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NANOMOTION

A Johnson Electric Company

# FlexDC™

# User Manual




**FLDC458000-00 REV:B** **November 2008**

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- IEC 61000: "Electromagnetic Compatibility (EMC)": Part 3. "Limits".
- EN 61000-6-2: "Electromagnetic Compatibility (EMC)": Part 6-2: Generic standards – Immunity for industrial environments" (2005).

# Revision History

| Ver/Rev | Date | Details |
|---|---|---|
| 00/A | September 2008 | New release. |
| 00/B | November 2008 | Add: Tuning with AB5 Driver, Sin/Cos Encoder Setup. Nanomotion Shell Application Installation. Erase: ECAM Mode (not supported). |
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Nanomotion Ltd. Technical Support Department at **techsupport@nanomotion.com**

# Table of Contents

**1 GENERAL ..... 12**

1.1 Scope ..... 12

1.2 Introduction ..... 12

1.3 Features ..... 12

1.4 Operation Principle ..... 12

1.5 Configuration Options Description ..... 13

1.5.1 Standard Configurations ..... 13

1.5.2 Analog Encoders Interfaces ..... 13

1.6 Reference Documents ..... 13

**2 QUICK START ..... 14**

2.1 Safety Precautions ..... 14

2.2 FlexDC™ System Connection ..... 15

2.3 Nanomotion Shell Application Installation ..... 15

2.4 Tuning the FlexDC™ ..... 20

2.4.1 Setup for Tuning Process ..... 20

2.4.2 Open Loop Tuning ..... 20

2.4.3 Closed Loop Tuning ..... 23

2.4.4 Tuning with AB1A Driver ..... 27

2.4.5 Tuning with AB5 Driver ..... 32

2.4.6 Sin/Cos Encoder Setup ..... 33

2.5 FlexDC™ Basic Macro Installation ..... 37

2.6 Basic Operation ..... 38

2.6.1 Custom Commands Installation ..... 38

2.6.2 The “INIT” Application ..... 39

2.6.3 The "RUN" Application ..... 39

2.6.4 The "HOME" Application ..... 39

2.6.5 The “HALT” Application ..... 39

**3 SYSTEM DESCRIPTION ..... 40**

3.1 Motion Modes ..... 40

3.1.1 Point To Point Motion Mode – PTP ..... 40

3.1.2 Repetitive Point To Point Motion Mode – Rep PTP ..... 40

3.1.3 Jogging Motion Mode – JOG ..... 40

3.1.4 Position Based Gearing Motion Mode ..... 41

3.1.5 Joystick Motion Modes ..... 41

3.1.5.1 Velocity Based Joystick Motion Mode ..... 41

3.1.5.2 Position Based Joystick Motion Mode ..... 41

3.1.6 Position Step Motion Mode ..... 41

3.2 The Control Filter ..... 42

3.2.1 Closed Loop - PIV Filter Mode ..... 42

3.2.2 Open Loop Operation ..... 43

3.3 AB1A Driver Special Algorithms ..... 43

3.4 AB5 Driver Brake Mode ..... 44

3.5 Fault Protections and Limits ..... 44

3.5.1 Protections ..... 44

3.5.2 Limitations ..... 45

3.6 Advanced Features ..... 45

3.6.1 Data Recording ..... 45

3.6.2 Position Compare Events ..... 46

3.6.3 Position Capture Events ..... 46

3.6.4 Joystick – Analog Input Interface ..... 47

3.6.5 Dynamic Error Mapping Correction ..... 47

3.7 FlexDC™ Protocols, Syntax and Commands ..... 47

3.7.1 Types of Communication and Protocols ..... 47

3.7.2 Language Notations and Syntax ..... 48

**4 TECHNICAL DATA ..... 49**

4.1 Specifications ..... 49
4.2 Thermal EOP (Envelop of Performance) ..... 50
4.3 Indicators and Connectors' Pinouts ..... 53
4.3.1 Front Panel Indicators ..... 53
4.3.2 Rear Panel Connections ..... 54
4.3.3 RS232/CAN Pinout ..... 54
4.3.4 Motor Output Port Pinout ..... 55
4.3.5 I/O Pinout ..... 56
4.3.6 Limit Interfaces ..... 57
4.3.7 General Purpose Digital Input Interfaces ..... 58
4.3.8 General Purpose Digital Output Interfaces ..... 59
4.3.9 Fast I/O Interfaces ..... 60
4.3.9.1 Fast Inputs Interfaces ..... 60
4.3.9.2 Fast Outputs Interfaces ..... 60
4.3.10 Joystick Interface ..... 61
4.3.11 A Quad B Encoder ..... 62
4.3.12 Sin/Cos Encoder ..... 62

**5 ORDERING INFORMATION AND CONFIGURATIONS ..... 63**
5.1 FlexDC™ Part Numbering Scheme and Configurations ..... 63
5.2 FlexDC™ Example Configurations ..... 63

**6 CONTACT INFORMATION ..... 64**
6.1 Customer Service ..... 64
6.2 Headquarters ..... 64

# List of Figures

Figure 1: Choosing the Communication in the Connection Drop-Down List....18
Figure 2: Nanomotion Shell Application Main Screen....19
Figure 3: Nanomotion Shell Application Main Screen (Axis X)....21
Figure 4: Setting the Position Counts Direction....22
Figure 5: Setting the “PIV Controller Parameters”....23
Figure 6: Defining the “Advanced Parameters”....24
Figure 7: Defining the “Driver Modes”....25
Figure 8: Setting the "PIV Controller Parameters"....26
Figure 9: The Data Viewer Window....27
Figure 10: Defining “Driver Modes” for AB1A Driver....28
Figure 11: Defining Servo Parameters for AB1A Driver....29
Figure 12: Data Viewer windows – with AB1A Driver....30
Figure 13: Inaccurate Position Error Converging – AB1A Driver....31
Figure 14: Defining “Driver Modes” for AB5 Driver....32
Figure 15: Analog Encoder Interface Setup Utility Dialog Box....33
Figure 16: The Data Viewer Windows....35
Figure 17: Macro Installation....37
Figure 18: Custom Commands Installation....38
Figure 19: Thermal EOP for AB5 Driver....50
Figure 20: FlexDC™ Front Panel....53
Figure 21: FlexDC™ Rear Panel....54
Figure 22: The RS232 Cable....55
Figure 23: Limit Switches Electrical Interfaces....57
Figure 24: Typical Optically Isolated Digital Inputs Electrical Interface....58
Figure 25: Typical Optically Isolated Digital Output Interface....59

# List of Tables

Table 1: Thermal EOP Standard LUT for HR Motors Driven by AB5 ..... 51
Table 2: Thermal EOP Reduced LUT for HR Motors Driven by AB51 ..... 52
Table 3: FlexDC™ LED Indicators Description ..... 53
Table 4: RS232 / CAN Pinout ..... 54
Table 5: Motor Output Port Pinout ..... 55
Table 6: I/O Pinout ..... 56
Table 7: Joystick Interface Pinout ..... 61
Table 8: AqB Encoder Pinout ..... 62
Table 9: Sin/Cos Encoder Pinout ..... 62
Table 10: FlexDC™ Part Numbering Scheme ..... 63

# List of Abbreviations

| | |
|---|---|
| UHR | Ultra High Resolution |
| EOP | Envelope of Performance |
| AC | Alternating Current |
| DC | Direct Current |
| LED | Light Emitting Diode |
| Vrms | Volts Root Mean Square |

# 1 General

## 1.1 Scope

This user manual provides complete information about the electrical specifications of the FlexDC™, its hardware and electrical interfaces, and useful getting started information.

## 1.2 Introduction

FlexDC™ Motion Controller — Nanomotion's dual-axis controller driver. The latest addition to Nanomotion drive/control series of products, the FlexDC™ Motion Controller is offered in either single or dual axis configurations. This compact motion controller is driven by your choice of AB1A-3U or AB5-3U driver cards, and a unique controller card designed with Nanomotion's proprietary Algorithm inside.

## 1.3 Features

- LED indicators on front panel
- All connectors and power inlets available on the rear panel
- PIV Control Algorithm, including UHR
- Data Recording
- Dual Axes Analog Joystick

## 1.4 Operation Principle

The FlexDC™ performs digital position and velocity control for one or two axes, using incremental encoder devices as the main position feedback. FlexDC™ also supports the analog Sin/Cos encoders as an option as well as the configurable analog feedback for position or velocity loop structures.

## 1.5 Configuration Options Description

FlexDC™ supports the following hardware configuration options:

### 1.5.1 Standard Configurations

FlexDC™ standard product configuration includes all standard single and dual axes options, which are not defined as special hardware configurations.

### 1.5.2 Analog Encoders Interfaces

With this option users can access analog Sin/Cos encoders for main position feedback, and use the integrated multiplier option supported by the product. The internal multiplier supports multiplication factors of up to x8192.

For specific information regarding the standard or the analog encoder configuration options, please contact the Nanomotion Sales Department.

## 1.6 Reference Documents

- Software User Manual and Commands Reference Manual
- Communication Protocols User Manual
- Nanomotion Shell Application and Source Code Editor User Manual
- Macro Language User Manual: Script Programming Language and the Integrated Development Environment.
- COM / DCOM Interface Library - Reference User Guide.

# 2 Quick Start

The purpose of this chapter is to provide the user with easy step-by-step instructions for first time operation of the FlexDC™ using RS232 communication.

**WARNING !**

**Before powering the FlexDC™, motors cable connectors must be connected to the motor outlets of the controller, as hazardous voltages may appear on controller's motor outlets. Only a person who has read the instructions in sections 2.1 and 2.2 may handle the FlexDC™.**

## 2.1 Safety Precautions

1. Do not open the FlexDC™ enclosure.
2. Verify that the motor is properly assembled on the stage and preloaded, before operating the stage.
3. Verify that the motor and the encoder connectors match the FlexDC™ rear panel connections (refer to sections 4.3.11 and 4.3.12).
4. Do not cover the vents on the top panel of the FlexDC™.
5. Verify that the stage's movement is not interrupted by nearby impediments.

**WARNING !**

**Connect / disconnect the motor cable from / to FlexDC™, only when the main power cord is disconnected from the wall outlet.**

## 2.2 FlexDC™ System Connection

Refer to Figure 23 for FlexDC™ Rear Panel layout.

1. Verify that the FlexDC™ power cord is disconnected from the wall outlet.
2. Connect the motor cable to the motor connector on the back panel of the FlexDC™ and secure it with screws (the screws can only be screwed / unscrewed with a screwdriver).
3. Verify that the motor and the encoder are connected to the proper axis.
4. Connect the RS232 communication cable between the PC and the FlexDC™.
5. Connect the Joystick and/or I/O connector to the FlexDC™ (if required).
6. Connect the FlexDC™ to the power outlet and switch the power ON.
7. Verify that the LED indicators are lit: "Power" is green, and "Enable" is orange.

## 2.3 Nanomotion Shell Application Installation

The FlexDC™ is supported by dedicated software, which requires a PC operating system with one of the following: Windows 98 / Windows 2000 / Windows XP. The software installation is user-friendly, using a dedicated Setup Utility provided on the product CD. The standard setup installation installs the FleXDC™ user manuals together with the Nanomotion Shell Application for user's convenience. For complete description of the software and its installation process, refer to the "Nanomotion Shell Application and Editor User Manual" and the "Macro Language User Manual".

A quick start procedue is as follows:

1. Insert the FlexDC™ CD (which is supplied with the "FlexDC™ User Manual") into a Windows computer. The AutoRun automatically starts the "Installation Menu".
2. On the "Installation Menu", click the "Nanomotion Shell Application Installation" and follow the step-by-step instructions.

3. After the installation is completed, there are 4 (four) icons show up on the desktop:

- The "SC-AT Shell" – is the Nanomotion Shell Application.
- The "SCServerScope.exe" – is for SCServer DCOM installation, necessary to run the Nanomotion Shell Application program, for users that use CAN communication.
- The "Srcedit.exe" – allows users to write and debug macro scripts
- The "Sdviewer.exe" – allows users to view recorded data. This is a powerful viewer for the graphic files created by Data Recording feature of the shell

4. Run the Nanomotion Shell Application (see the "SC-AT Shell" icon located on the desktop). The Nanomotion Shell Application initial main screen appears, see Figure 1:

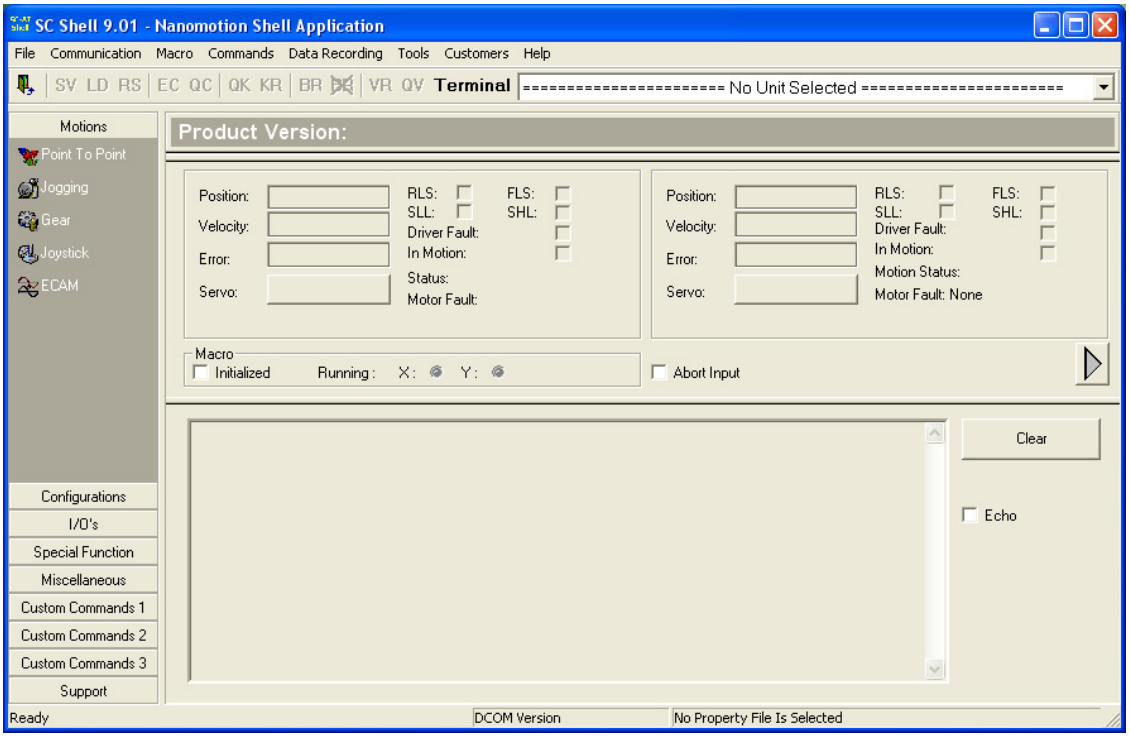



***Figure 1: Nanomotion Shell Application Initial Main Screen***

5. On "Communication" menu click "Setup Communication". The "Communication Settings" dialog box appears, see Figure 2.
6. In the "Controller Name" drop-down list choose the "RS232".
7. In the "Controller Communication Protocol" drop-down list choose "RS232".
8. In the "RS232 Port" choose the COM. For more information regarding the supported communication protocols, refer to the "Communication Protocols User Manual".
9. Press on Update button and then on Exit button.

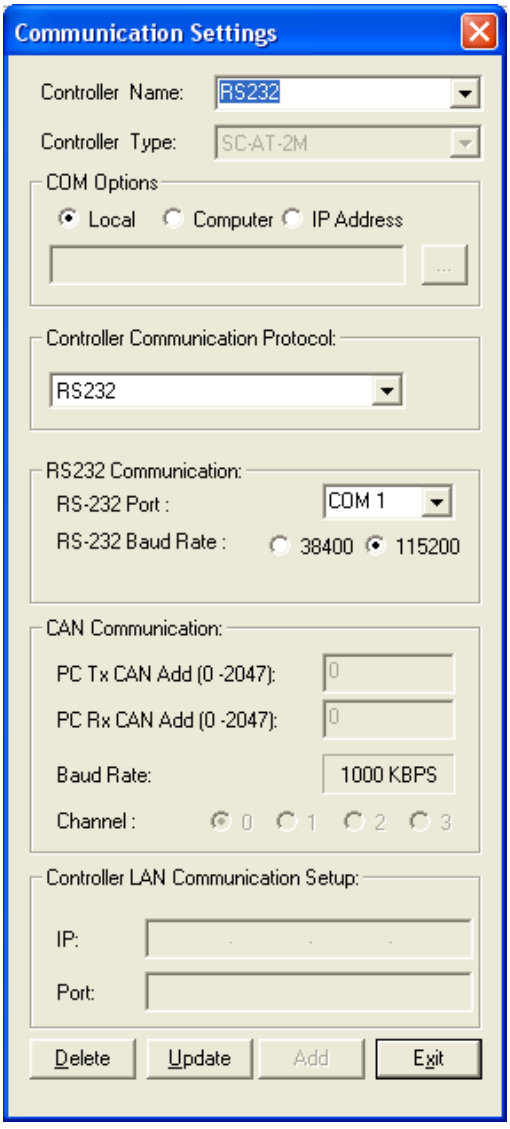



***Figure 2: Communication Settigs Dialog Box***

10. In the Connection drop-down list, select the type of communication connection, defined in the previous step (see Figure 3).

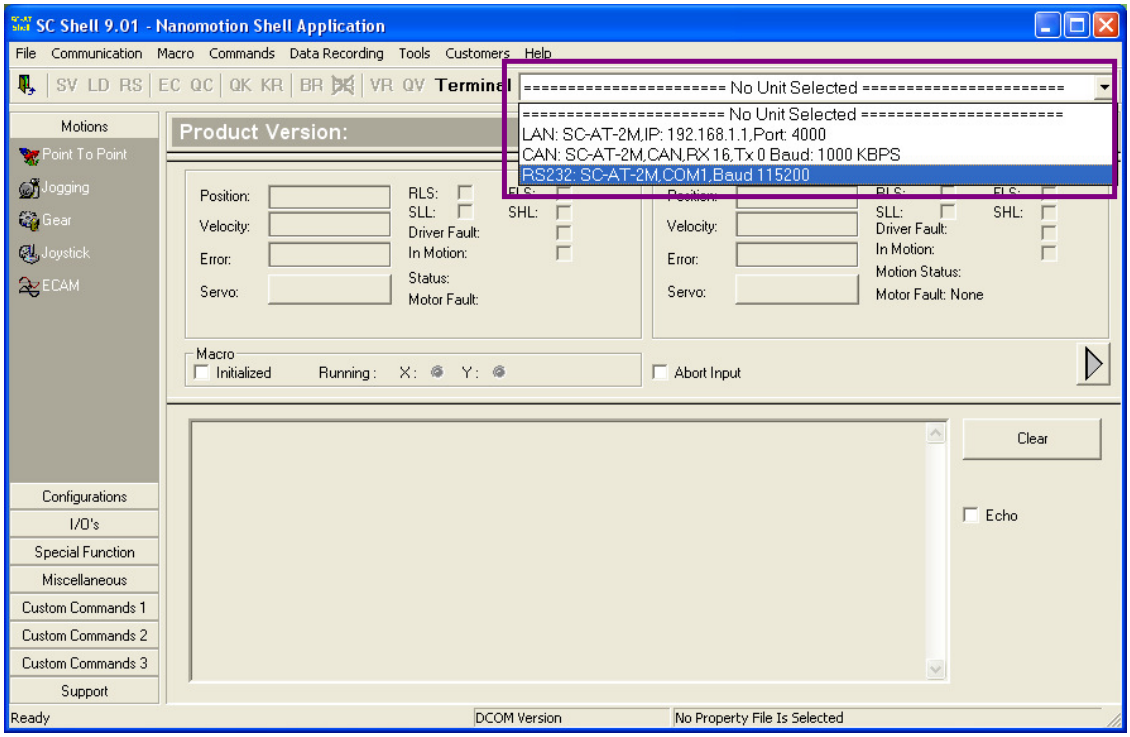



***Figure 3: Choosing the Communication Type in the Connection Drop-Down List***

11. At this point the Nanomotion Shell Application initiates the communication with the controller.

12. If the communication is established successfully, the main screen of the Nanomotion Shell Application automatically becomes active, see Figure 4. If communication fails, an error message appears.

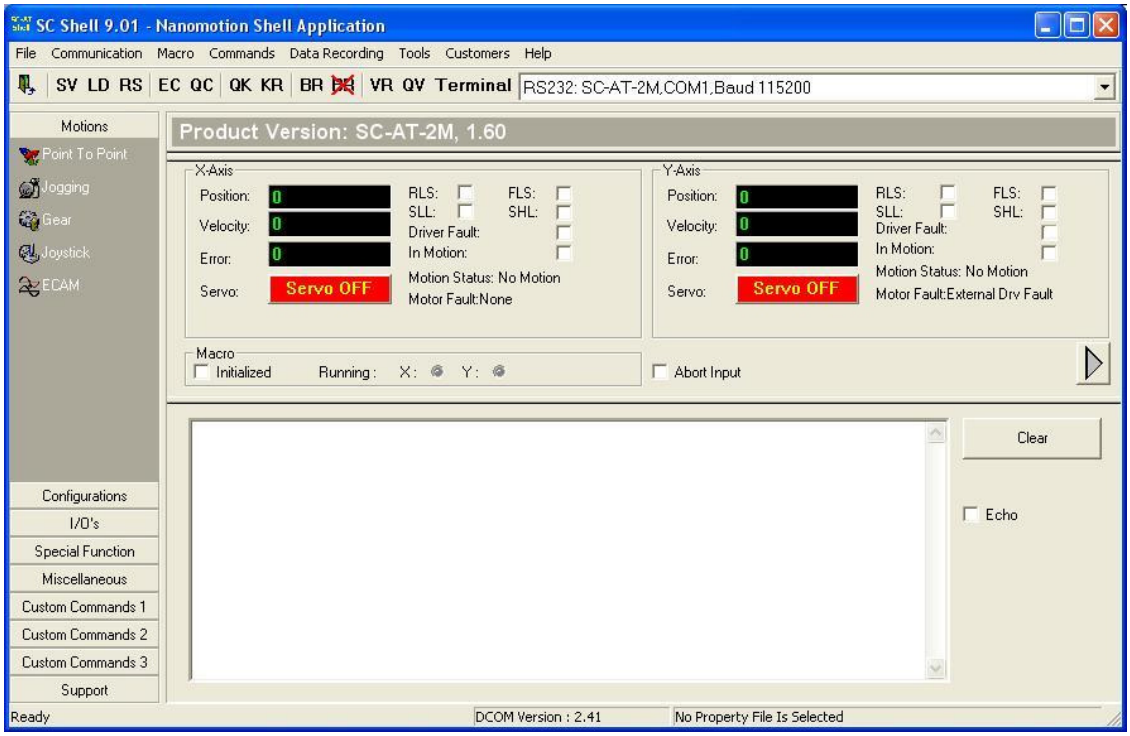



***Figure 4: Nanomotion Shell Application Main Screen***

***Note:***

- *The main screen information refers only to two axes configuration.*

## 2.4 Tuning the FlexDC™

***Note:***

- *The tuning process described in this chapter refers only to Nanomotion HR4 motor with moving mass of 500gr, encoder resolution 0.1µm. This tuning process is valid for all Nanomotion motors.*

### 2.4.1 Setup for Tuning Process

1. Move the stage manually to ensure that the encoder is reading the position. While moving the stage, observe the Nanomotion Shell Application main screen (refer to Figure 4).
2. In Terminal window type:

   **XER=8000000** *set critical position error*

### 2.4.2 Open Loop Tuning

1. In Terminal window type:

   **XNC=1** (or **YNC=1**) *set the system to open loop*

   **XPS=0** *set current position to zero*

2. Enable the motor by pressing the “Servo OFF” button. Ensure that the button changes from red color to green, see Figure 5.

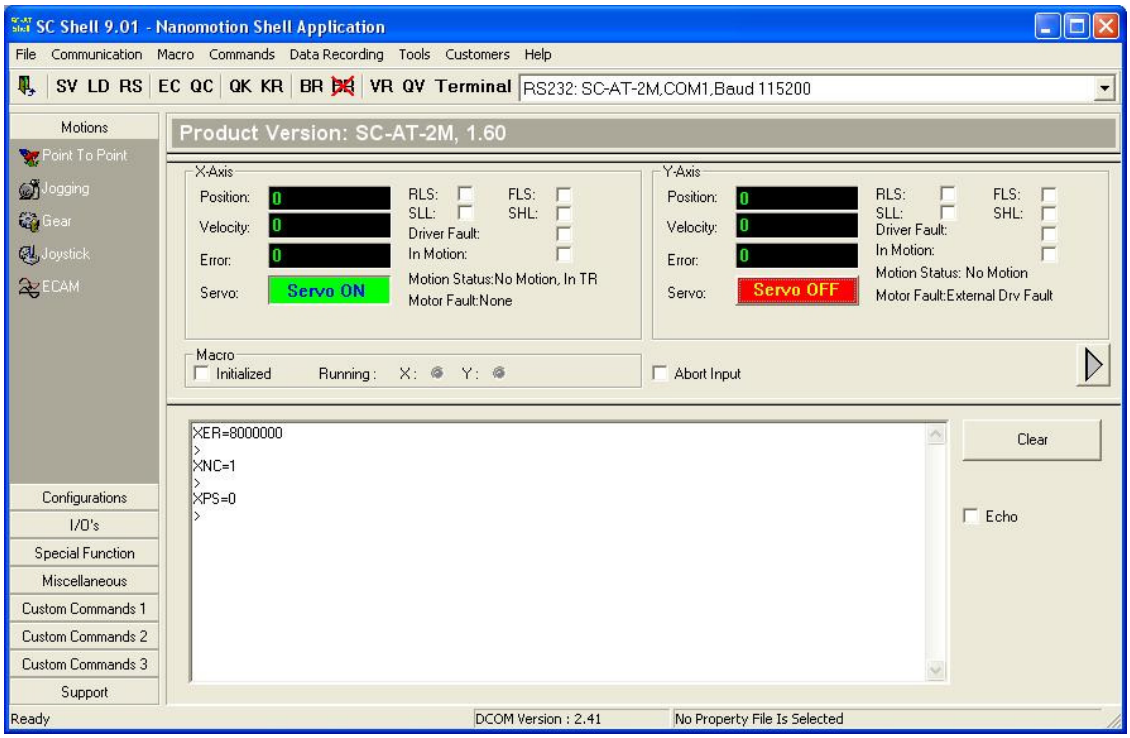



***Figure 5: Nanomotion Shell Application Main Screen (Axis X)***

3. Move the motor in open loop by sending the driver ~1.25V command:

   **XTC=4000**

4. Wait until the motor moves and disable the motor by pressing the "Servo ON" button. Ensure the button changes from green color to red.

5. If the position counts increased (positive) – the direction of the motor is correct. If the position counts decreased (negative), follow the next instructions:

   a) Click "Configurations" menu on the right pane of the main screen.

   b) Click "Configuration-X" menu.

c) Select the “Invert Motor Command Direction” check box (if this check box is clear, and vice versa) or select “Inverse Main Encoder[1] Direction” check box (if this check box is clear, and vice versa), see Figure 6.

6. Press on  ("Folders Menu") button and choose “Download Data to the Controller” (or just click on letter "D"). (For more details regarding this button, refer to the "FlexDC™ Nanomotion Shell Application and Source Code Editor User Manual").

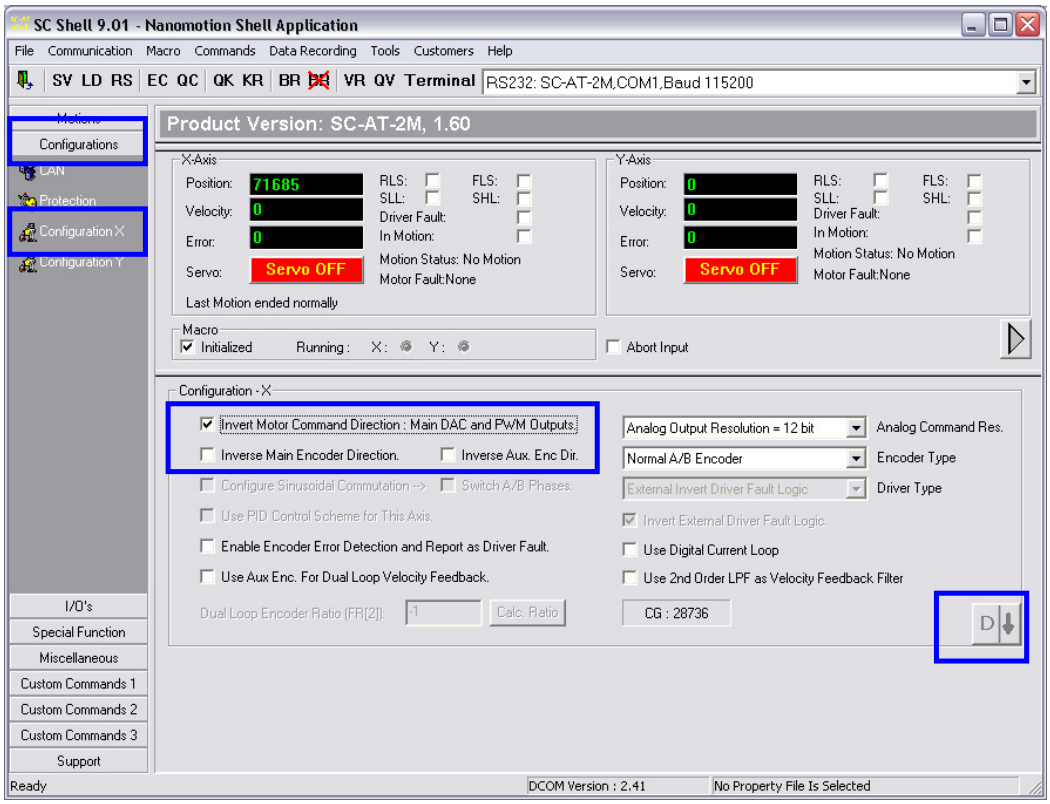



***Figure 6: Setting the Position Counts Direction***

***Note:***

- *In case, the Position increases in positive direction, but the user is interested in positive direction in the opposite direction, select both check boxes and press on*  *button to download data to the controller, see Figure 6.*

[1] The "Main Encoder" stands for the A Quad B encoder. See section **Error! Reference source not found.** for Tuning the FlexDC™ with Sin/Cos encoder.

### 2.4.3 Closed Loop Tuning

1. Type the following commands in Terminal window:

   **XTC=0** *set the system closed loop*

   **XNC=0**

2. Press ALT+P (or on the "Tools" menu, click "Servo Parameters Tuning Utility"), see Figure 7.

3. Set the initial parameters in the "PIV Controller Parameters" tab as follows:

   **KD=5** *(use the* Set all KD,KI Equal *button)*

   **KI=2500** *(use the* Set all KD,KI Equal *button)*

   **KP=0** *(use the* Set all KP Equal *button)*

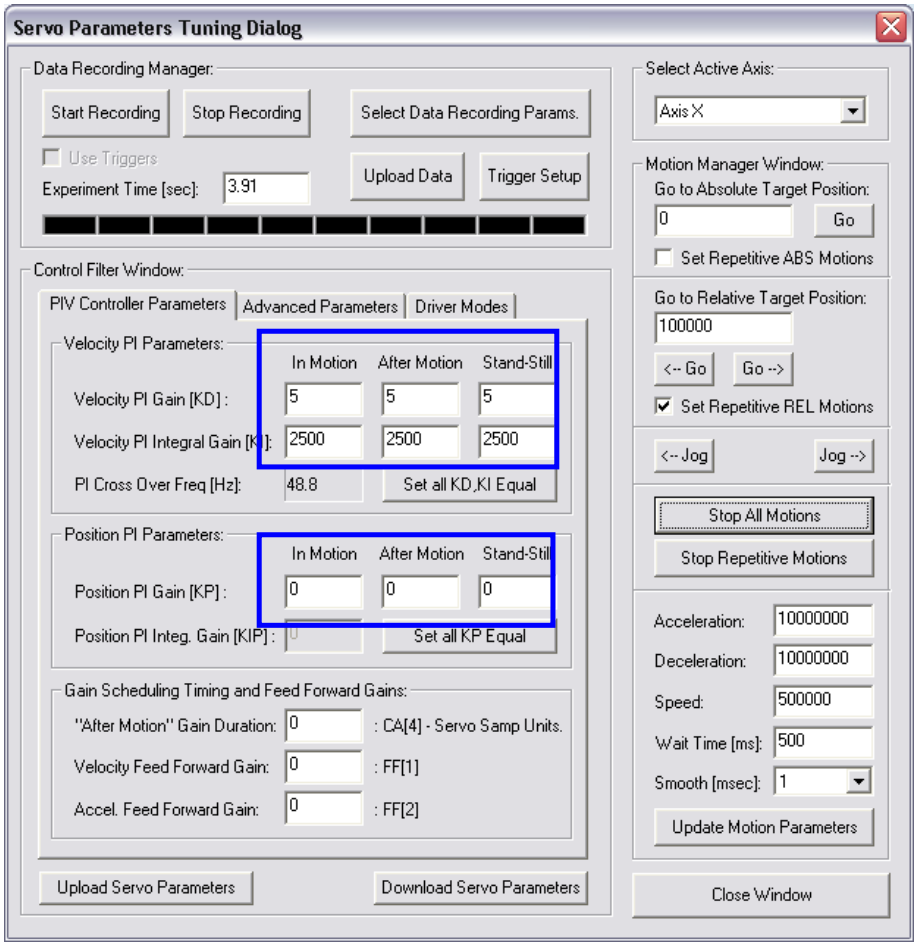



***Figure 7: Setting the "PIV Controller Parameters"***

4. Click the “Advanced Parameters” tab and under "Filter Type and Frequency Setup" see Figure 8:
   - Select the “2nd Order Filter LPF” check box.
   - Type **700** in the “Freq. [Hz]” box.
   - Type **0.6** in the “Damping” box.

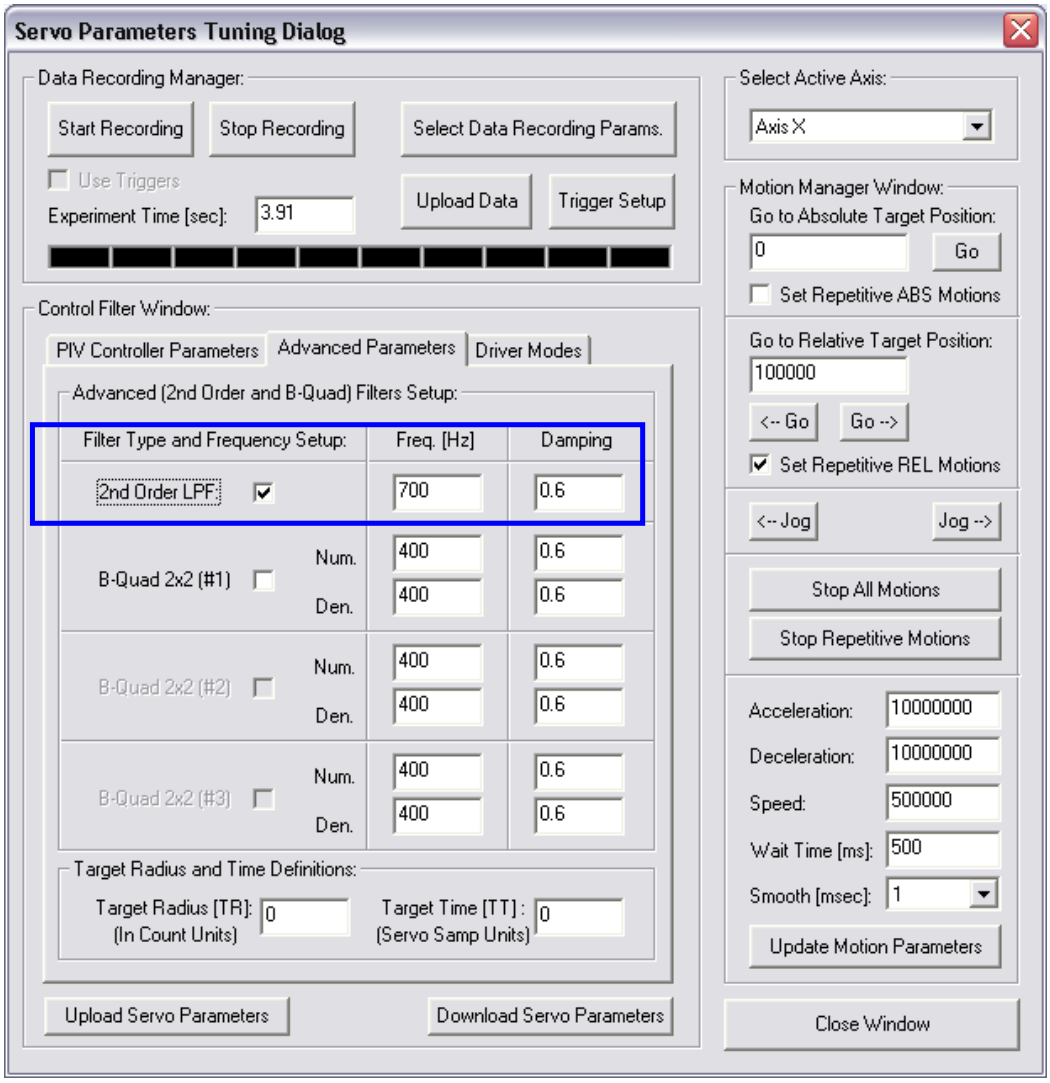



***Figure 8: Defining the “Advanced Parameters”***

5. Click the “Driver Modes” tab and clear the “Use Dead Zone Algorithm” check box, see Figure 9.
6. Clear the “Use Zero FF Algorithm” check box.

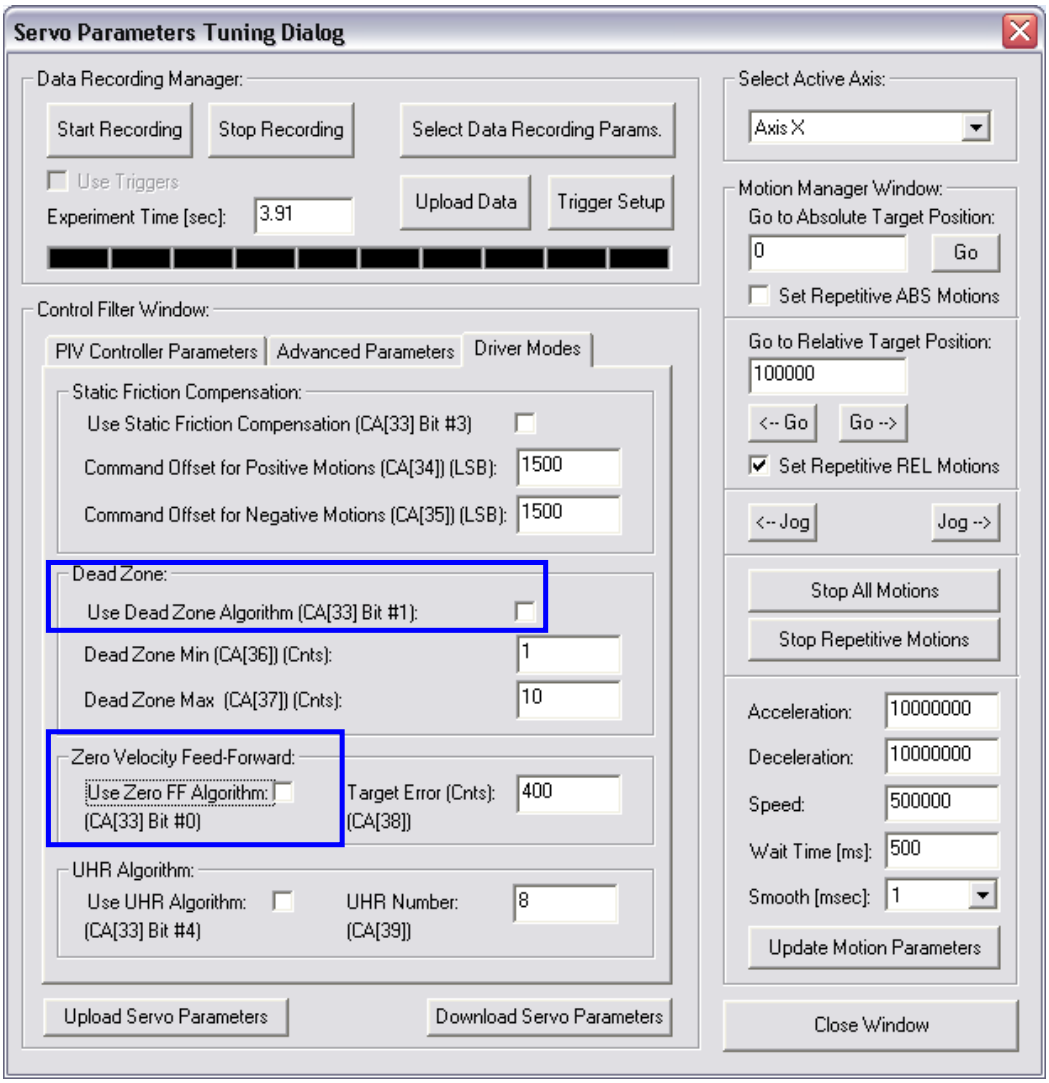



***Figure 9: Defining the “Driver Modes”***

7. In the “PIV Controller Parameters” tab gradually increase the “Velocity Gain [KD]” from 5 to 10 (use the Set all KD,KI Equal button, see Figure 10), until an audible (high frequency) sound appears. At this point, divide the KD parameter by 2. As a result, the sound disappears and the stage runs smoothly and nicely.

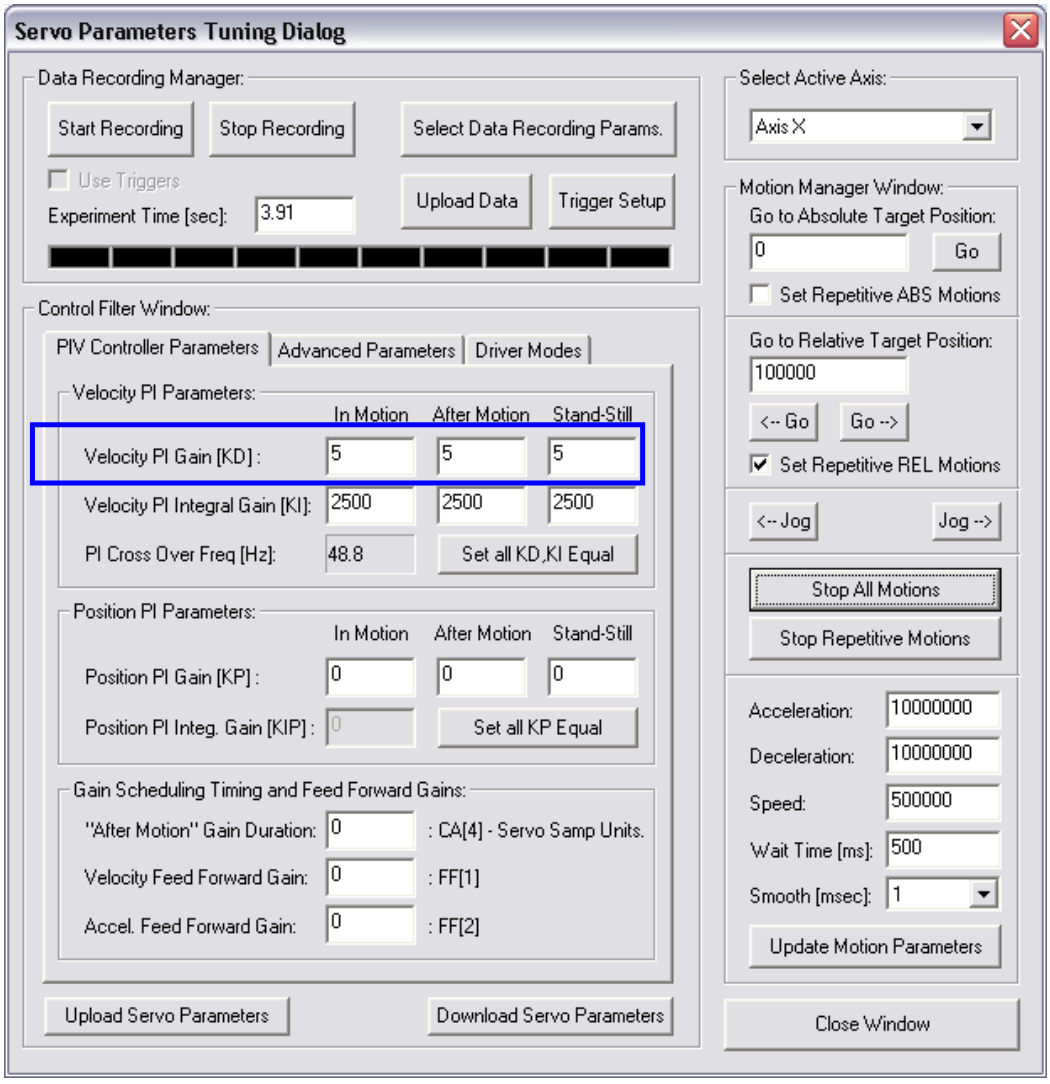



***Figure 10: Setting the "PIV Controller Parameters"***

8. Press Start Recording button and wait for the Data Viewer window to appear (see Figure 11).

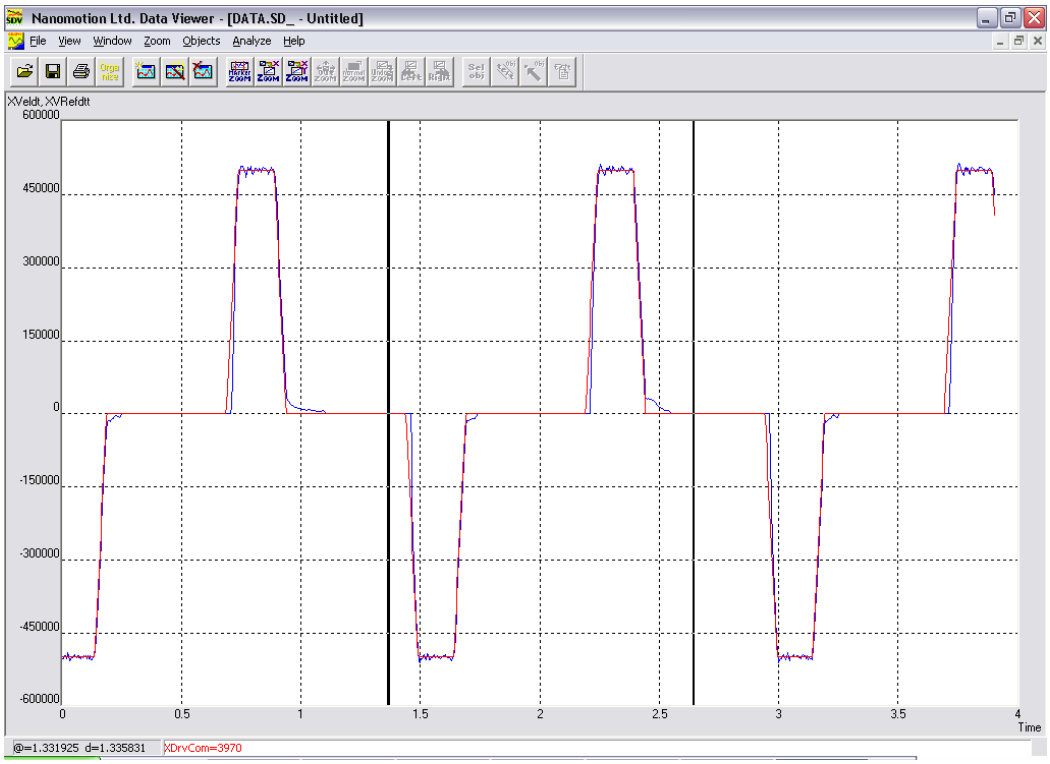



***Figure 11: The Data Viewer Window***

9. Press on Stop All Motions button.
10. Press on “Servo OFF” button on the main screen.

### 2.4.4 Tuning with AB1A Driver

1. In the “Servo Parameters Tuning Dialog” dialog box click the “Driver Modes” tab, see Figure 12.
2. Select the “Use static Friction Compensation” check box.
3. Type **1500** in "Command Offset for Positive Motions" and in "Command Offset for Negative Motions" boxes.
4. Select the “Use Dead Zone Algorithm” check box.

5. Type **1** in the “Dead Zone Min” box (1 is for 0.1µm resolution and 5 is for 0.01 µm resolution).
6. Type **10** in the “Dead Zone Max” box (10 is for 0.1µm resolution and 50 for 0.01 µm resolution).
7. Select the “Use Zero FF Algorithm” check box.
8. Type **400** in "Target Error [CA38]" box (400 is for 0.1µm resolution and 4000 for 0.01 µm resolution).
9. Ensure that under "UHR Algorithm" the "Use UHR Algorithm" check box is clear.

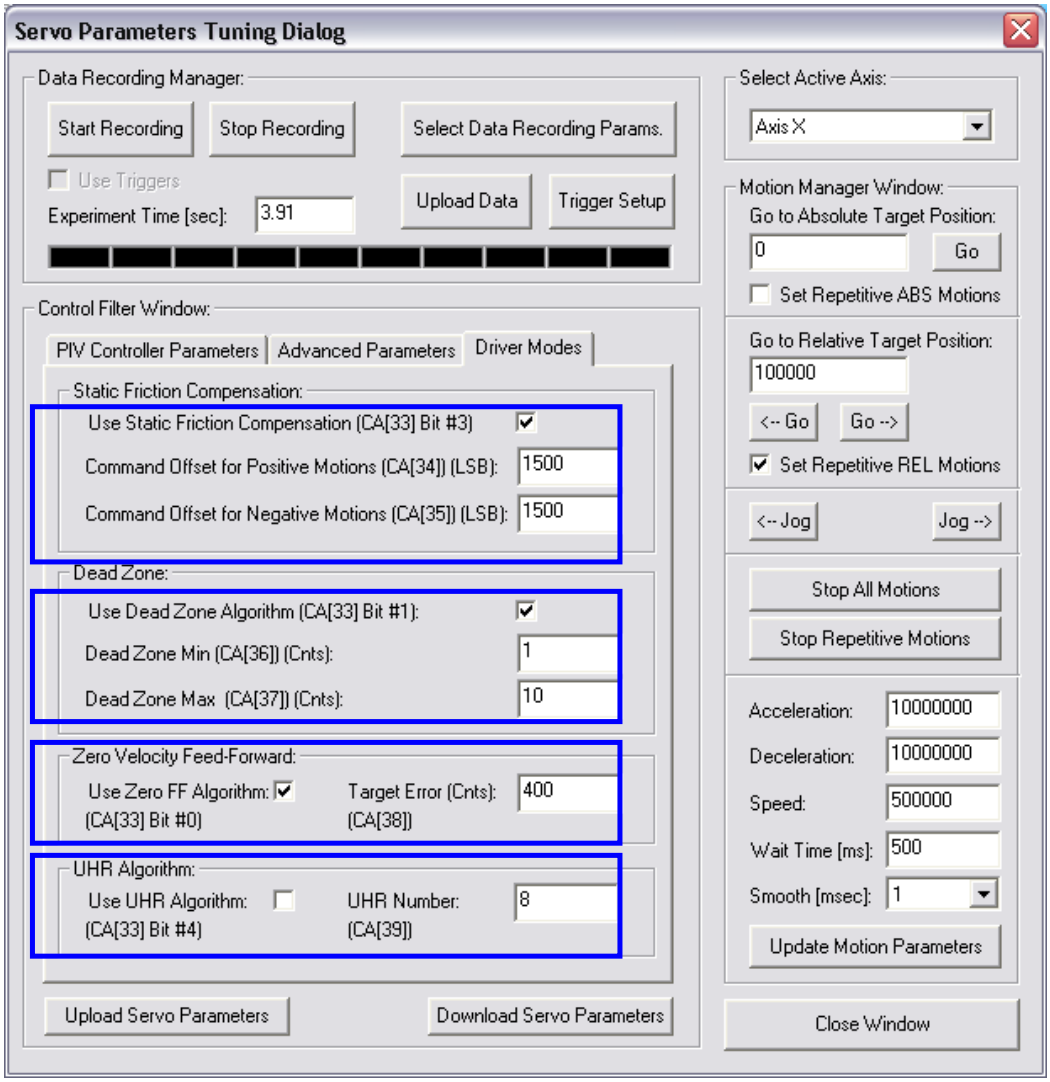



***Figure 12: Defining “Driver Modes” for AB1A Driver***

10. Click the “PIV Controller Parameters” tab (Figure 13) and type:

    **KP=1000** use the Set all KP Equal button

11. Select the “Set Repetitive REL Motion” check box.

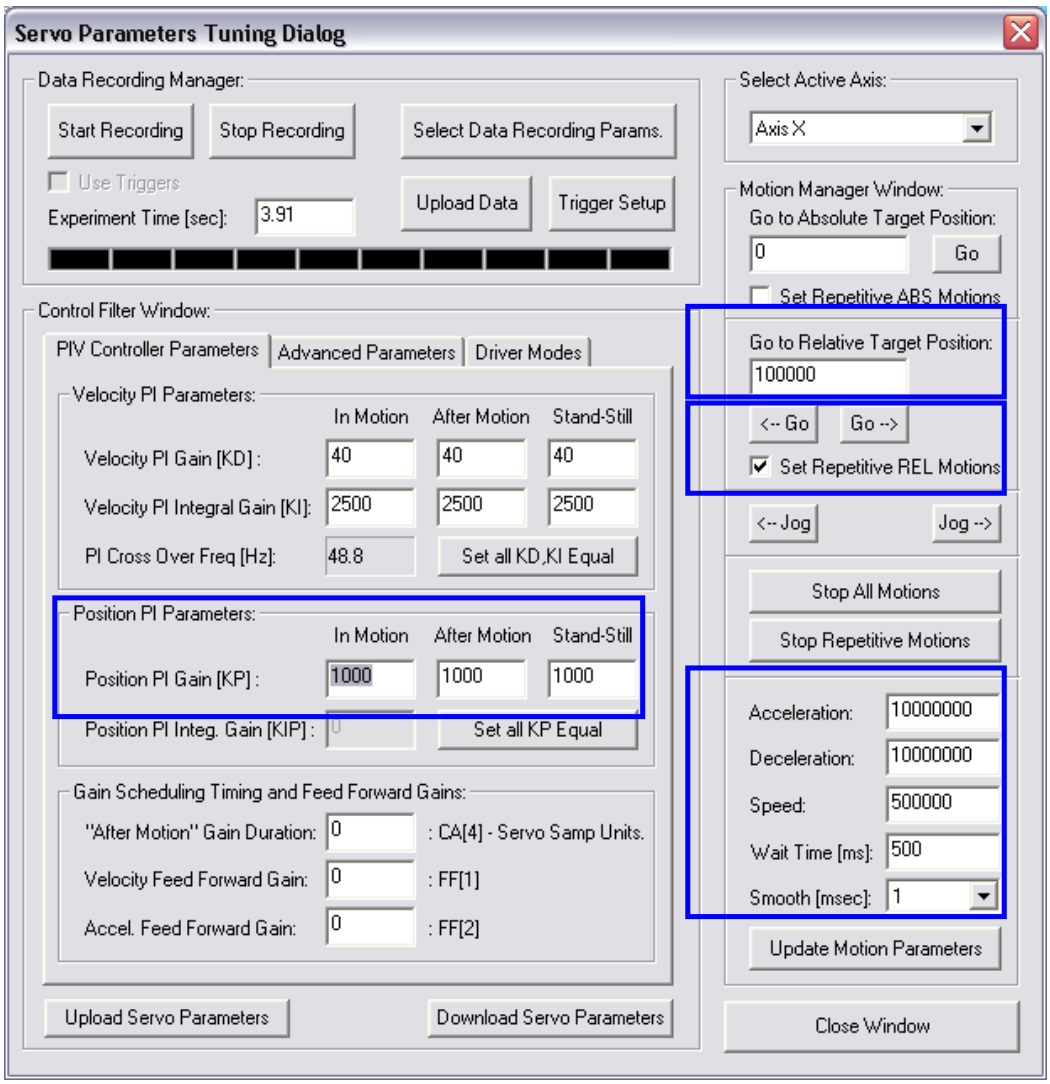



***Figure 13: Defining Servo Parameters for AB1A Driver***

12. Type **100000** (for instance) in the “Relative Target Position” box the desired relative move: (in 0.11µm resolution = 10mm).
13. Set the Acceleration, Deceleration, Speed to the desired values, for instance as shown in Figure 13.
14. Press on Go --> button in the desired direction.

15. Begin to increase “Position PI Gain [KP]” (from 1000) by 200 to max of 2000; record each step (use the Start Recording button) and observe the Position Error, driver command and velocity (see Figure 14). The goal is to optimize the Position Error and Position Error converging during the move.

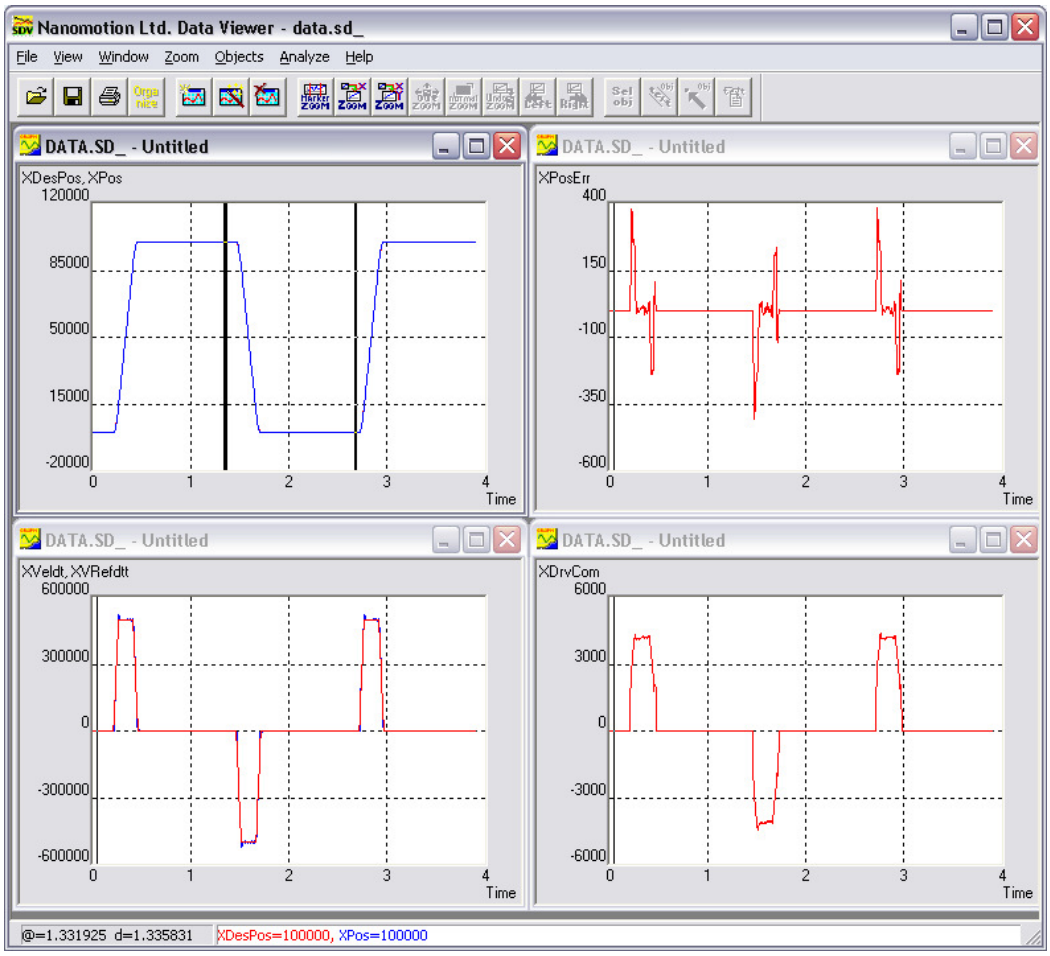



***Figure 14: Data Viewer windows – with AB1A Driver***

16. The driver shape should be similar to the velocity shape. Otherwise, as shown in Figure 15, reduce KP, record data and observe again.

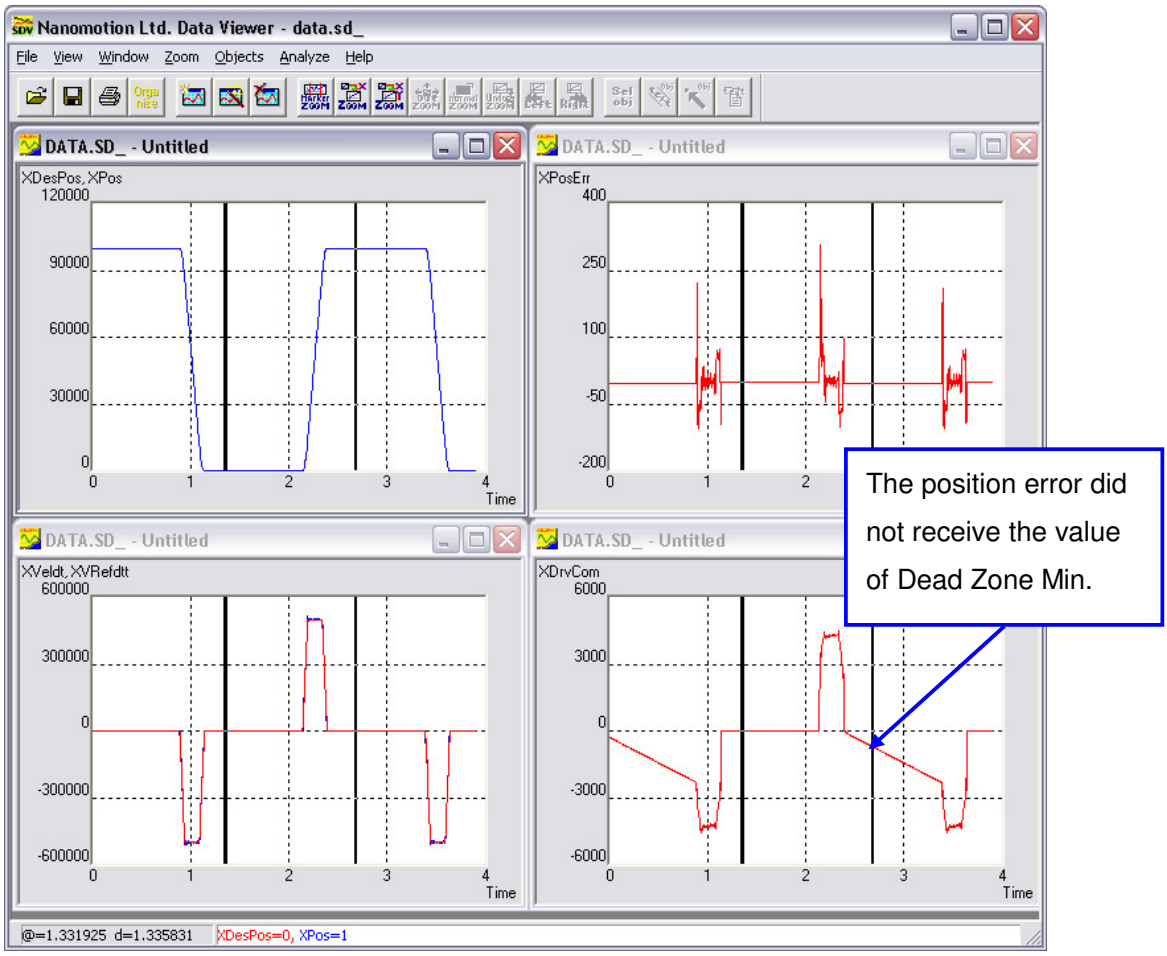



***Figure 15: Inaccurate Position Error Converging – AB1A Driver***

### 2.4.5 Tuning with AB5 Driver

1. Clear the following check boxes in the “Servo Parameters Tuning Dialog” dialog box, see Figure 16:
   - “Use Static Friction Compensation"
   - “Use Dead Zone Algorithm”
   - “Use Zero FF Algorithm”
   - “Use UHR Algorithm”

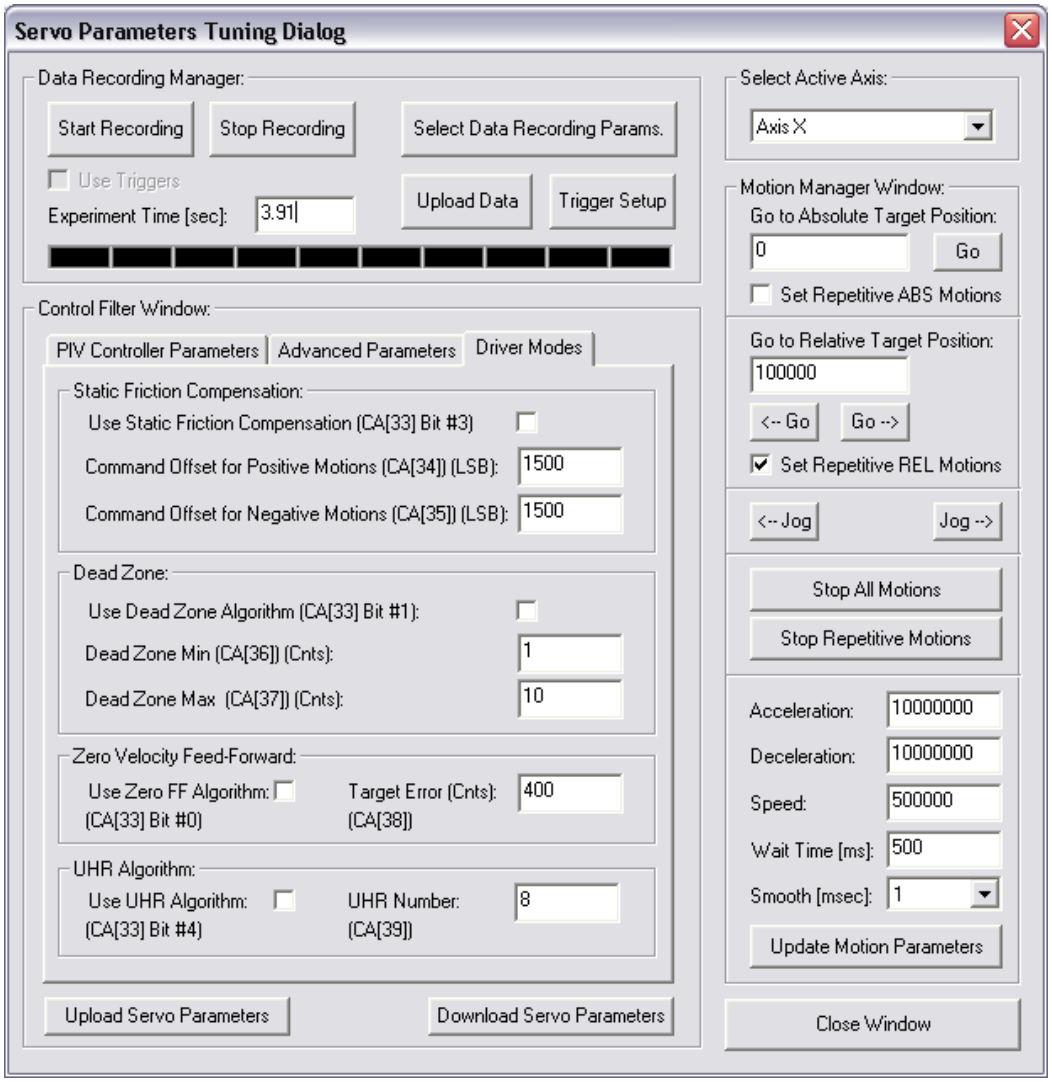



***Figure 16: Defining “Driver Modes” for AB5 Driver***

2. Perform steps from 1 to 16 as described in section 2.4.4.

### 2.4.6 Sin/Cos Encoder Setup

The Sin/Cos (Analog) encoder has two (2) differential output analog signals: "+Sine", "-Sine" and "+Cosine", "-Cosine". The amplitude of those signals is 1V PTP. Those signals are fed into a pre-amplifier before the A/D converter (12bit). The porpose of the pre-amplifier is to increase the signals to maximum value without saturation. A 5V amplitude gives ±2048 counts at the A/D output. The user has to provide the sine and the cosine signals after the pre-amplifier without saturating the A/D. Therefore, it is recommended that after the pre-amplifier those signals will be around 4V to 4.5V (between 1638 to 1843 counts) maximum.

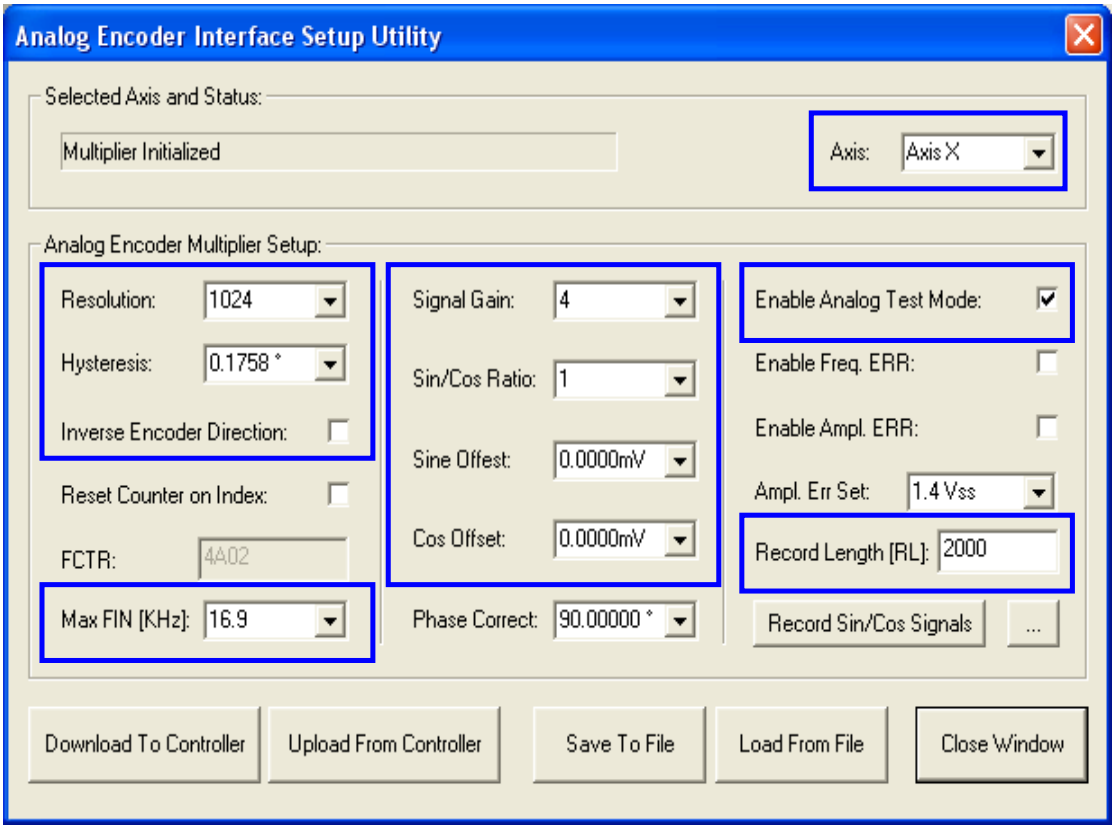


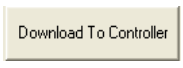

***Figure 17: Analog Encoder Interface Setup Utility Dialog Box***

Perform the following steps with "Servo OFF", and refer to Figure 17:

1. On the "Tools" menu, click "Analog Encoder Multiplier Setup" (or press ALT+E).
2. In the "Analog Encoder Interface Setup Utility" dialog box choose the axis.
3. Choose the requried resolution in the "Resolution" drop-down list box (up to **4096)**. For example, the required resolution is 20nm. The Renishaw encoder pitch is 20µm. In order to get 1 count of 20 nm the user should devide the pitch (20µm) by 20 nm = 1000. In this case, the user should choose the resolution value of 1024 (since 1 count = 19.53 nm).
4. In the "Hysteresis" drop-down list, choose the Hysteresis of **0.1758°**, which is less than 1 count, according to the following calculations: the Renishaw encoder pitch=360°. For example, Renishaw pitch =20µm. 360/1024=0.35°~20nm. Therefore, the user should choose the hysteresis which is less than 0.35°.

***Note:***

- *Pitch is the distance between two (2) lines, in linear position encoder.*

5. In "Max FIN [KHz]" drop-down list, set maximum frequency to 16.9KHz, according to the following calculations: the Maximum Velocity of Nanomotion motors is 300mm/sec. The maximum frequency should be >Maximum Velocity/Pitch. For example, Renishaw encoder pitch=20µm, therefore, maximum frequency is >$300*10^3/20$=15KHz. Thus, the value of 16.9KHz is > 15KHz, and is the closest.
6. Select the "Enable Analog Test Mode" check box.
7. Most of the Sin/Cos encoders are 1V PTP. The FlexDC™ Sin/Cos encoder interface is configured to 5V=2048 counts. For proper operation of the encoder miltiplier, the required radius should be ~4V (=1638 counts).. Thus, start with "Signal Gain"=4.
8. Type "2000" in the "Record Length [RL]" box.
9. Press on 

button to initialize the multiplier.

10. Move the stage manually very slowly and press on 

button.
11. Observe the both graphs located on the left pane of the Dataviewer window see Figure 18. The goal is to adjust the Sin/Cos parameters to get both circles centered around the "0".

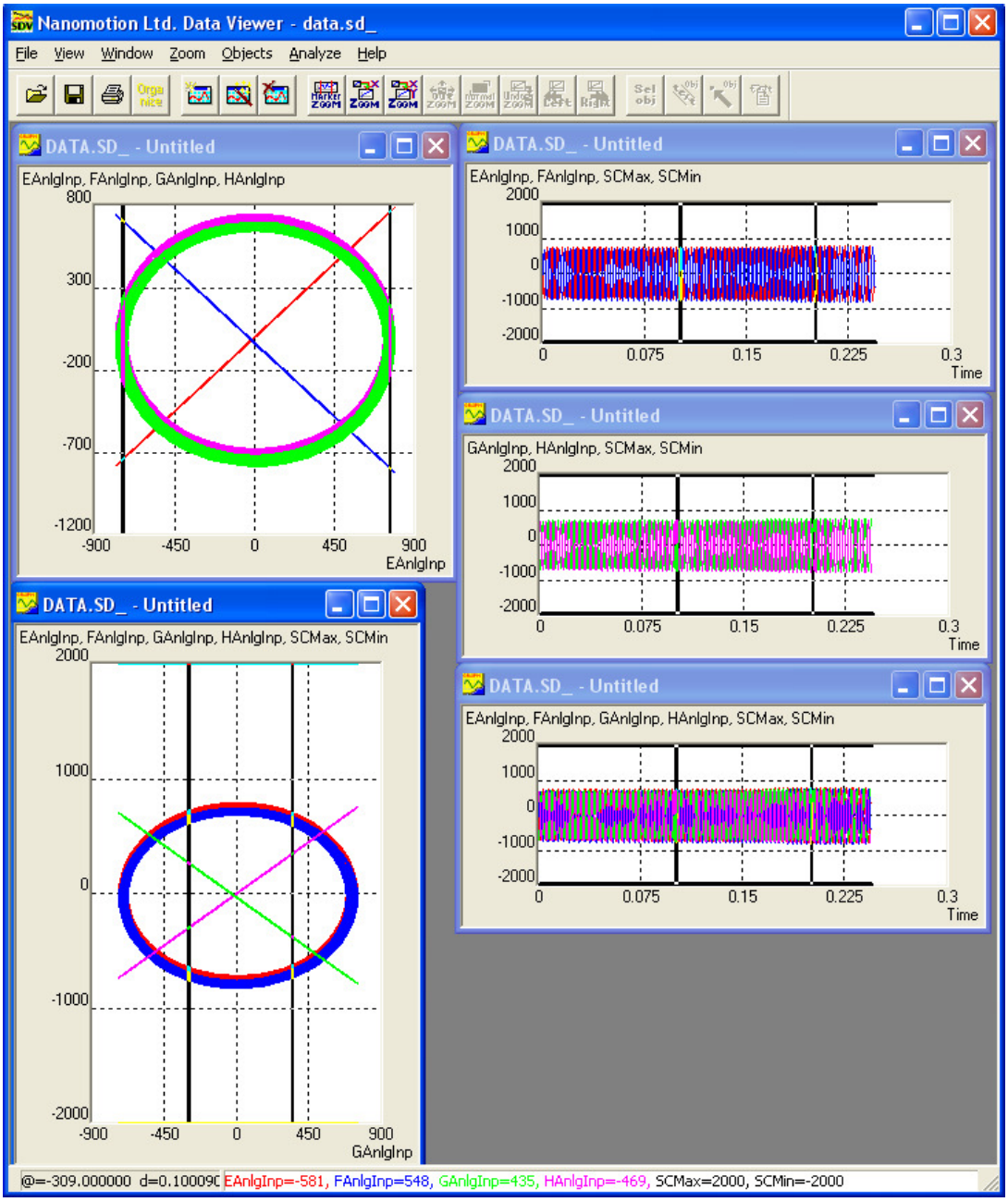



***Figure 18: The Data Viewer Windows***

- If the radius (see Figure 18) after the Gain of 4, is less than 1000 counts, it is recommended to adjust the clearance between the encoder read head and the strip to get maximum amplitude, before increasing the Gain value.
- In case the center of both circles do not ovelap, the user can adjust the offset by changing the "Sin Offset" or "Cos Offset" values. For example "Sin Offset" = -0.1094V, and repeat steps 9 and 10.
- In case, it is required to inverse the direction of the encoder select the "Inverse Encoder Direction" check box (see Figure 17).

## 2.5 FlexDC™ Basic Macro Installation

The FlexDC™ CD has sample Macros (scripts) that allows the user to run basic applications such as "HOME" and "RUN" (see section 2.6). Those macros are located in “SampleScripts” folder.

To install the macros follow the next steps:

1. On the "Macro" menu of the Nanomotion Shell Application, click "Download Macro" (see Figure 19):

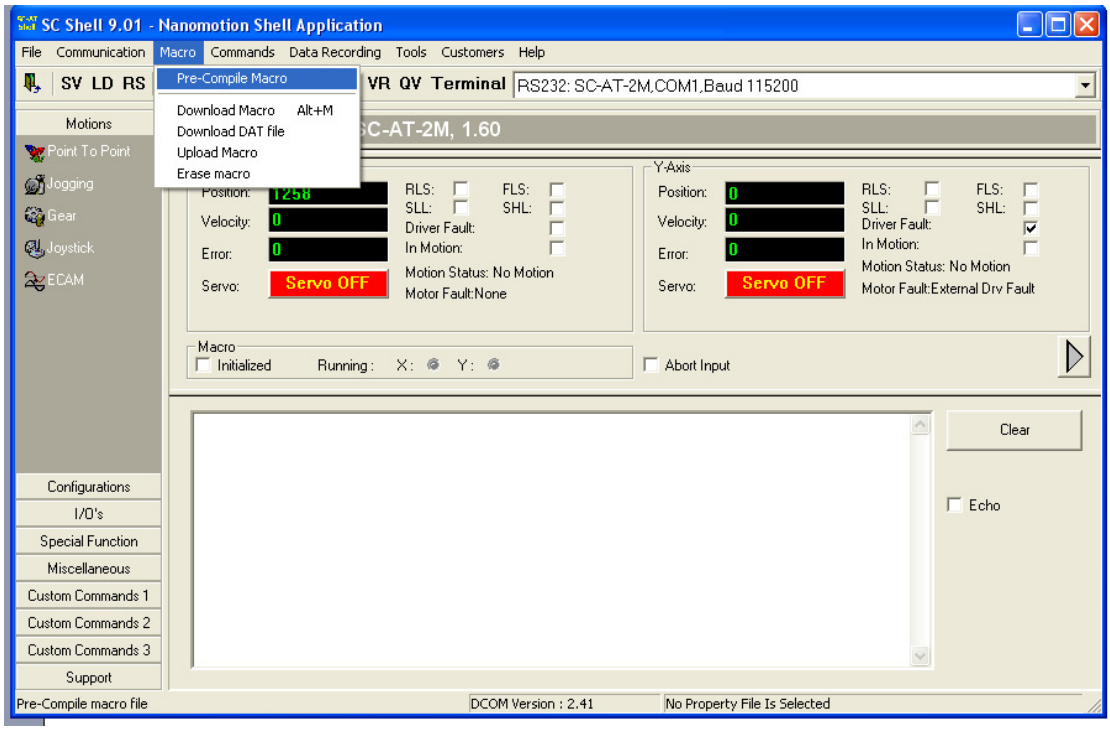



***Figure 19: Macro Installation***

2. Select the FlexDC _Home_Run_v1.01.scm script file in the “Download Macro” window and press OK.
3. The controller notifies the user if the download is successful.

# 2.6 Basic Operation

## 2.6.1 Custom Commands Installation

Basic Macro includes eight (8) sub-routines. The user can run each sub-routine by selecting predefined custom commands.

1. To install the custom commands, on the "File" menu click "Load Custom Commands" (see Figure 20). Select the ***FlexDC_Custom Commands v1.01.scc*** script file in the “Load Custom Controls” window and press OK.

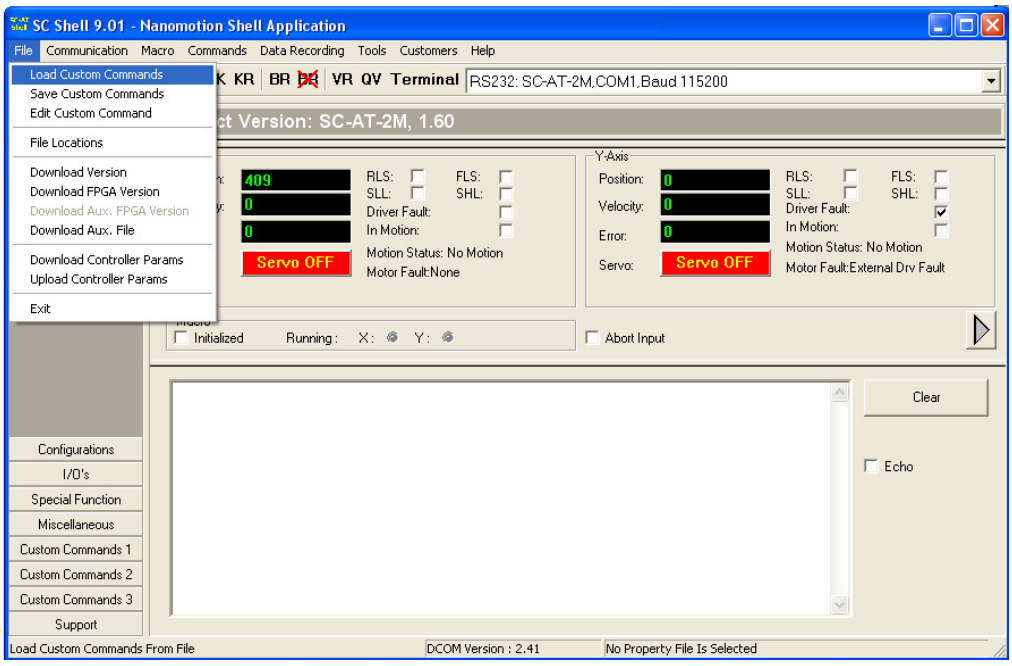



***Figure 20: Custom Commands Installation***

2. Choose a desired sub-routine from the "Custom Commands 1" menu on the left pane of the Nanomotion Shell Application main screen.

### 2.6.2 The “INIT” Application

This sub-routine sets up the correct controller configuration and servo parameters. These parameters are specially tuned for most Nanomotion motors. For high performance applications, it is recommended to perform fine tuning to these servo parameters (refer to chapter 2.4).

### 2.6.3 The "RUN" Application

There are three run-in sub-routines: RUN X, RUN Y and RUN XY. The sub-routine moves the accordant axis/axes between hard stops.

***Note***

- *Running one of these sub-routines ("INIT" or "RUN") automatically runs the “Home” sub-routine. The “Home” sub-routine prevents stage damage by setting the hard stops limitation for the motor.*

### 2.6.4 The "HOME" Application

There are three homing sub-routines: HOME X, HOME Y and HOME XY. The sub-routine moves the accordant axis/axes between the hard stops, then moves the stage toward a negative hard stop and zeroes the encoder. This action sets the software limits according to hard stops positions.

### 2.6.5 The “HALT” Application

This sub-routine immediately stops running both axes and turns the servo OFF.

# 3 System Description

## 3.1 Motion Modes

The FlexDC™ is programmed with advanced motion modes. For each Motion Mode, the exact motion is defined by a set of related parameters, such as speed, and acceleration. While most of these parameters can be modified on-the-fly (in real time) during active motion (practically affecting the motion profile), the Motion Mode itself cannot be modified during active motion. For more information regarding the Motion Modes, see the "FlexDC™ Software User Manual and Commands Reference".

The FlexDC™ supports the following motion modes features:

- **On-the-Fly Parameters Change:** full on-the-fly parameters modification (e.g.: all motion parameters).
- **Profile Smoothing:** an advanced, symmetric S-curve-like profile smoothing algorithm.
- **Monitoring Motions:** the motion can be monitored during the process or when completed, by using parameters.

### 3.1.1 Point To Point Motion Mode – PTP

In this mode the FlexDC™ calculates a standard smoothed trapezoidal profile from the current position to a user specified target position, using user specified acceleration and speed.

### 3.1.2 Repetitive Point To Point Motion Mode – Rep PTP

This mode is similar to the standard PTP motion mode, as described above. However, repetitive motion mode supports motions back and forth between two positions. This mode is excellent for tuning the PIV filter.

### 3.1.3 Jogging Motion Mode – JOG

In this mode the FlexDC™ calculates a standard acceleration profile, using user specified acceleration, toward the user specified speed. This speed is kept constant until the motion is stopped by a user command.

### 3.1.4 Position Based Gearing Motion Mode

Position based gearing (or electronic gearing) motion mode occurs when an axis follows another axis position with a pre-defined (fixed) ratio. The controller supports position gearing motion mode for both X and Y axes.

### 3.1.5 Joystick Motion Modes

#### 3.1.5.1 Velocity Based Joystick Motion Mode

This mode is similar to the Jogging motion mode. However, instead of jogging, in the user specified Speed value, the jogging speed is received from the analog input (when a Joystick or any other source of analog voltage is connected).

#### 3.1.5.2 Position Based Joystick Motion Mode

This mode is similar to the standard PTP motion mode. However, instead of using the user specified Absolute Position parameter as the target position, this mode uses the Analog Input parameter as its target position. This mode automatically supports on-the-fly changes of the Analog Input during motion.

### 3.1.6 Position Step Motion Mode

In this mode the desired position is assigned by the Absolute Position immediately after the Begin command. The profiler does not generate any motion profile and the Acceleration, Deceleration and Speed values are ignored. This mode is useful for measurement of closed loop step response and bandwidth.

## 3.2 The Control Filter

The controller filter is based on a Position over Velocity Loop PIV Filter. The FlexDC™ supports closed loop as well as open loop operation modes.

- As a standard, the controller has a PIV control filter structure which allows the user maximum flexibility in servo control loops tuning.
- The controller has a 16 bit DAC Output:
    - +10V is represented by +32,767; and
    - –10V is represented by –32,767

### 3.2.1 Closed Loop - PIV Filter Mode

In closed loop operation, the control loop structure can be considered as divided into two separated loops: an external position loop cascaded over the internal velocity loop. The linear velocity loop control filter output is fed into the 2nd Order Filter (in case it is enabled), and then passes the final output saturation for the DAC. In Position Error calculation, the variable is updated by the real time control loop. The maximum Position Error value is 8,000,000 counts.

- **2nd Order Filter**

The Controller includes a digital 2nd Order Filter, which is enabled in closed and open loops. The user can test the operation of the filter in open loop, and actually record the step response of the filter. The filter can be enabled or disabled using a special dedicated parameter.

- **Encoder Gain**

The controller's counts are quadrature encoder pulses. This implies a feedback gain. For example, a typical rotary system with an encoder of 1000 [ppr], mounted on the motor's axis, the encoder's gain is as follows:

Enc_Gain = (4 * 1000) / 2π [counts/rad].

- **Filter Gain Scheduling**

The controller software has a built-in control filter gain-scheduling logic. The gain-scheduling may be used for improving the system settling performances (mainly to reduce settling times).

- **Acceleration and Velocity Speed Forward**

The controller supports reference command Feed-Forward Features. Command Acceleration Feed-Forward (Acc-FF) is supported in closed loop modes.

Command Velocity Feed-Forward (Vel-FF) is currently supported in closed loop control mode only.

### 3.2.2 Open Loop Operation

The controller supports a dedicated open loop operation mode. In this mode the user can directly set the value of PO (the final control filter output command value), without the closed loop control filter, and regardless of the system position readings or the position or velocity errors. This mode should be monitored very closely, since the motor is not in closed loop control.

## 3.3 AB1A Driver Special Algorithms

The following AB1A driver special algorithms are integrated into the FlexDC™ Motion Controller:

- Dead Zone Algorithm
- Command Offset Algorithm
- Zero-Feed-Forward Algorithm
- UHR Algorithm

For more information, refer to the "FlexDC™ Software User Manual" and the "AB1A Driver User Manual".

## 3.4 AB5 Driver Brake Mode

The FlexDC™ Motion Controller has the Brake Mode when working with AB5 driver. In Brake ON Mode the driver disconnects the power supply to the motor; however servo is still active. As the motor is turned OFF, it consumes no power and the EOP can be extended (refer to section 4.2 for the EOP). See also the "AB5/AB51 Driver User Manual" for detailed information.

***Note:***

- *The combination of Brake ON while the driver is Enabled poses a conflict and the user must consider the transient upon returning to the Brake OFF Mode.*

## 3.5 Fault Protections and Limits

The controller includes various protection mechanisms and status report parameters which ensure safe operation and easy troubleshooting.

There are two types of groups of the protective mechanisms: protections and limitations.

### 3.5.1 Protections

Fault condition detection and immediate response, usually by disabling the servo, by means of hardware or software.

- **Driver Generated Faults**

Driver Fault is a condition indicating that something is wrong with the motor power driver connected to the controller. The Driver Fault is an actual hardware signal line that the driver outputs, for more information see the "Fault Output" and "TP (Termal Protection)" sections in the "AB5/AB51 Driver User Manual". The signal is continuously monitored by the controller real time servo loop, at the main control sample rate.

- **Software Generated Faults**

The FlexDC™ real time servo loop software can generate the following faults:

  - High position loop error.
  - Encoder signal error.
  - Motor Stuck condition.

Each one of the above axis-related fault conditions generates similar results to a Driver Fault condition. The specific axis is immediately disabled, and the relevant software status bits are updated.

- **Software Protections (Non-fault Conditions)**

The following software protections are managed by the FlexDC™ without generating a fault condition. This means that the servo axis stays enabled, even though the protection may be active:

- FPGA Version.
- CAN Hardware Initialization Failure
- Hardware and Software Motion Limits
- Torque Limit

### 3.5.2 Limitations

The controller offers special handling of software limits, which can be set by the user to any pre-defined value. This value allows axis movement within the pre-defined software limits. Any command that sends the axis to a position which exceeds these pre-defined software limits is ignored. For more information, see the "FlexDC™ Software User Manual and Commands Reference".

## 3.6 Advanced Features

### 3.6.1 Data Recording

The FlexDC™ has a Data Recording feature. This powerful feature allows the user to record internal controller variables, store them in local temporary arrays, and upload them to a host computer using either one of controller's communication channels. The user can access the recorded buffers from within a script program, if required. Data recording significantly improves the control filter adjustment process (control parameters tuning), application debugging and monitoring, and troubleshooting.

### 3.6.2 Position Compare Events

Position compare events is a hardware-supported feature of the FlexDC™ encoder interface that provides the ability to generate accurate hardware pulses based on comparing the actual encoder position with pre-defined values. When a condition for comparison is fulfilled, a hardware pulse is automatically generated by the controller, and is directed to one of the digital outputs of the FlexDC™.

### 3.6.3 Position Capture Events

Position Capture (Latching) events is a hardware-supported feature of the FlexDC™ encoder interface that provides the ability to latch the exact encoder position register based on an external or internal hardware pulse, regardless of the encoder's speed and motion velocity.

The FlexDC™ hardware Capture mechanism supports two types of trigger pulse sources:

- Capture position based on an Encoder Index Pulse
- Capture position based on a Digital Input Pulse

This feature can be used to find the exact (1 count resolution) homing location when operated on the encoder index, and to synchronously latch multiple axes system location when operated on digital inputs. FlexDC™ supports simultaneous capture on both of its two axes.

### 3.6.4 Joystick – Analog Input Interface

The FlexDC™ has two general-purpose analog inputs. Those analog inputs are nominally ±10V and are converted using 10 or 12 bits A2Ds. They are sampled at ~1kHz (each input is sampled every 8 Servo cycles). For a detailed description of the analog inputs hardware circuits, refer to Table 7.

### 3.6.5 Dynamic Error Mapping Correction

Dynamic Error Correction is required for correcting the non-linear mechanical position errors, caused by, for example, a lead or ball screw. The correction is performed by interpolating discreet positions user defined correction table, and by altering the actual encoder position readings. Each axis can be corrected independently.

## 3.7 FlexDC™ Protocols, Syntax and Commands

### 3.7.1 Types of Communication and Protocols

The FlexDC™ supports the following types of communication:

- RS232: ASCII Based RS232 communication protocol.
- CAN: Full Binary, high baud rate, CAN Bus communication protocol.
- LAN: IEEE 802.3 10BASE-T/100BASE-TX.

Using separate hardware interface layers, the RS232, CAN bus and LAN communication links (and their protocols) are completely independent from one another, and can operate simultaneously. For detailed description of types of communication and protocols, refer to the "Communication Protocols for FlexDC™ User Manual".

### 3.7.2 Language Notations and Syntax

The "Language Syntax Rules" apply to any command source (RS232/CAN Bus, etc.).

The communication keywords are divided into two groups:

- Parameters Keywords – parameters which can report their value or can be assigned with a certain value.
- Command Keywords – initiate a process.

Each keyword is defined by its attributes, and has conditions that must be fulfilled in order to accept the command clause.

The FlexDC™ supports group definitions for axes identifiers. Its language syntax requires an axis identifier before any keyword. Thus, when a specific axis identifier is given, the command interpreter interprets the clause and acts upon the specific axis only. For Language Syntax description, refer to "FlexDC™ Communication Protocols User Manual".

# 4 Technical Data

## 4.1 Specifications

| | |
|---|---|
| **Dimensions - 2U Enclosure** | 123mm H x 361mm W x 308mm D |
| **Weight** | 5.2 kg (depends on configuration) |
| **Technical Specification** | |
| Up to 2 axes integrated | AB1A or AB5 driver cards, driving up to 16 elements per axis |
| Servo Rate: | 8kHz |
| DAC Output: | +/- 10V, 16 bit |
| AquadB Encoder Input | (one per axis) |
| Sin/Cos Encoder with on board interpolators | Optional (one per axis) |
| **I/O** | |
| 8 x Digital Isolated Inputs | |
| 2 x Digital Isolated Outputs | Valid when AB1A is configured |
| 2 x Digital Fast Inputs | |
| 2 x Digital Fast Outputs | |
| **Communication** | RS232, CAN-open, Ethernet |
| **Power** | |
| Universal input voltage: | 100-240 VAC, 50-60 Hz |
| Power consumption: | 140VA max |
| **Environmental** | |
| Ambient operating temperature: | 0º-45ºC |
| Storage temperature: | Up to 70ºC |
| Operating humidity: | Up to 80%, non-condensing |
| Lead free | |

## 4.2 Thermal EOP (Envelop of Performance)

***Note:***

- *Data given in this section is for user's convenience. For detailed information, refer to the "AB5/AB51 Driver User Manual", the "AB1A Driver User Manual" and the relevant HR motor user manual.*

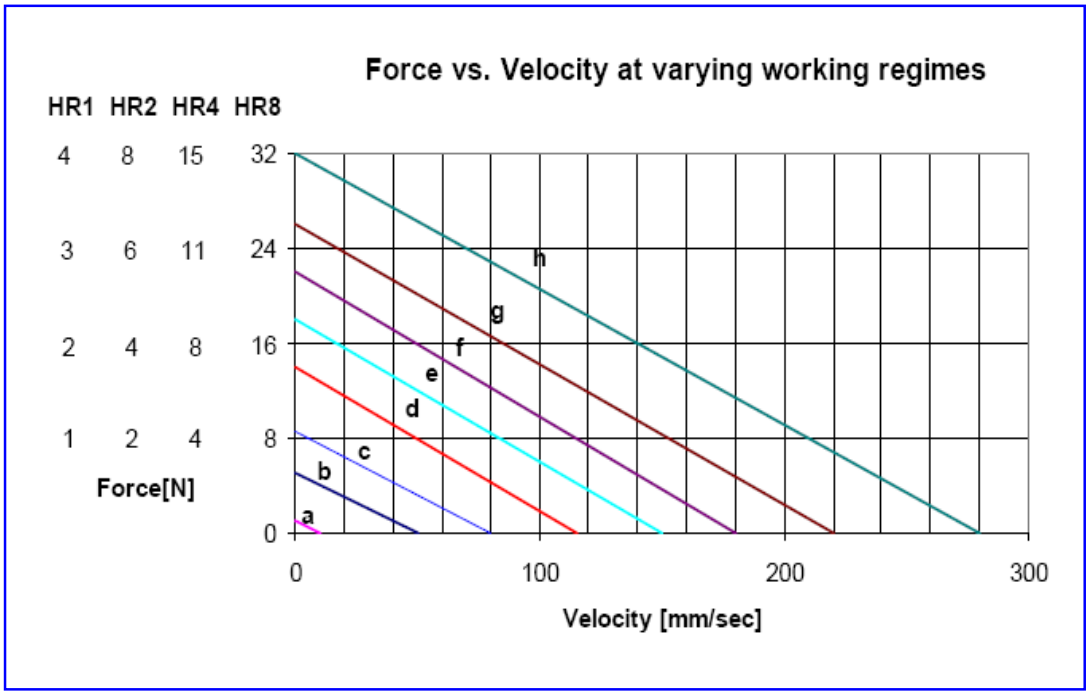



***Figure 21: Thermal EOP for AB5 Driver***

| AB5 | | | | | |
|---|---|---|---|---|---|
| Curve | Duty Cycle [%] | | | Maximal Continuous Operation time [sec] | |
| | Environment Ambient Temperature | | | Environment Ambient Temperature | |
| | Air 25°C Brake_ Off | Air 25°C Brake_On | Vacuum Brake_On | Air 25°C | Vacuum |
| a | 100 | 100 | 28 | … | 230 |
| b | 100 | 100 | 23 | … | 210 |
| c | 100 | 100 | 19 | … | 150 |
| d | 100 | 100 | 14 | … | 110 |
| e | 50 | 80 | 13 | 280 | 90 |
| f | 33 | 58 | 12 | 170 | 66 |
| g | 24 | 45 | 10 | 77 | 44 |
| h | 11 | 28 | 6.5 | 32 | 25 |

***Table 1: Thermal EOP Standard LUT for HR Motors Driven by AB5***

| AB51 | | | | | |
|---|---|---|---|---|---|
| Curve | Duty Cycle [%] | | | Maximal Continuous Operation time [sec] | |
| | Environment Ambient Temperature | | | Environment Ambient Temperature | |
| | Air 25°C Brake_Off | Air 25°C Brake_On | Vacuum Brake_On | Air 25°C | Vacuum |
| a | 100 | 100 | 56 | … | 500 |
| b | 100 | 100 | 54 | … | 450 |
| c | 100 | 100 | 45 | … | 280 |
| d | 100 | 100 | 33 | … | 170 |
| e | 99 | 99 | 23 | … | 100 |
| f | 53 | 58 | 12 | 170 | 66 |
| g | 33 | 48 | 10 | 77 | 44 |
| h | 17 | 28 | 6.5 | 32 | 25 |

***Table 2: Thermal EOP Reduced LUT for HR Motors Driven by AB51***

## 4.3 Indicators and Connectors' Pinouts

### 4.3.1 Front Panel Indicators

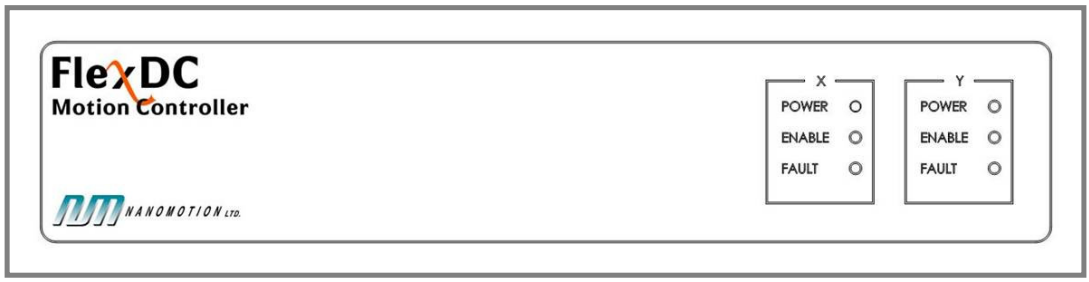



***Figure 22: FlexDC™ Front Panel***

The FlexDC™ includes the following indicators on its front panel (see Figure 22):

| Status | Power | Enable | Fault |
|---|---|---|---|
| **Driver Vcc <4.6V/ Driver does not exist** | OFF | OFF | OFF |
| **Driver Vcc>4.6V and motor is not connected** | Green | OFF | OFF |
| **Motor connected and disabled** | Green | Orange | OFF |
| **Motor connected and enabled** | Green | Green | OFF |
| **AB1A over current**<br>**AB5 motor over temperature** | Green | Orange | Red |
| **AB5 over current/voltage** | Green | Red | Red |

***Table 3: FlexDC™ LED Indicators Description***

***Note:***

- *This table refers to both axes: X and Y.*

### 4.3.2 Rear Panel Connections

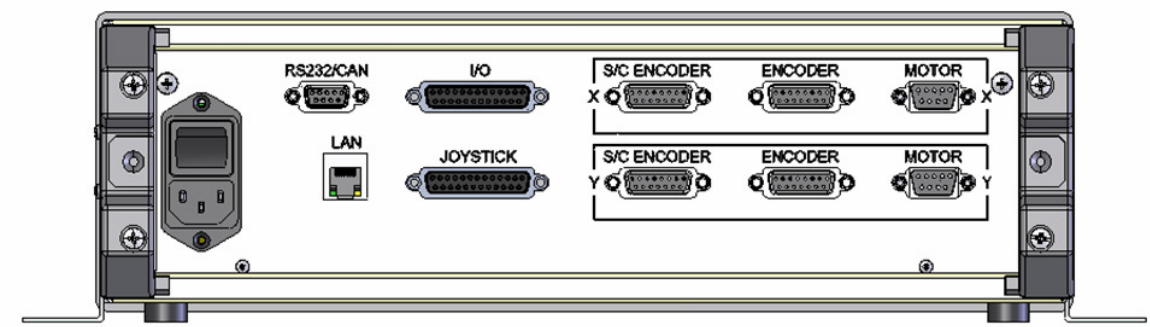



***Figure 23: FlexDC™ Rear Panel***

### 4.3.3 RS232/CAN Pinout

- The RS232/CAN includes D-SUB 9pin female support RS232 and CAN bus (last) communication channels (see Figure 23).

| Pin # | Pin Name | Function |
|---|---|---|
| **1** | N.C. | Not connected |
| **2** | RS232-TxD | FlexDC™ RS232 Transmit Output |
| **3** | RS232-RxD | FlexDC™ RS232 Receive Input |
| **4** | CAN-High | CAN Communication High Differential Line |
| **5** | GND | Signal GND |
| **6-8** | N.C. | Not connected |
| **9** | CAN-Low | CAN Communication Low Differential Line |

***Table 4: RS232 / CAN Pinout***

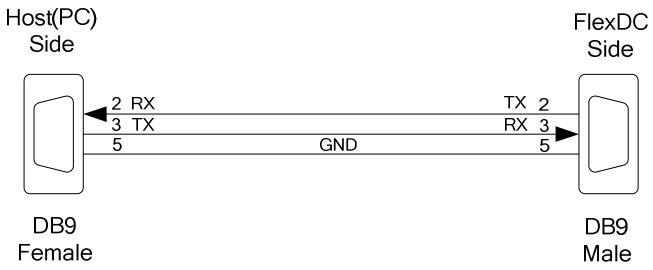



***Figure 24: The RS232 Cable***

- The FlexDC™ is controlled via a main RS232 line (up to baud rate of 115,000 bps) and/or a CAN bus (up to 1MBit/sec).
- Through this line, users can communicate with the FlexDC™ by both RS232 and CAN bus networks simultaneously.

***Note:***

- *Since the CAN hardware requires termination resistors in each end of the network link, FlexDC™ includes a built-in termination resistor.*

### 4.3.4 Motor Output Port Pinout

(See Figure 23)

| Pin # | Pin Name | Function |
|---|---|---|
| **1** | GND | Power supply ground |
| **2** | N.C. | Not connected |
| **3** | Motor_Up | High voltage output |
| **4** | Motor_Common | High voltage output |
| **5** | Motor_Down | High voltage output |
| **6** | Motor Connected | Input |
| **7** | N.C. | Not connected |
| **8** | N.C. | Not connected |
| **9** | N.C. | Not connected |

***Table 5: Motor Output Port Pinout***

### 4.3.5 I/O Pinout

(Refer to Figure 23)

| Pin # | Pin Name | Function |
|---|---|---|
| **1** | XRLS | Limit Switches X Axis Reverse Limit Switch Input |
| **2** | YRLS | Limit Switches Y Axis Reverse Limit Switch Input |
| **3** | LSCOM | Limit Switches Common Input |
| **4** | Din2 | General Purpose Digital Inputs #2 |
| **5** | Din4 | General Purpose Digital Inputs #4 |
| **6** | Din6 | General Purpose Digital Inputs #6 |
| **7** | Din8 | General Purpose Digital Inputs #8 |
| **8** | Dout1 | General Purpose Digital Output #1 * |
| **9** | Dout_Com | General Purpose Digital Outputs Common Return Line |
| **10** | Din9_Fast | TTL Fast Input #9 |
| **11** | Din10_Fast | TTL Fast Input #10 |
| **12** | Vcc | Vcc Supply: +5 [v] max 100mA |
| **13** | GND | Logic Supply Ground |
| **14** | XFRS | Limit Switches X Axis Forward Limit Switch Input |
| **15** | YFRS | Limit Switches Y Axis Forward Limit Switch Input |
| **16** | Din1 | General Purpose Digital Inputs #1 |
| **17** | Din3 | General Purpose Digital Inputs #3 |
| **18** | Din5 | General Purpose Digital Inputs #5 |
| **19** | Din7 | General Purpose Digital Inputs #7 |
| **20** | InCom1÷8 | General Purpose Digital Inputs Common Anode Line |
| **21** | Dout2 | General Purpose Digital Output #2 * |
| **22** | Vuser | General Purpose Digital Outputs Common Supply Line |
| **23** | Dout5_fast | TTL Fast output #5 |
| **24** | Dout6_fast | TTL Fast output #6 |
| **25** | GND | Logic Supply Ground |

***Table 6: I/O Pinout***

* Valid when AB1A is connected.

### 4.3.6 Limit Interfaces

FlexDC™ supports isolated limit switches interface as described in the following figure (refer to Table 6):

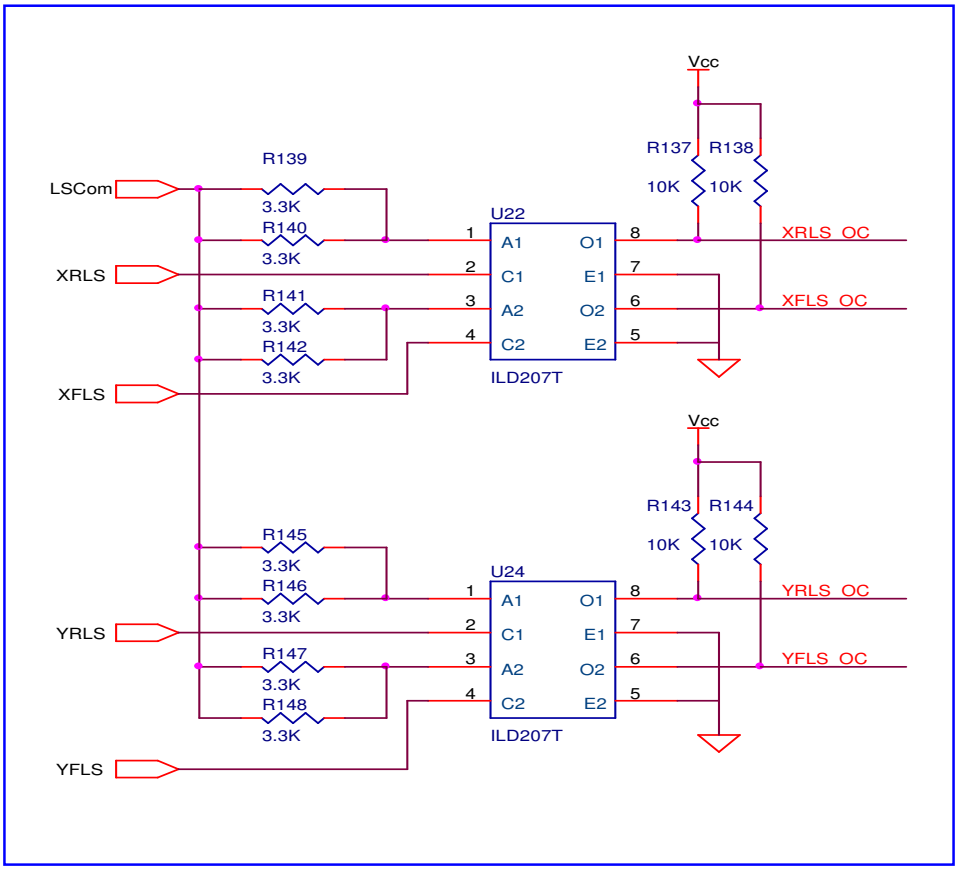



***Figure 25: Limit Switches Electrical Interfaces***

Normal operation of the limit switches requires the LS-Common line to be pulled up to any voltage from +5[v] to +24[v], while activating an input requires that the specific input will be pulled down to the return line (GND). Any current above 2.5 mAmp flowing through a Limit Input will activate the input.

The Limit Switches inputs are fully optically isolated, and are compatible to NPN drive outputs.

The Active Logic Level of Limit Switches inputs can be configured by software.

### 4.3.7 General Purpose Digital Input Interfaces

The FlexDC™ supports 8 general-purpose digital inputs. The inputs are all optically isolated, and use a common anode line shared for all 8 inputs. The following figure shows a typical interface description of the FlexDC™ general-purpose isolated inputs.

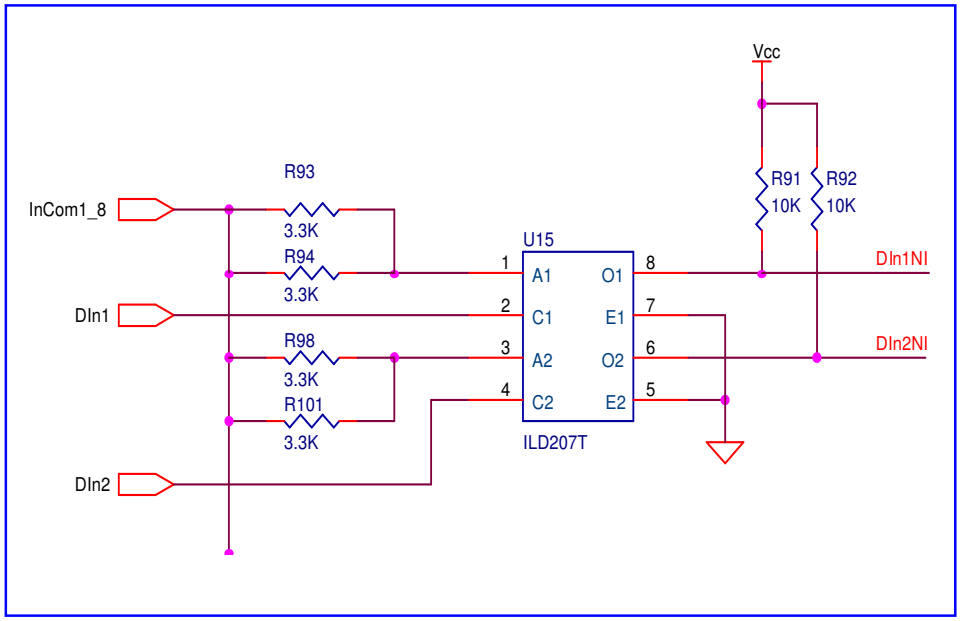



***Figure 26: Typical Optically Isolated Digital Inputs Electrical Interface***

All inputs are NPN compatible, and require an external pull down for the inputs to be electrically activated. For normal operation, a current of at least 2.5 mAmp should be flowing through the common anode connection (InCom1÷8, Pin#20) to any one of the inputs (Din-1, Pin #16 through Din-8, Pin#7, see Table 6).

The Max allowed voltage on the InCom1÷8 input (relative to any of the inputs) is +28 VDC.

The active logic level of all digital inputs can be controlled by software. Refer to the "FlexDC™ Software User Manual and Commands Reference" for “IL” and “IP” keywords description.

### 4.3.8 General Purpose Digital Output Interfaces

The FlexDC™ supports 4 general-purpose digital outputs, as follows:

- When AB5 driver is on axis X, Dout1 controls the driver's Brake Input.
- When AB1A driver is on axis X, Dout1 is a General Purpose Digital Output on the I/O connector (see to Figure 27).
- When AB5 driver in on axis Y, Dout2 controls the driver's Brake Input.
- When AB1A driver is on axis Y, Dout2 is a General Purpose Digital Output on the I/O connector (see to Figure 27).
- Dout3 controls the Set/Offset of Driver X.
- Dout4 controls the Set/Offset of Driver Y.

The schematic diagram in Figure 27 below shows the electrical interface of the isolated digital outputs.

The user should supply +5 ÷ +24 VDC to the Vuser input. All used Digital outputs should be pulled up to that line with appropriate load (max 15 mAmp per output).

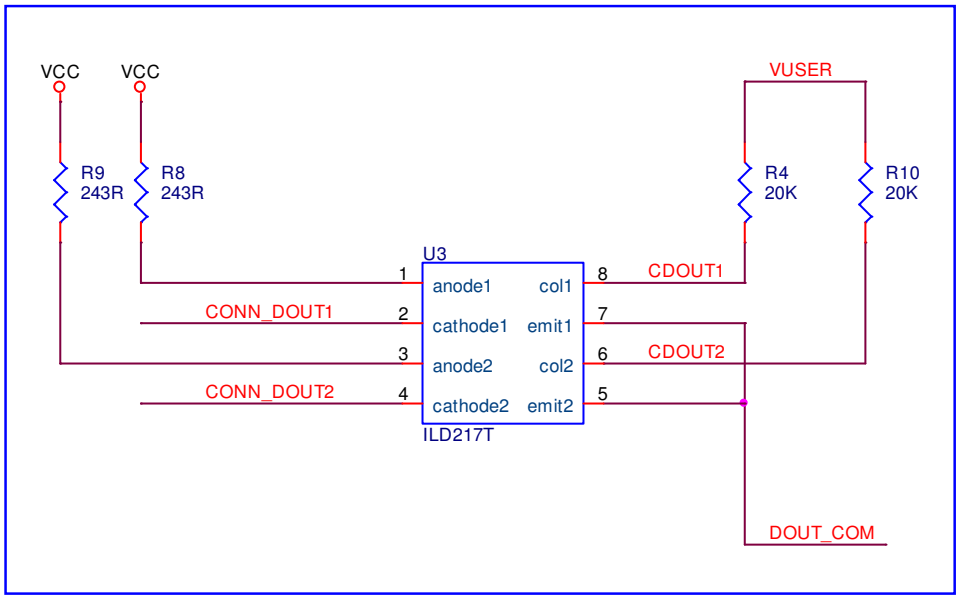



***Figure 27: Typical Optically Isolated Digital Output Interface***

### 4.3.9 Fast I/O Interfaces

The FlexDC™ also supports Fast digital I/O's (0 ÷ +5 VDC TTL Level), in addition to the standard isolated general-purpose input/output lines.

There are 2 additional fast input lines (Din9-Fast, Pin#10 and Din10-Fast, Pin#11) and 2 additional fast output lines (Dout5-Fast, Pin#23 and Dout6-Fast, Pin#24), see Table 6 for reference.

#### 4.3.9.1 Fast Inputs Interfaces

The fast inputs are interfaced through a 74VHC541 buffer, with a 15 nano-sec propagation delay between the connector input line to the controller FPGA. These inputs can be used as standard TTL inputs, or dedicated capture inputs to capture by hardware exact encoder positions at fast rate with "0" delay.

The fast inputs AC/DC characteristics definitions are:

- 15 nano-sec propagation delay.
- Inputs must be related to FlexDC™ logical GND.
- An input voltage level less then 1.4V will be recognized as logic "0" level.
- An input voltage higher then 3.35V will be recognized as logic "1" level.
- Max allowed input voltage range: 0 ÷ +5 VDC.

#### 4.3.9.2 Fast Outputs Interfaces

The fast outputs interface is a 74VHCT541 buffer, with a 15 nano-sec propagation delay between the controller FPGA and the connector fast output line. These outputs can be used as normal TTL outputs or as dedicated outputs of the encoder Position Compare Logic function. In that case the software can control the pulse width. Refer to the "FlexDC™ Software User Manual and Commands Reference" for "PG" keyword description.

The fast outputs AC/DC characteristics definitions are:

- 15 nano-sec propagation delay.
- Outputs are related to the FlexDC™ logical GND.
- Output Logical for LOW “0” : VOL = 0.44 V maximum.
- Output Logical for HIGH “1” : VOH = 3.8 V minimum.
- Max allowed output stage load: 8mAmp (sink and source).

### 4.3.10 Joystick Interface

(Refer to Figure 23)

| Pin # | Pin Name | Function |
|---|---|---|
| **1** | VIN_X | Axis X Analog Input at ±10 Volts |
| **2** | VIN_Y | Axis Y Analog Input at ±10 Volts |
| **3-10** | N.C. | Not Connected |
| **11** | +V_JOYSTICK | +10V Supply for Joystick |
| **12-22** | N.C. | Not Connected |
| **23** | -V_JOYSTICK | -10V Supply For Joystick |
| **24-25** | N.C. | Not Connected |

***Table 7: Joystick Interface Pinout***

***Note:***

- *It is recommended to use a Nanomotion joystick.*

### 4.3.11 A Quad B Encoder

The encoder connector is a D-Type 15pin, female, (refer to Figure 23). The FlexDC™ connector's pinout is compatible to Renishaw RGH24 Digital.

| Pin # | Pin Name | Function |
|---|---|---|
| **7, 8** | 5V | Power |
| **2, 9** | 0V | |
| **14** | A+ | Incremental signals |
| **6** | A- | |
| **13** | B+ | |
| **5** | B- | |
| **12** | Z+/Q- | Reference mark/Limit switch |
| **4** | Z-/Q+ | |
| **15** | Inner | Shield |
| **1, 3** | N.C. | Not connected |
| **10-11** | N.C. | Not connected |

***Table 8: AqB Encoder Pinout***

### 4.3.12 Sin/Cos Encoder

The encoder connector is a D-Type 15pin, female (refer to Figure 23). The FlexDC™ connector's pinout is compatible to Renishaw RGH24 Analog.

| Pin # | Pin Name | Function |
|---|---|---|
| **6** | 5V | Power |
| **5** | 0V | |
| **8** | $V_1+/I_1+$ | Incremental signals |
| **7** | $V_1-/I_1-$ | |
| **4** | $V_2+/I_2+$ | |
| **3** | $V_2-/I_2-$ | |
| **2** | $V_0+/I_0+$ | Reference mark/Limit switch |
| **1** | $V_0-/I_0-$ | |
| **9** | Inner | Shield |

***Table 9: Sin/Cos Encoder Pinout***

# 5 Ordering Information and Configurations

## 5.1 FlexDC™ Part Numbering Scheme and Configurations

| Axis | X | Y | X | X | Y | Y | X | Y |
|---|---|---|---|---|---|---|---|---|
| FlexDC (L) | Driver | Driver | Motor Type | Ex | Motor Type | Ey | Sin/Cos | Sin/Cos |
| Options | 1=AB1A<br>5=AB5 | 1=AB1A<br>5=AB5 | H=HR<br>D=DM<br>S=ST | 1<br>2<br>4<br>8<br>16 | 0=single axis<br>H=HR<br>D=DM<br>S=ST | 0<br>1<br>2<br>4<br>8<br>16 | 1=sin/cos<br>0=digital | 1=sin/cos<br>0=digital |

***Table 10: FlexDC™ Part Numbering Scheme***

***Notes:***

- ***Ex****= is a number of elements on X axis*
- ***Ey*** *= is a number of elements of Y axis*
- *For configuration options description, see section 1.5.*

## 5.2 FlexDC™ Example Configurations

- Dual axes with AB1A drivers:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **L** | 1 | 1 | H | 4 | H | 4 | 0 | 0 |

- Dual axes with AB5 drivers:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **L** | 5 | 5 | H | 4 | H | 2 | 0 | 0 |

- Dual axes with AB1A and AB5 drivers:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **L** | 1 | 5 | D | 8 | H | 2 | 1 | 0 |

# 6 Contact Information

## 6.1 Customer Service

Contact your local distributor or email Nanomotion Ltd. Technical Support Department **at techsupport@nanomotion.com**, with detailed problem description and the following information:

- FlexDC™ P/N.
- FlexDC™ Current Firmware version.
- Nanomotion Shell Application Software version.
- Operating System on host PC.

## 6.2 Headquarters

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