XCD Controller

User Manual

1 Revision History

Revision	Date	Details
00/A	8-Aug-10	Prerelease

2 Introduction

XCD Controller is a small but powerful integrated motion controller and drive for Nanomotion piezo-electric motors.

The controller provides positioning control of one axis, with configurable motion profile and servo parameters.

The controller supports user programming using XMS motion script. With XMS, the customer is able to define complex sequence of motions along with sophisticated calculations and execution control. Prepared XMS program can be stored in the controller flash memory to be executed immediately after power up.

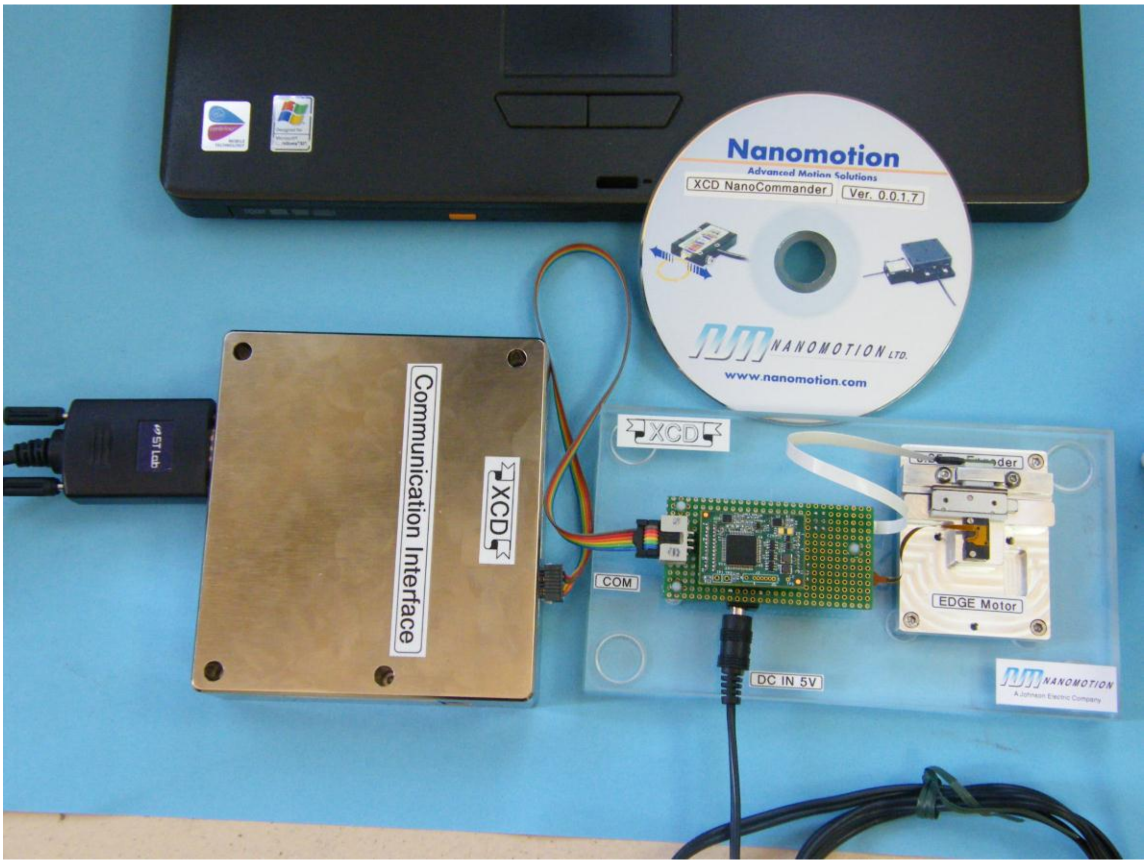
3 Quick Start

Use XCD Presentation Package for quick start and experiments with the XCD controller.

3.1 Package Components

XCD Presentation Package consists of the following components:

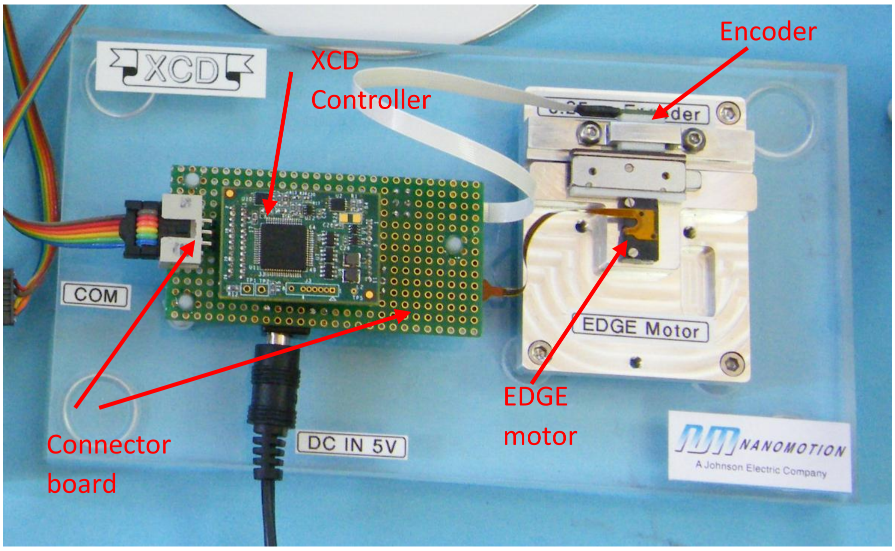
1. Motor-drive assembly
2. Communication box
3. Power adapter
4. Software installation disk



3.1.1 Motor-drive Assembly

Components of Motor-drive assembly:

- XCD controller
- Connector board
- EDGE motor + stage + Encoder



The XCD controller is supplied with application stored in the flash memory. See First example of XMS program for explanation of the stored application.

Attention: Stored application begins moving the motor immediately upon connecting the power jack.

The Motor-drive assembly is a self-sufficient unit, and only requires power adapter connection to be used for simple demonstration. Connection to computer through Communication box is only required for additional actions, like real-time monitoring or changing the motion program.

3.1.2 Communication Box

Communication Box is a passive device providing RS232 connection to the XCD controller.

The only Communication Box function is translation of RS232 voltage level to TTL level, which is necessary for the XCD controller.

3.1.3 Power Adapter

Power adapter provides 5 V to XCD controller.

3.1.4 Software Installation Disk

The disk contains installation files of XSD NanoCommander and several examples of motion programs.

3.2 Initial Steps

3.2.1 Hardware Installation

3.2.1.1 Minimal Installation

For minimal installation, use the Motor-drive assembly and connect power adapter to power jack. The application stored in XCD controller begins moving the motor (see Details of Motion Program).

3.2.1.2 Connection to a Computer

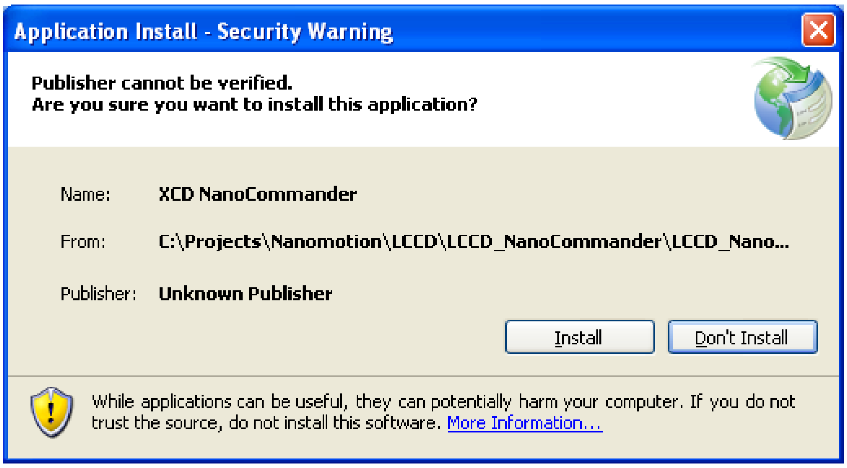
- Connect the Communication box to the Connector board using supplied cable
- Connect Communication box to computer’s COM port connector using standard RS232 cable
- If the computer doesn’t have COM port, use USB-COM adapter instead of standard RS232 cable

3.2.2 Software Installation

- Insert the installation disk into the computer’s CD drive. Installation should start automatically.

If auto-start doesn't work (e.g., disabled by computer's security settings), start manually SETUP.EXE on the installation disk.

- If the following dialog appears, press Install:



Application Install - Security Warning

Publisher cannot be verified.
Are you sure you want to install this application?

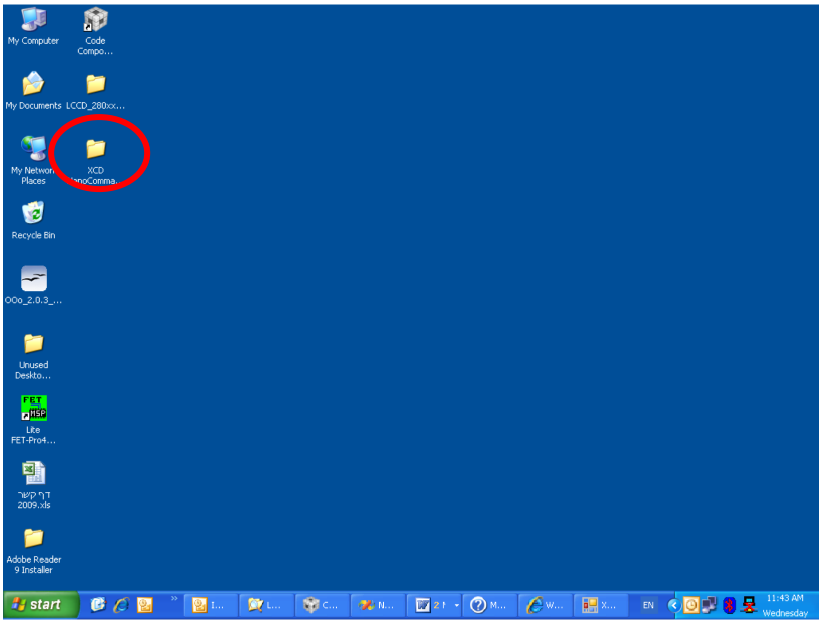
Name: **XCD NanoCommander**

From: **C:\Projects\Nanomotion\LCCD\LCCD_NanoCommander\LCCD_Nano...**

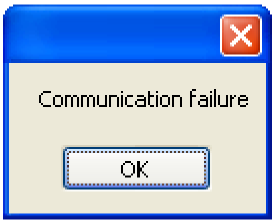
Publisher: **Unknown Publisher**

While applications can be useful, they can potentially harm your computer. If you do not trust the source, do not install this software. More Information...

- Installation creates group Nanomotion in the Start/Programs menu, and also creates directory XCD NanoCommander on the desktop that contains NanoCommander shortcut and examples of motion programs:



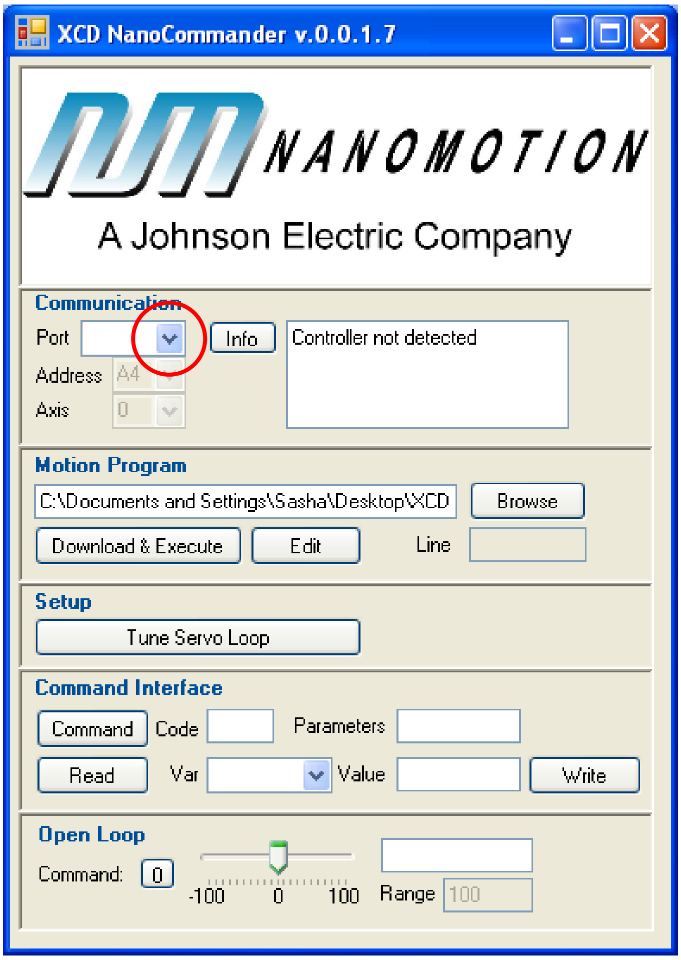
In the end of the installation, XCD NanoCommander starts automatically.
If message appears reporting communication problem, press Ok:



Communication failure

Normally, this or similar message appears only during the first connection.

- If connection with the controller is not established, the NanoCommander screen looks as follows:



Address: A4

Axis: 0

Controller not detected

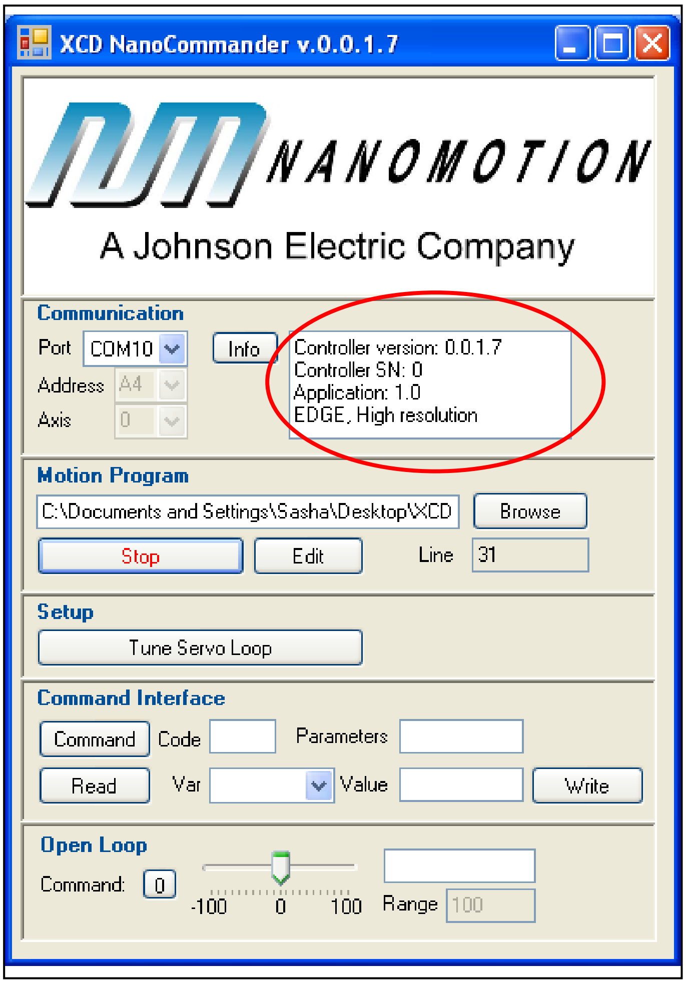
C:\Documents and Settings\Sasha\Desktop\XCD

Command: 0

Range: 100

Select correct communication port from the Port drop-down list to start communication. If USB-COM adapter is used, the corresponding COM appears in the drop-down list only when the adapter is connected to computer’s USB port.

Once communication is established, NanoCommander displays controller data in the Info box:



Port: COM10
Address: A4
Axis: 0

Controller version: 0.0.1.7
Controller SN: 0
Application: 1.0
EDGE, High resolution

C:\Documents and Settings\Sasha\Desktop\XCD

Line: 31

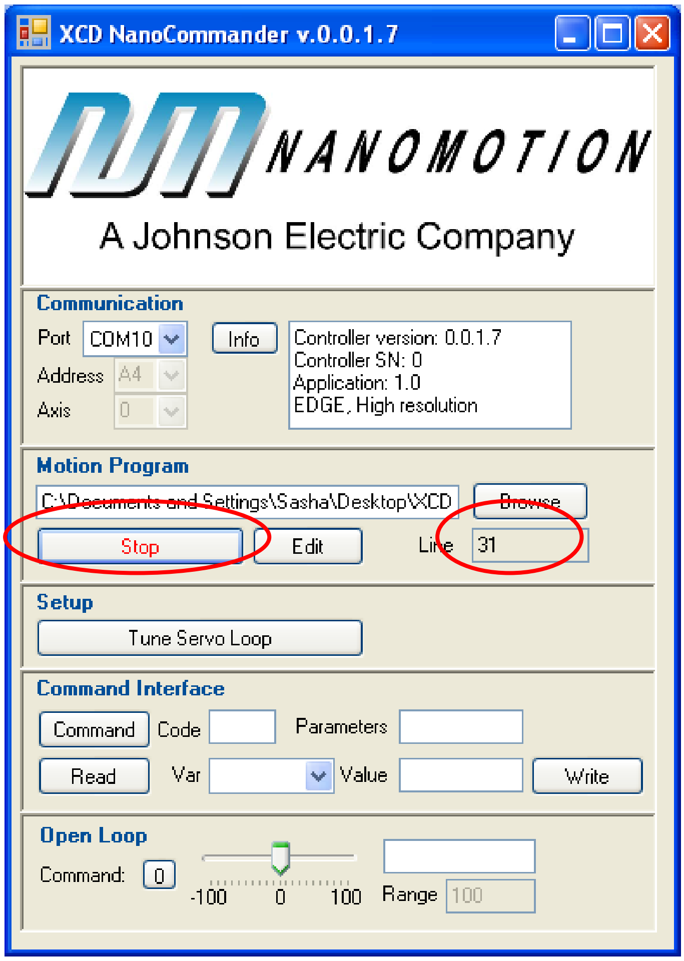
Command: 0

Range: 100

3.3 Further actions with Presentation Package

3.3.1 Monitor Program Execution

On the main NanoCommander window, big button in the Motion Program pane reads either **Download & Execute** if motion program is idle, or **Stop** if the program runs:



Port COM10
Address A4
Axis 0

Controller version: 0.0.1.7
Controller SN: 0
Application: 1.0
EDGE, High resolution

C:\Documents and Settings\Sasha\Desktop\XCD

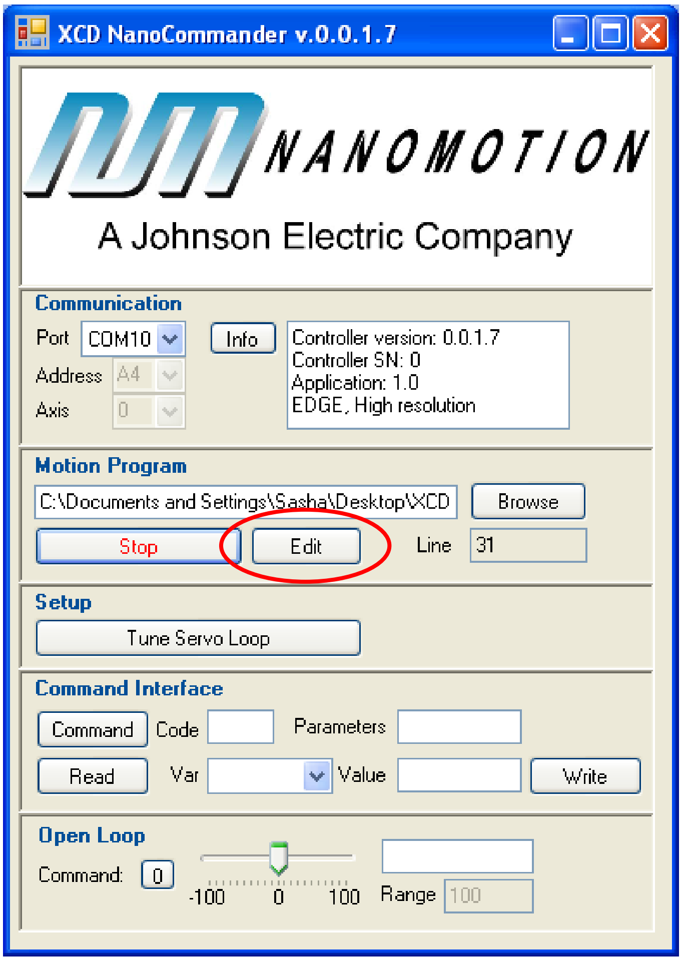
Line 31

Command: 0

Range 100

If motion program runs, Line indicator displays number of the currently executed line.

Press Edit button:



Controller version: 0.0.1.7
Controller SN: 0
Application: 1.0
EDGE, High resolution

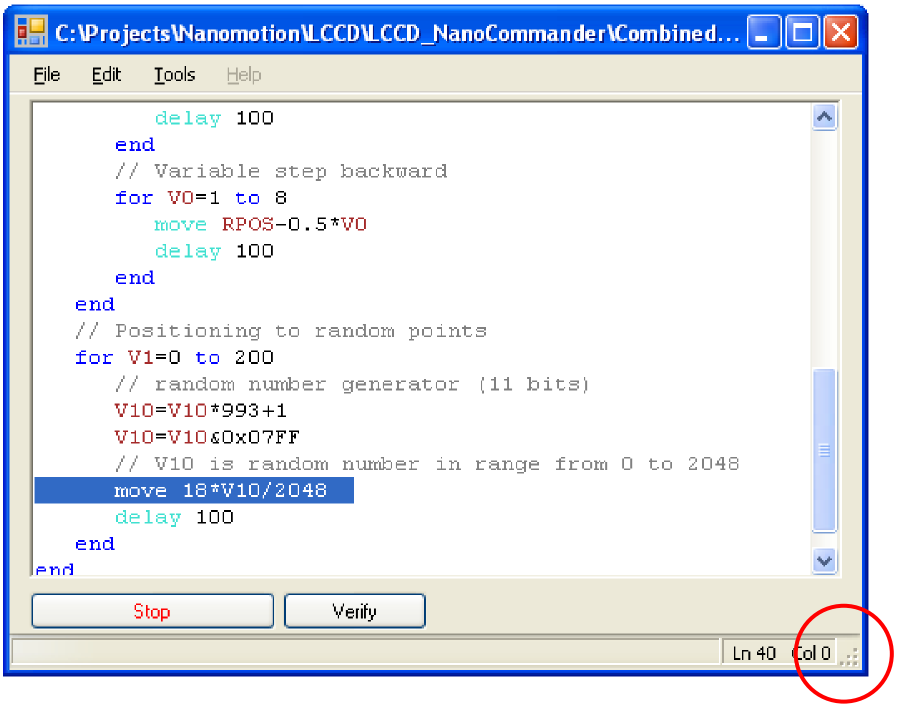
C:\Documents and Settings\Sasha\Desktop\XCD

Line 31

Command: 0

The NanoCommander opens Editor window. The Editor highlights currently executed line.

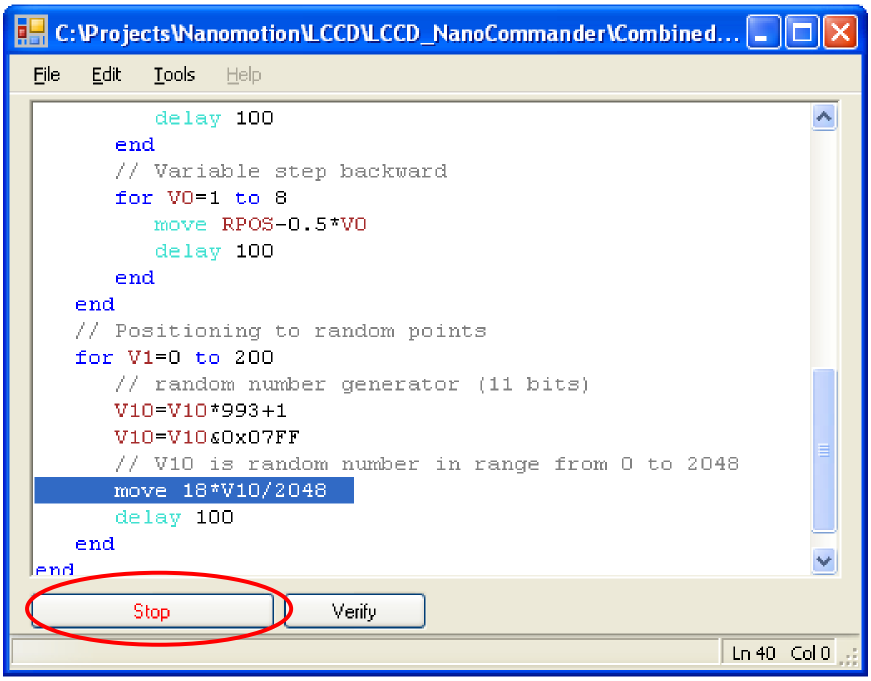
If necessary, extend Editor window by dragging the bottom-right grip:



```
         delay 100
      end
      // Variable step backward
      for V0=1 to 8
         move RPOS-0.5*V0
         delay 100
      end
   end
   // Positioning to random points
   for V1=0 to 200
      // random number generator (11 bits)
      V10=V10*993+1
      V10=V10&0x07FF
      // V10 is random number in range from 0 to 2048
      move 18*V10/2048
      delay 100
   end
end
```

3.3.2 Change Motion Program

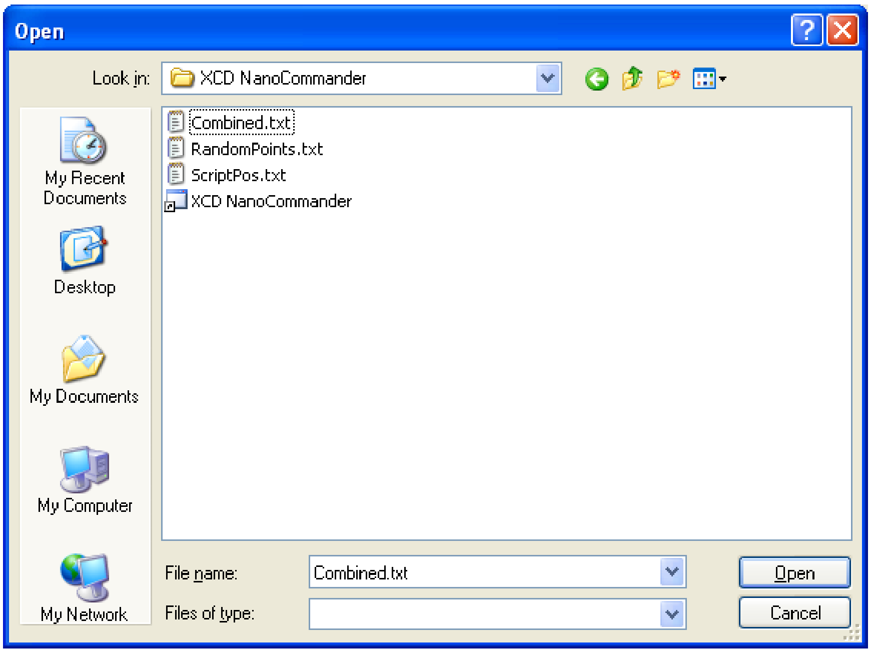
If current motion program runs, stop it by pressing **Stop** button in the Editor window (or in the main window):



```
         delay 100
      end
      // Variable step backward
      for V0=1 to 8
         move RPOS-0.5*V0
         delay 100
      end
   end
   // Positioning to random points
   for V1=0 to 200
      // random number generator (11 bits)
      V10=V10*993+1
      V10=V10&0x07FF
      // V10 is random number in range from 0 to 2048
      move 18*V10/2048
      delay 100
   end
end
```

The button text changes to **Download & Execute**, indicating the program is idle.

Activate menu File / Open in the Editor window. Dialog box appears:



Motion program have extension TXT. Select desired motion program and press **Open**.

Start the new program by pressing **Download & Execute** button.

Three motion programs are supplied in the Presentation package:

- SCRIPTPOS.TXT – the program starts from long motion in both directions, then executes series of equal short steps in both directions and finishes with series of variable steps in both directions. The operations are repeated in an infinite loop.
- RANDOMPOINTS.TXT – the program activates random number generator to obtain random coordinate of the next point. The program operates in an infinite loop.
- COMBINED.TXT – default program stored in the controller flash memory. The program combines operations of two above programs in one infinite loop.

For more details, see Details of Motion Program.

3.3.3 Change Motion Velocity

Attention: The last versions of COMBINED.TXT and SCRIPTPOS.TXT assign motor velocity in the program, so that default velocity VEL is not used. In order to use the following procedure, delete line

```
VEL=10+V0*35
```

in the motion program.

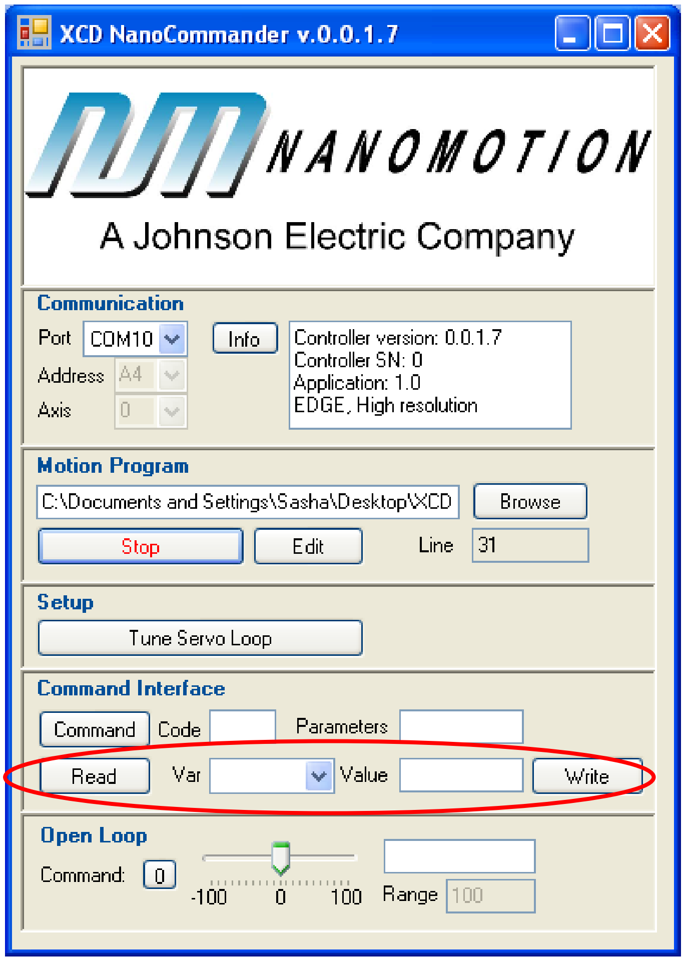
All supplied motion program use default motion velocity specified by VEL variable.

In the main window, select VEL in the **Var** combo box.

Press **Read** button to see current VEL value in the **Value** text box in mm/sec.

Type new value in the **Value** text box (mm/sec), and press **Write** button to activate new value.

Attention: don't specify more than 200 mm/sec, as the motor is not able to move faster.



Port: COM10
Address: A4
Axis: 0

Controller version: 0.0.1.7
Controller SN: 0
Application: 1.0
EDGE, High resolution

C:\Documents and Settings\Sasha\Desktop\XCD

Line: 31

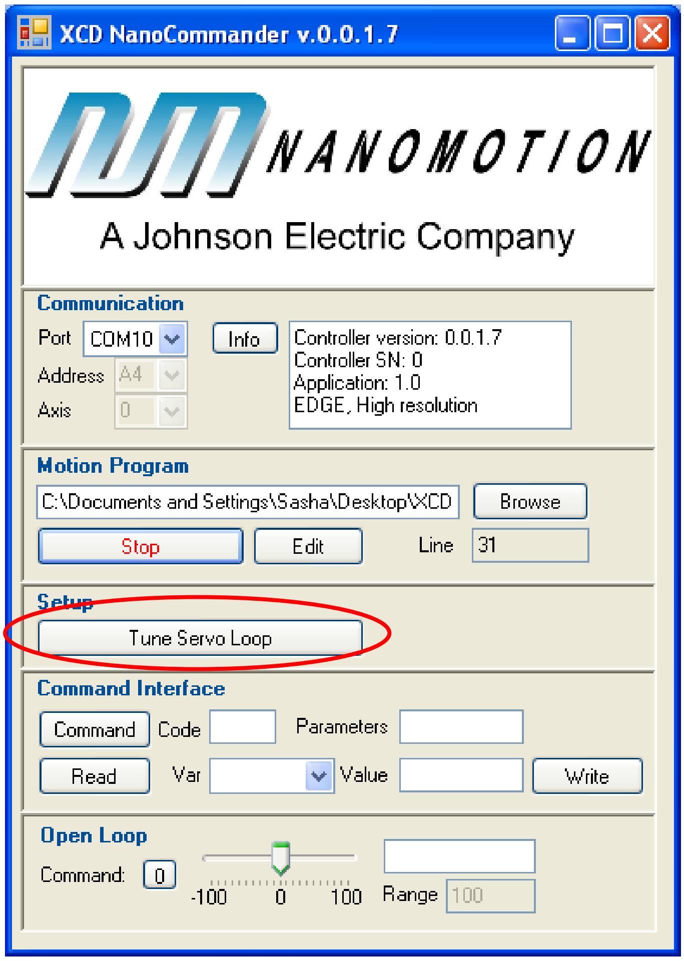
Command: 0

Range: 100

3.3.4 Monitor Feedback Position

Continuous monitoring of feedback position is provided in the Servo Loop window.

Press **Tune Servo Loop** button:



Communication

Port: COM10

Address: A4

Axis: 0

Controller version: 0.0.1.7
Controller SN: 0
Application: 1.0
EDGE, High resolution

Motion Program

C:\Documents and Settings\Sasha\Desktop\XCD

Line: 31

Setup

Command Interface

Code

Parameters

Var

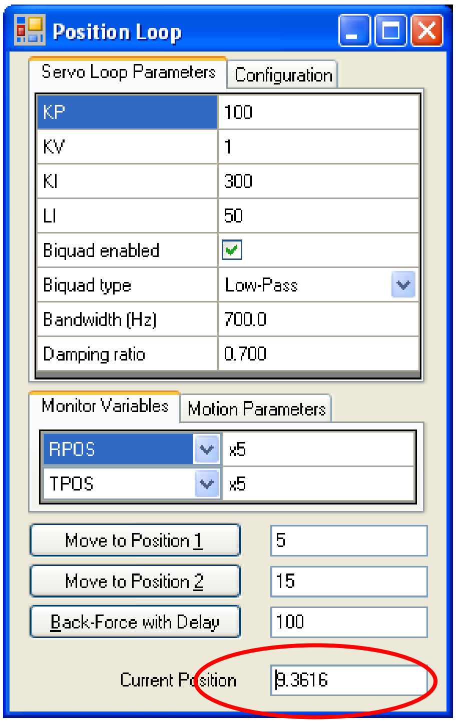
Value

Open Loop

Command: 0

Range: 100

The Servo Loop window opens. Watch feedback position (mm) in the **Current Position** window.



KP	100
KV	1
KI	300
LI	50
Biquad enabled	☑
Biquad type	Low-Pass
Bandwidth (Hz)	700.0
Damping ratio	0.700

RPOS	x5
TPOS	x5

Move to Position 1: 5

Move to Position 2: 15

Back-Force with Delay: 100

Current Position: 9.3616

Attention: avoid changing servo loop parameters, as improper values may deteriorate motor performance, and even make servo loop unstable. Proper values of servo parameters are already stored in the controller flash memory, and should not be changed. If, however, some parameter has been unintentionally changed, the simplest way of returning the controller to default state is restarting the controller with power cycling.

4 XCD Motion Script (XMS)

4.1 First example of XMS program

The following example (program COMBINED.XMS) executes a set of motions. Each motion is positioning to a point in range 0 – 20 mm. The program demonstrates usage of the following language elements:

- User variables (**V0**, **V1**, **V10**)
- System variables (**VEL**, **RPOS**)
- Literal constants in integer, real, and hexadecimal formats
- Expressions containing variables, constants, arithmetic and logical operations
- Commands (**move**, **home**, **delay**)
- Execution control commands (**while**, **for**, **end**)

The following table provides step-by-step explanation of the motion program COMBINED.XMS.

`V10=999`	Seed of random number generator assigned to variable V10.
`while 1`	WHILE loop executes forever, as condition expression is always non-zero.
`    home   30`	Homing, scheme 30 to the left hard stop
`    for V1=0 to 5`	FOR loop executes 6 times, loop variable V1 changes from 0 to 5.
`        // Force-back move`	Comment.
`        for V0=0 to 5`	Inner FOR loop executes 6 times, loop variable V0 changes from 0 to 5.
`            VEL=10+V0*35`	Set required motion velocity. Velocity starts from 10 mm/sec, then grows to 45, 80, 115, 150, and finally to 185 mm/sec.
`            move  5`	Move to absolute position 5 mm.
`            move  15`	Move to absolute position 15 mm.
`        end`	End of inner FOR loop.
`        move  0`	Move to absolute position 0 mm.

// Incremental move forward	Comment.
for V0=0 to 3	Inner FOR loop executes 4 times, loop variable V1 changes from 0 to 5.
move RPOS+4	Move to relative position, increment 4 mm.
delay 100	Delay 100 milliseconds.
end	End of inner FOR loop.
// Incremental move backward	Comment.
for V0=0 to 3	Inner FOR loop executes 4 times, loop variable V1 changes from 0 to 5.
move RPOS-4	Move to relative position, increment -4 mm.
delay 100	Delay 100 milliseconds.
end	End of inner FOR loop.
// Variable step forward	Comment.
for V0=1 to 8	Inner FOR loop executes 8 times, loop variable V1 changes from 1 to 8.
move RPOS+0.5*V0	Move to relative position, increments 0.5, 1, 1.5, etc.
delay 100	Delay 100 milliseconds.
end	End of inner FOR loop.
// Variable step backward	Comment.
for V0=1 to 8	Inner FOR loop executes 8 times, loop variable V1 changes from 1 to 8.
move RPOS-0.5*V0	Move to relative position, increments -0.5, -1, -1.5, etc.
delay 100	Delay 100 milliseconds.
end	End of inner FOR loop.
end	End of outer FOR loop.
// Positioning to random points	Comment.
for V1=0 to 200	FOR loop executes 201 times, loop variable V1 changes from 0 to 200.
// random number generator (11 bits)	Comment.
V10=V10*993+1	Generate random number equally distributed in the range from 0 to 2048. Symbol & designates logical AND, literal 0x07FF is hexadecimal constant equal to decimal 2047.
V10=V10&0x07FF	

`        // V10 is random number in range from 0 to 2048`	Comment.
`        move 18*V10/2048`	Move to random absolute position in the range from 0 to 18 mm.
`        delay 100`	Delay 100 milliseconds.
`    end`	End of FOR loop.
`end`	End of WHILE loop.

4.2 Numbers

4.2.1 Floating point values

All numbers in XMS program are floating point values complying with IEEE 754 definition of single precision arithmetic.

Range of values is from approximately -3.4*10^{38} to +3.4*10^{38}.

4.2.2 Literal constants

In XMS program, literal constant can appear in different formats. Format of a literal constant doesn’t affect its internal presentation; the controller converts each constant to floating point number before using it in calculations.

The following table summarizes available formats:

Format	**Examples**
Integer	1, 20, -1078
Real	0.1, 20.35, 0.000009
Scientific	1e-5, 2.3e10
Hexadecimal	0x07FF, 0x1E23

4.2.3 Units

The controller supports predefined measuring units for physical values. For example, position or distance in XMS program is always specified in millimeters.

The following table summarizes usage of measuring units:

Value	**Example of variables**	**Measuring unit**
Position, distance	**POS**, **RPOS**, **FPOS**, **TPOS**	Millimeter (mm)
Velocity	**VEL**, **RVEL**, **FVEL**	Millimeter per second (mm/sec)
Acceleration	**ACC**	Millimeter per second per second (mm/sec^2)
Time interval	**delay** parameter	Millisecond (msec)

Scaled values	**AIN0**, **AOUT1**, **DOUT**	Percents of maximum (%)

4.3 Variables

All variable names in XMS program are predefined; the customer is not allowed to define a new variable name.

XMS variables are subdivided into two classes:

- System variables; each system variable has predefined meaning, like

  VEL – required motion velocity

  FPOS – feedback position

- User variables with predefined names V0, V1, V2 … V19. A user variable has no predefined meaning, and can store any number required in a program.

The following table summarizes XMS variables in categorical order:

ID	**Name**	**Comments**
Required motion parameters		
0	POS	Position
1	VEL	Velocity
2	ACC	Acceleration
4	KDEC	Kill deceleration – used in fault conditions; e.g., if limit switch was activated.
Instant reference motion variables		
5	TPOS	Target position
6	RPOS	Reference position
7	RVEL	Reference velocity
8	RACC	Reference acceleration
Instant feedback motion variables		
9	FPOS	Feedback position
10	FVEL	Feedback velocity
11	FACC	Feedback acceleration
12	PE	Position error
Servo loop and drive configuration		
13	KP	Position loop gain
14	KV	Velocity loop gain
16	LI	Velocity loop integrator limit

17	BQA1	Bi-Quad filter parameters
18	BQA2	
19	BQB0	
20	BQB1	
21	BQB2	
22	ENR	Encoder resolution (millimeters per one encoder count)
23	MFREQ	Motor frequency (PWM frequency)
24	SPRD	Servo loop sampling period (milliseconds)
25	DMODE	Drive mode, reads the following values: 1 – EDGE drive, low resolution 2 – EDGE drive, high resolution 11 – HR drive, low resolution 12 – HR drive, high resolution
26	MFREQ1	Alternative motor frequency. If MFREQ1 value is different from MFREQ value, the motor frequency depends on PWM duty cycle. At zero PWM, the frequency is MFREQ; at 100% PWM, the frequency is MFREQ1; in between the frequency changes linearly. See explanation in <>.
27	PWMZERO	PWM characteristic. See explanation in <>.
28	PWMMIN	
29	PWMMAX	
40	DZMIN	Dead zone min (Nanomotion algorithm)
41	DZMAX	Dead zone max (Nanomotion algorithm)
42	ZFF	Zero feed forward (Nanomotion algorithm)
43	FRP	Friction in positive direction
44	FRN	Friction in negative direction
45	DOUT	Instant drive output (% of maximal output)
Safety		
39	DOL	Drive output limit (% of maximal output)
47	SLP	Software limit positive
48	SLN	Software limit negative
49	PEL	Position error limit
50	TEL	Temperature Limit

51	MTL	Motion Time limit
Analog inputs/outputs		
30	AIN0	Analog input 0 (%)
31	AIN1	Analog input 1 (%)
34	AOUT0	Analog output 0 (%)
35	AOUT1	Analog output 1 (%)
User variables		
1000 - 1019	V0 – V19	User variables
Flags (accept values 0 or 1 only)		
2000	SC_IDO	Inverse drive output
2001	SC_IEN	Inverse feedback direction
2002	SC_EBQ	Enable bi-quad filter
2007	IN_0	Digital input 0
2008	IN_1	Digital input 1
2011	OUT_0	Digital output 0
2012	OUT_1	Digital output 1

4.4 Expressions

Expression is a formula calculating a numerical value.

In its simplest form, expression consists of a single variable or literal constant.

General expression may include the following elements:

- Variables like VEL, V10, IN_0
- Literal constants like 10, -0.0001, 0x0FFF
- Parenthesis: (and)
- Arithmetical operations: +, -, *, /
- Compare operations: = (equal), <> (non-equal) , < (less), <= (less or equal), > (greater), >= (greater or equal)
- Logical operations: & (and), | (or), ^ (exclusive or)

4.5 Commands

Command is a main building block of a motion program.

The following table includes syntax definition statements, using the following formats:

bold	Bold text specifies literal terms, which appear in the script exactly as specified.
italic	Italic text specifies syntax units explained in the right column. Any syntax unit belongs to one of the following groups: *variable* – one of the variable names *expression* – arithmetical/logical expression *commands* – any sequence of the controller commands

For example, in definition "**move** *absolute_position*", *absolute_position* is an expression that generates variety of possible lines, for example:

```
move 750
move TPOS+225
move V19*300+600
```

Definition "*variable* **=** *expression*" generates assignment commands, for example:

```
V9 = V9 +1
VEL = V10*10
```

Command syntax	**Comments**
variable **=** *expression*	Assignment. Right-part *expression* is calculated and its result is assigned to *variable* in the left.
move *absolute_position*	Move to absolute position. *absolute_position* is an expression that defines new target position.
kill	Kill motion. Current motion is terminated, and the controller provides deceleration using KDEC parameter.
home *home_scheme, position, velocity1, velocity2*	Homing. *home_scheme* selects one of the standard homing sequences. *position* (optional) is an expression that sets position value in the home point. If omitted, zero is used. *velocity1* and *velocity2* (optional) are expressions that define velocities at different homing stages. If omitted, VEL value is used.
openloop *command*	Open loop. The controller switches to open-loop operation; *command* is an expression that defines drive output

Command syntax	Comments
	value.
velocityloop *velocity*	Velocity loop. The controller switches to velocity-loop operation; *velocity* is an expression that defines target velocity.
setposition *position*	Set position. *position* is an expression that defines new position in the current point. The command effectively defines new axis origin.
delay *time*	Delay. *time* is an expression that defines delay time in milliseconds.

if *expression* **then**
commands1
else
commands2
end
	Conditional statement.
	If the *expression* yields non-zero value, *commands1* are executed, else *commands2* are executed.
	The <**else** *command2*> close can be omitted.

for *variable* **=** *initial* **to** *final* **step** *step*
commands
end
	For loop.
	The *commands* within a loop are repeated specified number of times.
	The loop header defines loop *variable* (one of user variables V0-V19), *initial* value of the loop variable, *final* value of the loop variable, and *step*.
	Loop variable is incremented by *step* on each repetition.

while *expression*
commands
end
	While loop.
	The *commands* within a loop are repeated while *expression* yields non-zero value.

5 Host Communication

5.1 Communication channels

Communication with the host computer is provided through the following physical channels:

- UART (RS232) 115000 baud
- I2C up to 400 kHz
- SPI up to 10 MHz

5.2 Communication address

Each controller stores its communication address, which is a number within range from 0 to 254. Factory default is zero. The customer can change controller's address with command **Set address** (16). Then newly defined address can be stored in the controller flash memory with command **Save** (13) to be retrieved at each power-up.

Each host command includes destination address. If destination address is in range from 1 to 254, the controller accepts and responds the command only if its address matches the command destination address. Zero destination address defines broadcasting, i.e. any connected controller accepts and responds the command.

5.3 Communication protocol

The controller is a communication client and performs passive role. Other side (customer processor or PC) is a communication host and performs active role.

Communication executes in a ping-pong manner. Each communication session includes two events:

- Host initiates communication by sending a command.
- Controller sends reply; in many cases, the reply is simply a prompt reporting if the command was accepted or rejected.

The host commands and the controller replies are similar in all supported communication channels. Each host command consists of the following parts:

Command prefix	Command prefix depends on the communication channel. Command prefix is the same for all commands.
Command body	Command body doesn't depend on the communication channel. Command body is specific for each command.

Controller reply has similar parts:

Reply prefix	Reply prefix depends on the communication channel. Reply prefix is the same for all commands.
Reply body	Reply body doesn't depend on the communication channel. Reply body is specific for each command.

5.4 Prefixes

5.4.1 UART (RS232)

Command prefix and reply prefix are identical and consist of 4 bytes:

Byte offset	**Size in bytes**	**Content**
0	1	Constant 0xE4 (228).

1	1	Constant 0xA5 (165).
2	1	Destination address.
3	1	Length of command/reply body in bytes.

5.4.2 I2C

Command prefix consists of 2 bytes:

Byte offset	**Size in bytes**	**Content**
0	1	Destination address (write address).
1	1	Length of command body in bytes.

Reply prefix consists of 2 bytes:

Byte offset	**Size in bytes**	**Content**
0	1	Destination address plus one (read address). This byte is sent by the host.
1	1	Length of reply body in bytes. This byte is sent by the controller.

5.5 Command body

5.5.1 General format

Command body is a sequence of bytes in the following order:

Byte offset	**Byte size**	**Content**
0	1	Command code.
1	Up to 49	Parameters.

If a command requires no parameters, the whole body includes only one byte – command code.

In most commands, the command code is followed by parameters. Each parameter occupies one or several bytes. No delimiting bytes are added between the command code and parameters or between the parameters.

Each parameter is a numerical value. Each command requires specific format for each of its parameters. All formats are binary, least significant byte appears first. The following formats are used:

Format	**Number of bytes**	**Range**
Int8	1	-128 to +127

Int16	2	-32768 to +32767
Real	4	$-3.4*10^{38}$ to $+3.4*10^{38}$ approximately (complying with IEEE 754)
ID	2	0 to 65535

Some commands require a parameter that specifies a controller variable. The variable is referenced by its numerical ID. See Variables table for variable ID’s.

5.5.2 Command table

Command	Code	Parameters	Format (size in bytes)	Comments
Move	1	*position*	Real (4)	Move to absolute position. *position* defines new target position in mm.
Assign	3	*variable* *value*	ID (2) Real (4)	Assignment. The *value* is assigned to the *variable*.
Home	4	*scheme* *origin (opt)* *velocity1 (opt)* *velocity2 (opt)*	Int8 (1) Real (4) Real (4) Real (4)	Homing. *scheme* selects one of the standard homing sequences. *origin* defines position in the home point. If omitted, zero is taken. *velocity1* defines first stage velocity. If omitted, VEL value is taken. *velocity2* defines second stage velocity. If omitted, one fourth of *velocity1* is taken.
Velocity loop	6	*velocity*	Real (4)	Execute velocity loop control. Parameter *velocity* defines required velocity in mm/sec.
Open loop	7	*command*	Real (4)	Execute open loop control. Parameter *command* defines command value in percents, from -100 to +100.
Set position	11	*position*	Real (4)	Set position. Parameter *position* defines new position in the current point. The command effectively defines new axis origin.

Command	Code	Parameters	Format (size in bytes)	Comments
Set frequency	12	*freq* *freq1 (opt)*	Real (4)	Set frequency. Parameters *freq* and *freq1* define motor (PWM) frequency in Hz. If omitted, *freq1* is taken the same as *freq*. If *freq1 ≠ freq*, the motor frequency depends on PWM duty cycle. At zero PWM, the frequency is *freq*; at 100% PWM, the frequency is *freq1*; in between the frequency changes linearly. See explanation in <>.
Save parameters	13	*addr* *90 (0x5A)*	Int8 (1) Int8 (1)	Save parameter values into flash memory. At the next start-up, the controller reads the parameters from the flash and starts with the stored parameters instead of default values. The parameters are required to prevent unintentional use of the command. *addr* specifies communication address of the controller. The second parameter is constant 90 (0x5A).
Set address	16	*addr* *90 (0x5A)* *newaddr*	Int8 (1) Int8 (1) Int8 (1)	Change communication address. First two parameters are required to prevent unintentional use of the command. *addr* specifies current communication address of the controller. The second parameter is constant 90 (0x5A). *newaddr* specifies new communication address of the controller.
Read version	19			Read version. The command requests information about controller firmware. See format of controller reply below.

Command	Code	Parameters	Format (size in bytes)	Comments
Monitor	20	*channel* *variable* *scale*	Int8 (1) ID (2) Real (4)	Monitor variable. Being commanded, the controller in each cycle converts the *variable* using the *scale* and passes it to analog output. *channel* defines analog output to use: 0 – AOUT0, 1 – AOUT1. *variable* specifies variable to monitor. *scale* defines a conversion factor.
Monitor address	21	*channel* *address* *scale*	Int8 (1) Int16 (2) Real (4)	Monitor variable. Being commanded, the controller in each cycle converts the specified RAM address using the *scale* and passes it to analog output. *channel* defines analog output to use: 0 – AOUT0, 1 – AOUT1. *address* specifies variable to monitor. *scale* defines a conversion factor.
Set mode	22	*mode*	Int8 (1)	Set drive mode. *mode* specifies one of the following values: 1 – EDGE drive, low resolution 2 – EDGE drive, high resolution 11 – HR drive, low resolution 12 – HR drive, high resolution
Report	26	*var1* *var2 (opt)* … *var10 (opt)*	ID (2) ID (2) … ID (2)	Report variable values. The command requests current variable values. From 1 to 10 variables can be requested in one command. See format of controller reply below.
Set PWM	38	*zero* *min* *max*	Real (4) Real (4) Real (4)	Set PWM characteristic. *zero*, *min*, and *max* define the characteristic. See <> for more details.

Command	**Code**	**Parameters**	**Format (size in bytes)**	**Comments**
Configure safety	39	*addr* *90 (0x5A)* *config*	Int8 (1) Int8 (1) Int8 (1)	Configure safety signals. First two parameters are required to prevent unintentional use of the command. *addr* specifies communication address of the controller. The second parameter is constant 90 (0x5A). *config* is a bit mask that defines signal polarity: Bit 0 – Negative Limit Bit 1 – Positive Limit Bit 2 – Emergency Stop Zero value of a bit defines active-high polarity (fault occurs if the signal has high level); value one defines active-low polarity. By default, all safety signals are configured active-low.
Disable safety	40	*addr* *90 (0x5A)* *disable*	Int8 (1) Int8 (1) Int8 (1)	Configure safety signals. First two parameters are required to prevent unintentional use of the command. *addr* specifies communication address of the controller. The second parameter is constant 90 (0x5A). *disable* is a bit mask: Bit 0 – Negative Limit Bit 1 – Positive Limit Bit 2 – Emergency Stop Bit 3 – Motor Not Connected Zero value of a bit enables safety signal; value one disables safety signal. By default, all safety signals are enabled.

5.6 Reply body

5.6.1 General format

Reply body is a sequence of bytes in the following order:

Byte offset	Byte size	Content
0	1	Command code – copied from replied command.
1	1	Result: 1 – Command accepted. 2 – Command rejected.
2	Up to 48	Extension.
Total	2 ÷ 50	

For most commands, the controller sends back only two bytes with no extension.

5.6.2 Reply body for specific commands

5.6.2.1 Read version (19)

Byte offset	Byte size	Content
0	1	Command code – copied from replied command.
1	1	Result: 1 – Command accepted. 2 – Command rejected.
2	4	Version.
6	4	Serial number.
10	2	Application code.
Total	12	

5.6.2.2 Report (26)

Byte offset	Byte size	Content
0	1	Command code – copied from replied command.
1	1	Result: 1 – Command accepted. 2 – Command rejected.
2	4	Variable 1 in Real format.
6	4	Variable 2 in Real format (if requested).
…	…	…
38	4	Variable 10 in Real format (if requested).

Total	6 ÷ 42	