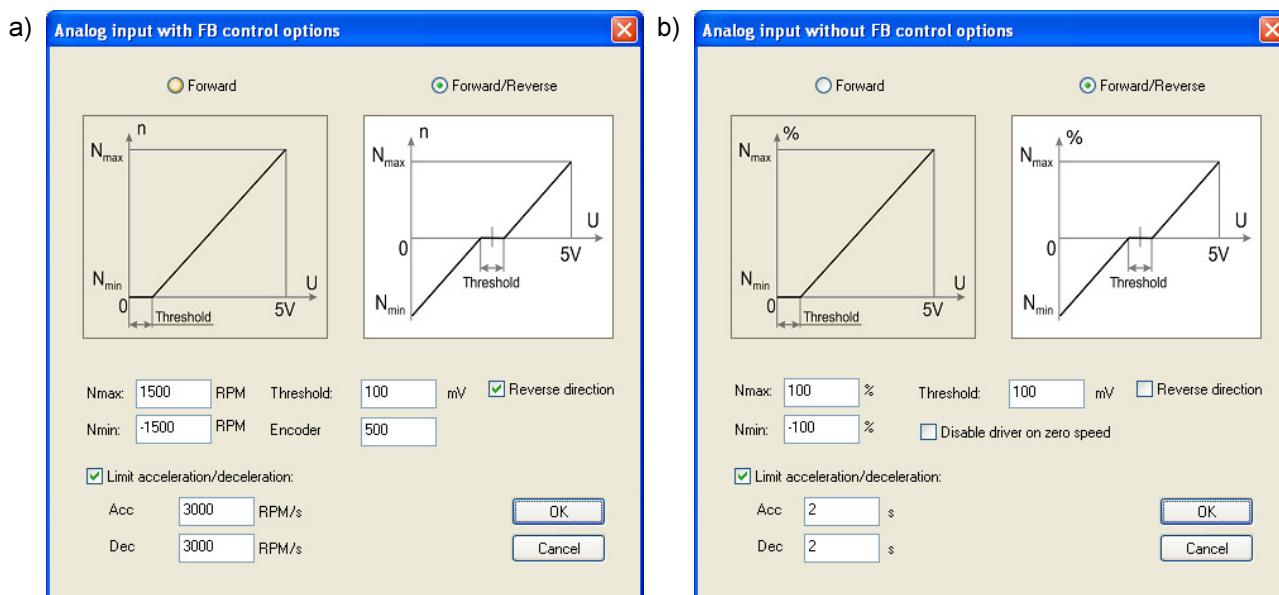

Figure 9.8 Dialog box for setting parameters, a) analog input with feedback (Analog with FB) and b) analog input without feedback (Analog without FB)

Dialog box for setting parameters of analog input provides a choice:

- One or two directions of rotation of DC motor (Forward or Forward/Reverse),
- Change the direction of rotation DC moror (Reverse direction),
- Maximum Nmax and minimum Nmin revolution speed.
  - In case of choosing the analog input with feedback (Analog with FB) values Nmax and Nmin are in revolutions per minute (RPM).
  - In case of choosing the analog input without feedback (Analog without FB) values Nmax and Nmin are in percents (%) in relation to power voltage of DC motor.
- Width of inactive zone (Threshold) expressed in mV.
- Number of encoder lines (Encoder) in case of choosing analog input with feedback (Analog with FB).
- Options of disabled DC motor in case that adjusted speed is equal to zero in case of choosing analog input without feedback (Analog without FB).
- Parameters of acceleration (Acc) and slowing down (Dec) (Limit acceleration/deceleration).
  - In case of choosing the analog input with feedback (Analog with FB) values Acc and Dec are in revolutions per minute per one second (RPM/s).
  - In case of choosing the analog input without feedback (Analog without FB) values Acc and Dec are in second (s).

9.10.2 Setting the PWM frequency
This option provides the ability to adjust the PWM frequency:

- 10 kHz,
- 12 kHz,
- 14 kHz,
- 16 kHz (default),
- 18 kHz and
- 20 kHz.

For frequency of PWM bellow 20 kHz can be heard "whistling" coming from DC motor.

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9.10.3 Logic level on Error output in case of error

The selection of logic level in case of errors at Error output is presented in the table below.

	Name	Option of choice – description
Error out: [High on error ▼]	Error out	**High on error** – In the case of error Error output will be at logical high level
		Low on error – In the case of error Error output will be at logical low level
		Always low – Error output will always be at logical low level independently of the existence of errors

9.10.4 Digital filter for encoder

An adjustment of digital filter for encoder is performed through selection of upper cut-off frequencies:

- switched off digital filter (Turn OFF),
- the frequency of filter 6.667 MHz,
- the frequency of filter 3.333 MHz (default),
- the frequency of filter 1.667 MHz,
- the frequency of filter 416.7 kHz,
- the frequency of filter 208.3 kHz,
- the frequency of filter 104.2 kHz,
- the frequency of filter 52.1 kHz i
- the frequency of filter 26.0 kHz.

Option of digital filtering of signals from the encoder can be useful in the environment with strong electromagnetic interference, which can lead to errors in reading the incremental encoder position.

9.10.5 Detecting encoder errors

If this option is enabled, the drive checks if there is a change at levels of both encoder inputs (A and B). If this is not the case, the output stage will be disabled and OP/ER LED indicator will show the encoder error.
NOTE: This option has not been fully tested, and it is recommended that the checker remains off.

9.10.6 Reading power supply voltage of DC motor and temperature of drive

In the appropriate fields (framed fields in Figure 9.9) is performed reading power supply voltage of DC motor in volts (Supp. Voltage) and temperature of DC servo drive DCS-3010 close to the microcontroller in $^{\circ}$C (Temperature).

Figure 9.9

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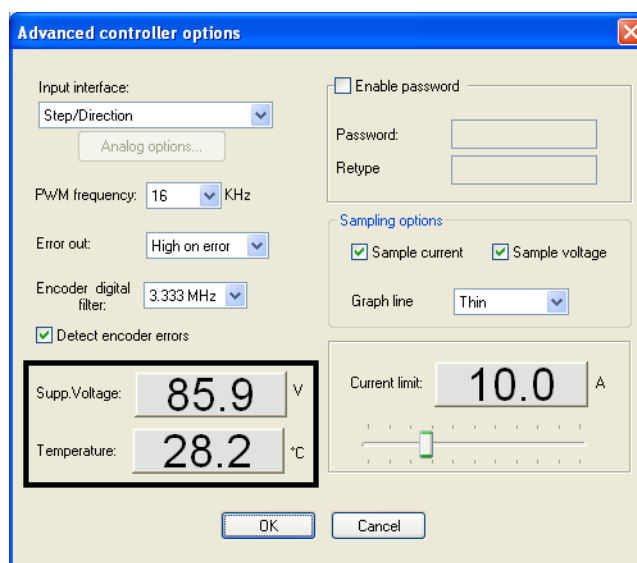Tel. +381 34 330 200, web: www.prizma.rs e-mail: prodaja@prizma.rs
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9.10.7 Entering the password

The ServoTune3 software provides the ability to enter password to prevent unauthorized changes to the parameters of DC servo drive DCS-3010.

In order to activate this option it is necessary to select a checker **Enable password** first as it is shown in Figure 9.10 thereby **Password** and **Retype** become active and in them is then possible to enter the password. When the password is entered then during each of the next start-up of ServoTune3 software and the connection to the DC servo drive DCS-3010 dialog window (Figure 9.11) for the typing of password will open, which becomes a requirement for approach settings.
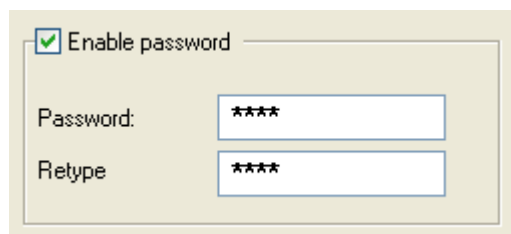
Figure 9.10 Password dialogue

Figure 9.11 Password dialogue on ServoTune3 software startup

9.10.8 Selection of options of the main diagram

The part of dialogue in the advanced settings (Advanced setup) shown in Figure 9.12 (Sampling options) allow choosing of:

- What parameter will be shown in the main diagram and
- The thickness of the diagram line that will be plotted (Thin, Medium and Thick).
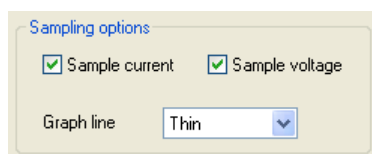
Figure 9.12

9.10.9 Setting the maximum DC motor current

Over the slider shown in Figure 9.13 maximum current of DC motor is adjusted. The adjusted value is readable in the appropriate field. Maximum current through DC motor can be adjusted in the range of 3÷30 A.

Figure 9.13

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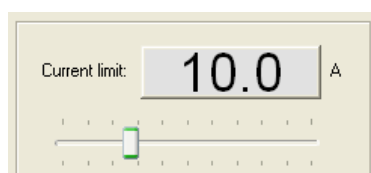
9.10.9 LOG File recording

Recording of Log file with the values of present position and position error, as well as present current and voltage at DC motor is activated by pressing the **Log** button (Figure 9.14) which opens the **Loging** dialog (Figure 9.15).
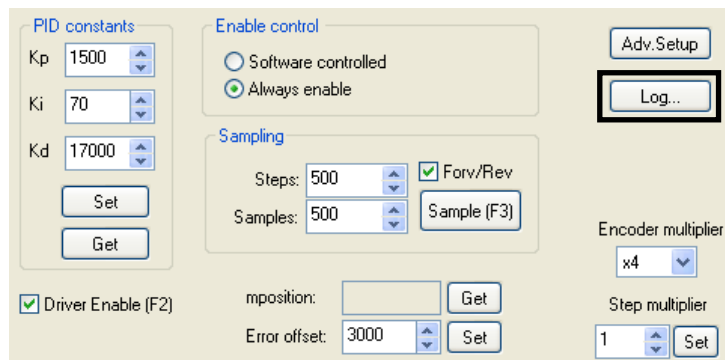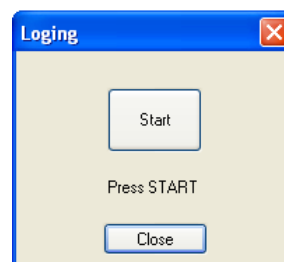

Figure 9.14 Position of **Log** button

Figure 9.15 Log dialog

Start recording a log file activates by pressing **Start** and **Stop** recording by pressing this button again. Data will be stored in a file called `servo.log` that is located in the same folder as the ServoTune3 software. The following is a small part of the `servo.log` file.

```
% *********** ServoTune log output file ************
% Date and time: 07.12.2012 19:00:05
%  Time[s]    Position   PosDiff Current[mA] Voltage[V]
   0.020960     -401        0         0        98.23
   0.023580     -401        0         0        98.23
   0.025676     -401        0         0        98.23
   0.027772     -401        0         0        97.78
   0.029868     -401        0         0        98.23
   0.032488     -401        0         0        98.23
   0.034584     -401        0         0        98.89
   0.036680     -400        1         0        98.23
   0.000000     -396        5         0        98.23
   0.001572     -386       13         0        98.23
   0.003668     -373       20         0        97.78
   0.005764     -349       32       119        97.02
   0.007860     -325       39       833        95.45
   0.009956     -296       44      1310        94.02
   0.012576     -263       39      1905        93.25
   0.014672     -226       38      2381        92.15
```

At that:

- **The first** column is time in seconds,
- **The second** column is present position of DC motor,
- **The third** column is position error (tracking error), i.e. difference between specified and current position of DC servo motor is expressed in the steps,
- **The fourth** column represents the value of the current through the DC motor expressed in mA and
- **The fifth** column is supply voltage of DC motor expressed in V.

Data from file `servo.log` file can be easily loaded into any software for drawing and for further analysing. (Excel, MATLAB etc.).

In Figures 9.16, 9.17 and 9.18 is shown an example of parameter changes from one recording `servo.log` data file.
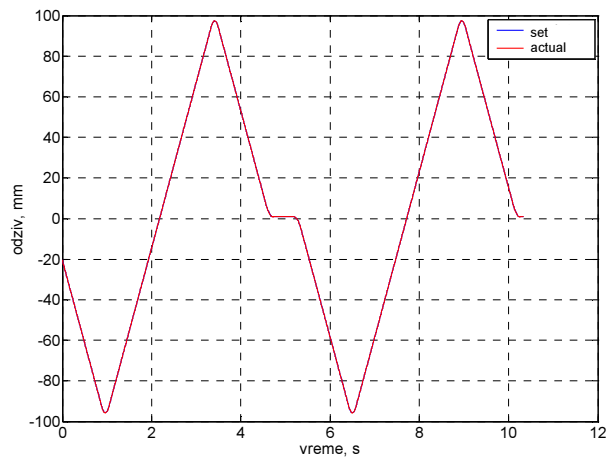
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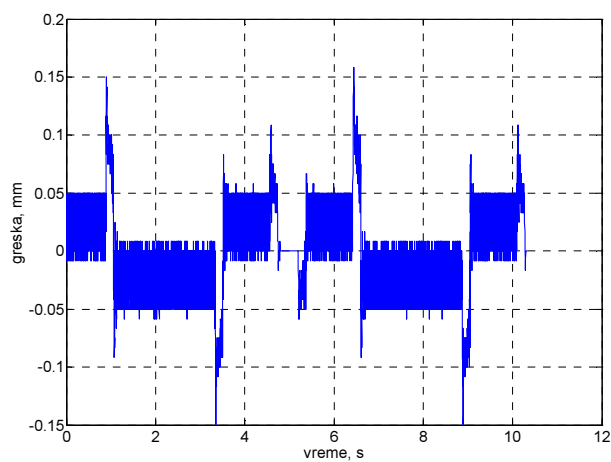**Figure 9.16** Diagram of set and actual position of DC servo motor

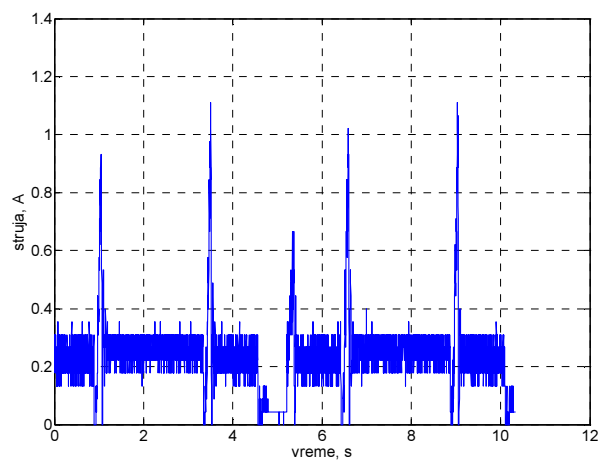**Figure 9.17** Diagram of the positioning error calculated in mm

Figure 9.18 Diagram of the electric current through the DC servo motor

10. PID CONSTANTS SETUP PROCEDURE

> **NOTE:** **During setting of PID constants take all precautions as it may cause oscillation of DC servo motor-mechanics.**
>
> **When setting up start from low value of maximum current through the DC motor during which should check the behaviour of DC motor. After this gradually increase the set value of maximum DC motor current.**

The values of the PID constants depend on:
- Characteristic of DC motor (moment of inertia, supply voltage, maximum electric current etc.),
- Physical characteristics of mechanics, which is connected at DC motor (mass, damping etc.),
- Resolution of the incremental encoder mounted on the DC motor,
- Selected encoder resolution multiplication (x1, x2 or x4), and
- Some other factors (ambient temperature, lubricant, etc.).

Adjusted PID constants are valid only for that configuration. If there is a change of configuration (some of the above parameters) it is necessary to readjust the PID constants.

The following is a description of the adjustment of PID constants. Encoder resolution in this case is 500 PPR, encoder resolution multiplication is x4, so that the overall encoder resolution is 2000 PPR.

STEP 1: Initial value of PID constants is:
- Proportional constant $Kp = 50$,
- Integral constant $Ki = 0$ i
- Derivate constant $Kd = 0$.

Slowly increase the constant Kp until you get response similar to the response shown in Figure 10.1.

STEP 2: Increase constant Kd until the system response is not "calm" as is shown in Figure 10.2. The constant Kd may be significantly larger than the constant Kp.

STEP 3: Gradually increase the constants Kp and Ki to the response as shown in Figure 10.3. Here it should be noted that the constant Ki is much smaller compared to the other two constants.

Repeat steps 2 and 3 to the point where the shaft of DC motor behaves as "locked". Also check the motor running at various revolution speeds (must not occur oscillation and vibration during operation).

STEP 4: Final values of the PID constants and the response of the motor are shown in Figure 10.4.

It is necessary to check determined PID constants during the work of the machine and, if it is necessary, to correct them.
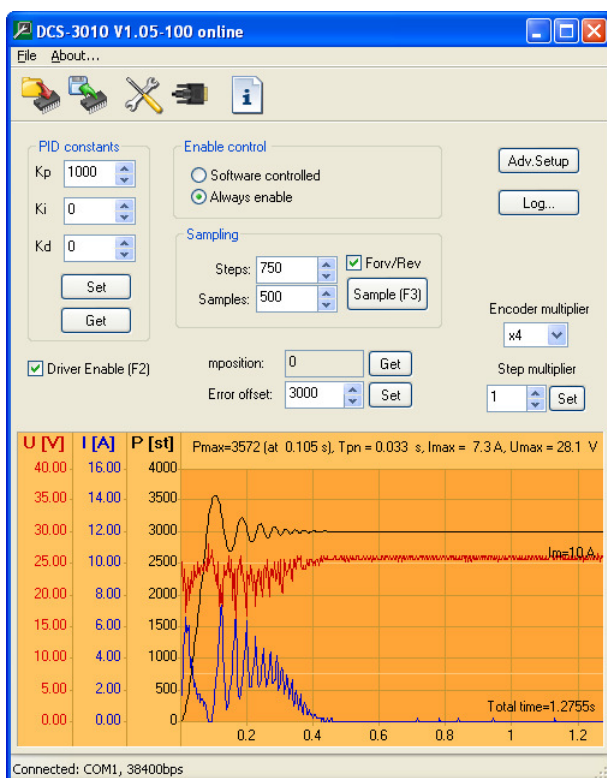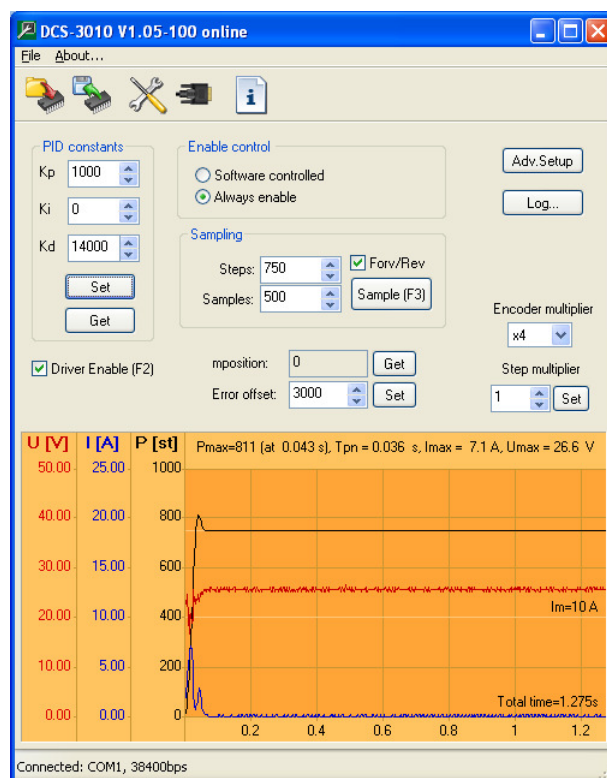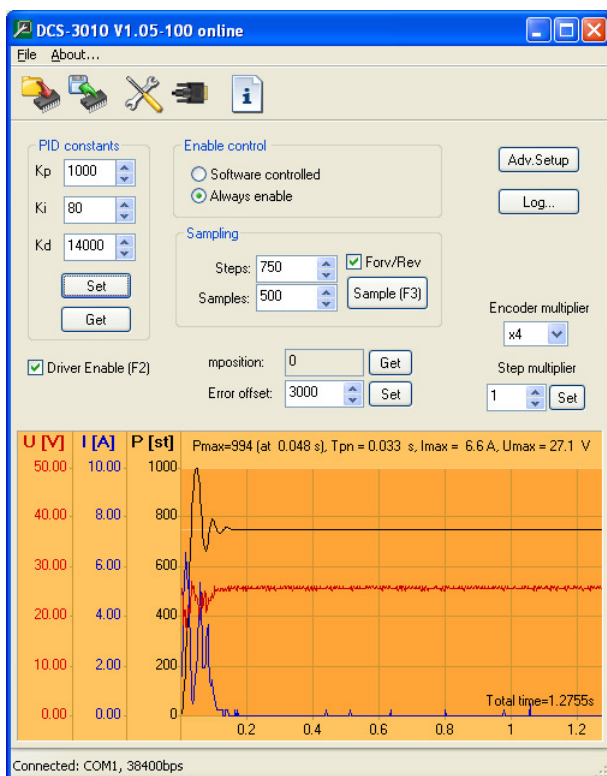
Figure 10.1

Figure 10.2
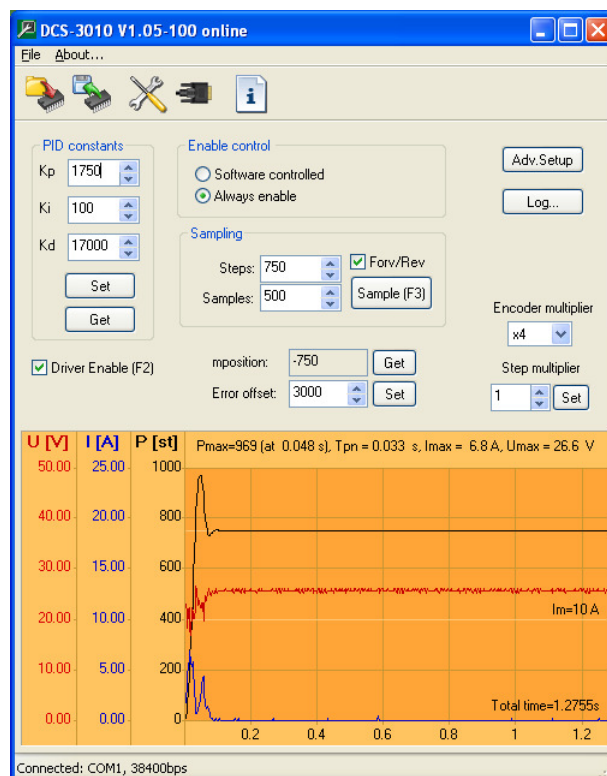

Figure 10.3

Figure 10.4

10.1 Automatic adjustment of PID parameters

The auto-configuring and adjusting PID parameters is available from ServoTune3 software version v3.07. The dialog for automatic adjustment of PID parameters opens by pressing button **AutoPID** (Figure 10.5). This will display a warning dialog shown in Figure 10.6.
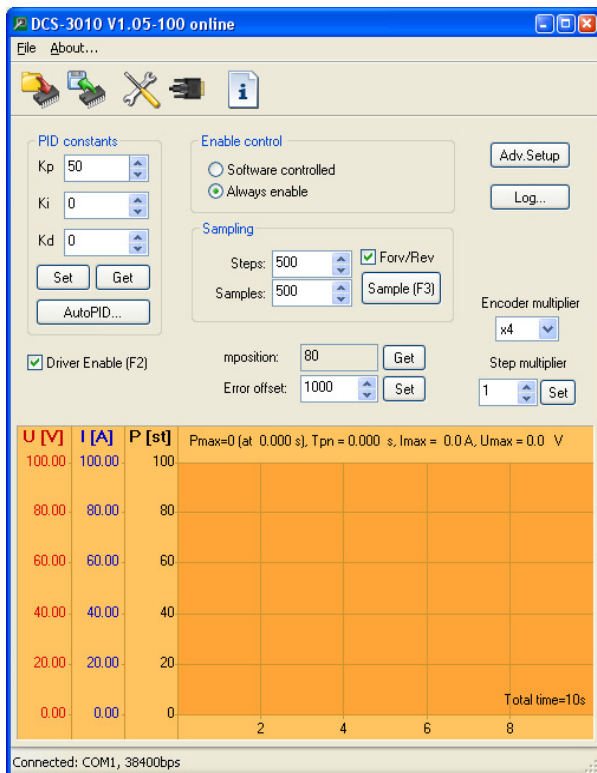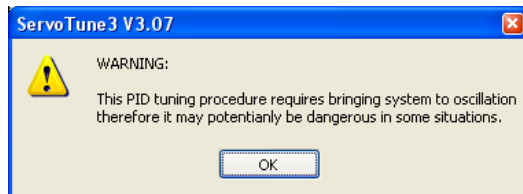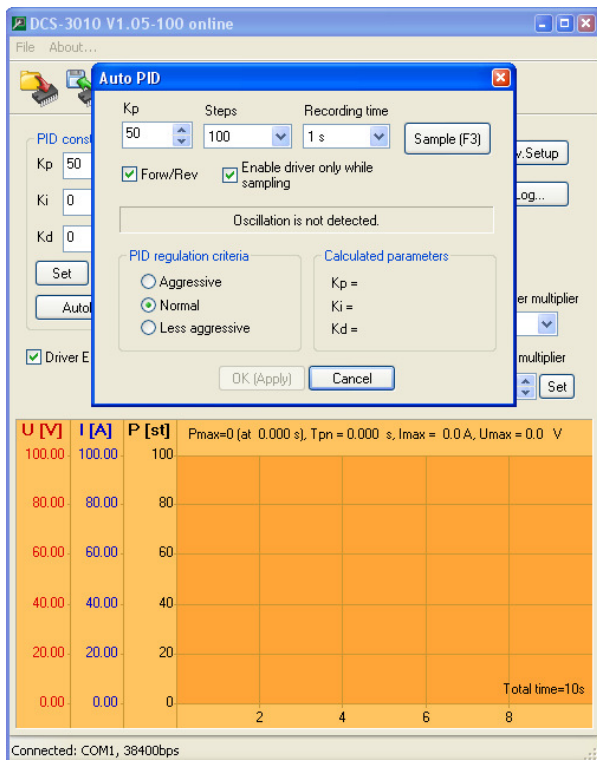
Figure 10.5

Figure 10.6

Figure 10.7

Within **AutoPID** dialog, which is shown in Figure 10.7., it is possible to set the following parameters:

- Proportional constant **Kp**.
- Number of **Steps** to define the step function. Pull-down menu provides a choice of predefined values for the number of steps: 100, 150, 200, 250, 300, 400, 500, 750 and 1000. Choose one value of the number of steps corresponding to approximately 5-10% of the number of steps required to DC motor make a full circle.

  EXAMPLE: Encoder has 500PPR and selected the option Encoder multiplier x4. In this case it is necessary 500 x 4 = 2000 steps to the DC motor make a full revolution. Recommended values for Steps would be 100, 150 or 200.

- The duration of the measurement of **Recording time** that can be selected via the pull-down menu: 1s, 2s, 3s, 4s and 5s. Whereas during the recording system response required bringing the system into oscillation it is recommended that this time be as short as possible.
- Alternately reversing DC motor when recording step function (option **Forw/Rev**). It is recommended that this option should be active.
- Option **Enable drive only while sampling**. It is recommended that this option should be active.

The process of automatic adjustment of the of PID constants involves gradually increasing the constant Kp. With every change of constants **Kp**, it is necessary to press the **Sample (F3)** or function key **F3** to record the system response. The parameter **Kp** is increased gradually and gently, until it comes to the appearance of the oscillation of the system, such as that shown in Figures 10.8, 10.9 and 10.10. It is important to note that in these figures are not shown all the steps in gradual increasing of the parameter **Kp**.

ServoTune3 software will recognize that there is a system oscillation, as is shown in Figure 10.10 (**Oscillation is detected ...**) and will suggest PID controller constants **Kp, Ki, and Kd** according to the given criteria. There is a choice of the following criteria:

- **Aggressive**,
- **Normal** or
- **Less aggressive**.

Pressing the **OK** button (**Apply**) calculated PID parameters will be stored in EEPROM microcontroller.

Check the behaviour of DC servo motor according PID parameters calculated on this way (Figure 10.11).

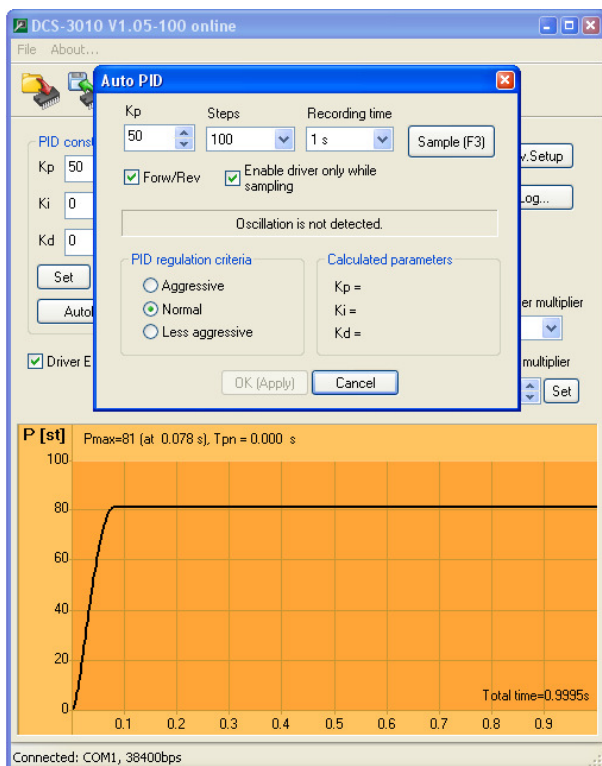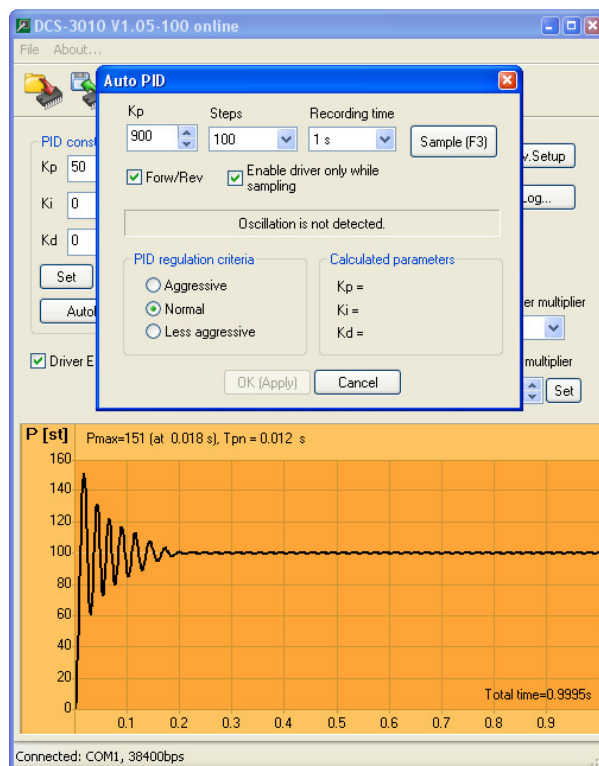If necessary, perform manual fine tuning of PID parameters.

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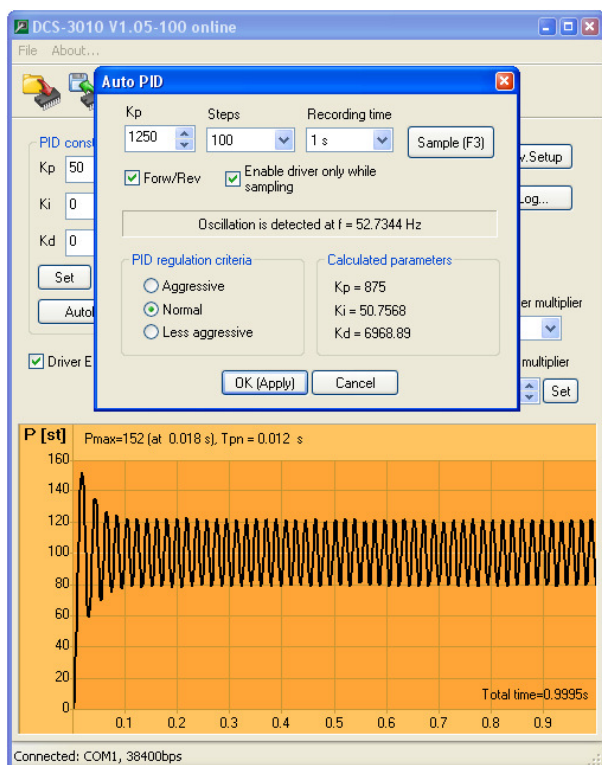
Figure 10.8
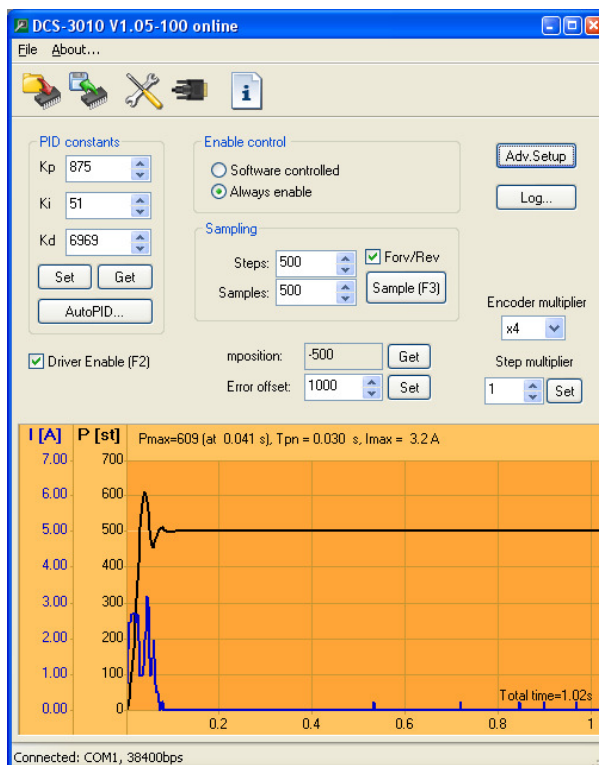

Figure 10.9

Figure 10.10

Figure 10.11

DOKUMENT REVISION:

- Ver. 1.0, January 2014., English version
- Ver. 1.01, March 2014., Minor corrections
- Ver. 1.07, January 2015., Minor corrections in Figure 4.6