User Guide

Instructions for EZ4AXIS and EZ4AXIS23WV

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Important Notices

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1. Quick guide

This EZ4AXIS can be commanded by sending simple text messages to the drive. It is not necessary to compile software etc. For example sending the text ***P1000*** makes the drive go in the Positive direction **1000** steps. The drive will also respond back with a text message. The text messages can also be stored on the drive and executed on power-up.

Quick setup

Hook up the EZ4AXIS using the Quick Start guide and the wiring diagram from links at the bottom of appropriate web page:
http://www.allmotion.com/Stepper_Pages/EZ4AXISdescription.htm
http://www.allmotion.com/Stepper_Pages/EZ4AXIS17XRdescription.html

Per quick start guide find the com port that appears *and disappears* when the USB is plugged in and out. This is the com port to select. If a *new* com port does not appear, then install the latest windows/mac drivers for the CP2101 Virtual Com Port chip from Silicon Labs manually at http://www.silabs.com/products/mcu/pages/usbtouartbridgevcpdrivers.aspx. NOTE: Do NOT download files named "VCP with Serial Enumeration."

CAUTION: Do not unplug the motors when the power is on, because the inductance of the motor will generate a high voltage when the current in the motor is interrupted, which will damage the drive.

1. Using the EZCommander windows App, issue the command */1&*. The drive should respond with its firmware version.
2. With the power off plug in Motor #1. Turn on power, issue the command */1P1000R*. The drive should move forward 1000 microsteps.
3. Turn off power and plug in up to four motors.
4. Issue the command

   /1aM2P1000R. Motor 2 should move.

   /1aM3P1000R Motor 3 should move.
5. Issue the command */1P1000,1000,1000,1000R*

   All 4 motors should spin
6. Issue the command */1P1000,1000,,1000R*

   Motors 1, 2, and 4 will spin.

   /1V100,200,300,400R sets motor speeds
7. */1?aA* reads back the position of all four motors.

Please see the additional examples "Single-Axis programming supplemental examples" starting on page 38, "Multiple-axis/multiple drive supplemental examples" on page 40, and the "Command list" on page 72.

2. Introduction

About this manual

This document describes how to program and operate the EZStepper® EZ4AXIS (Stepper Controller + Driver).

These sections are included:

- **Basic Programming Operations**. (Starting page 13) This describes how to set up basic motor moves, first on one axis and then multiple axes.
- **Advanced Programming Operations.** (Starting page 26) This describes how to set up more complex moves, including conditional moves based on signals at the inputs. Many examples are provided. This section also contains essential information about how the product operates, and describes operations not covered in the Basic Operations section.
- **Sections focused on specific Programming applications.** (Starting page 42) Limits, Digital IO (switch-controlled) Applications, Analog Control Applications, Homing, and Using Encoders.
- **Appendices.** (Starting page 69) The appendices contain reference information to supplement the instructions, such as an extensive command set for the product. There is also additional technical information that you may find helpful in applying the product.

Before you start

Obtain communications software

- If you are using a Windows-based system to communicate with your AllMotion product, we recommend that you download and install the EZ Commander™ application from the AllMotion website Support page.

  Alternatively, a terminal program such as HyperTerminal may be used.
- If you are using a Macintosh system to communicate with your product, any text-based terminal program will be adequate.

  NOTE: The EZStepper® communicates over the RS485 EZ bus at 9600 baud, 1 stop bit, no parity, no flow control. If necessary, this can be changed with the *b* command, after getting hooked up. This is covered in "Essential setup information" on page 26.

Obtain needed documentation

Obtain the following for the EZ4AXIS via links at the bottom of this web page: http://www.allmotion.com/Stepper_Pages/EZ4AXISdescription.htm http://www.allmotion.com/Stepper_Pages/EZ4AXIS17XRdescription.html

- EZ Start document (EZ Starter Kit Instructions) for your product. This will get you started with setting up communications and confirming operation.
- Wiring diagram. This will serve as a guide to hookups and various ways of applying your AllMotion product.
- Data sheet.

Gather needed equipment

Ensure that you have compatible stepper motor(s), a PC or other device capable of running a terminal program, and a power supply. Typically use a 12V or 24V capable of 3A. If starting out use a current limited lab supply set to 0.5A current limit.

- Do not connect or disconnect motor cable while power is on. This causes a high voltage spark due to the inductance of the motor, and can damage the chips on the drive. This includes loose connections.

About the EZStepper® command language

Features

This EZ4AXIS can be commanded by sending simple text messages to the drive. It is not necessary to compile software etc. For example sending the text ***P1000*** makes the drive go in the **P**ositive direction **1000** steps. The drive will also respond back with a text message. The text messages can also be stored on the drive and executed on power-up. The drive can also test the status of inputs and execute commands conditional on the status of an input with no computer attached.

Syntax

Commands consist of single alpha characters usually followed by a numeric value. The alpha character represents "what to do" and the numeric value represents "how much to do it." A complete command string contains a start character, a device address, a command, and a Run command—which tells a particular motor (or axis) to accept the command string.

Example: */1P1000R*

Command string breakdown:

/ Start character. Tells the EZStepper® that a command is coming in.

1 (One) Device address. This is the number set on the rotary mechanical Address switch on the drive for numbers 1-9. (See addressing details if addressing more than 9 boards. Note that the 1 refers to the entire board and not to the individual motors within the board.)

P1000 Command. Move 1000 steps in the positive direction. From wherever the motor currently is. By default on power up this command goes to motor#1.

R Run the command. This is the end of the command string.

Multiple commands can be entered in a single string and they are executed one at a time starting with the command on the left.

Example: */1V1000P1000V2000P1000R*

where the first *P1000* will happen at a velocity of 1000 and the second *P1000* will happen at a velocity of 2000.

Example: */1aM1P1000aM2P1000R*

Moves motor#1 one thousand steps then moves motor #2 one thousand steps.

3. Basic programming operations

This section describes how to enter basic commands to the EZ4AXIS. A complete listing of commands is contained in Table 1 on page 72.

First things

Make sure system is connected and operating

Follow the instructions in the EZ Start document for EZ4AXIS, to make sure you have it hooked up properly and it is communicating with your host PC. The EZ4AXIS board should be set to address 1 as described in the EZ Start document.

http://www.allmotion.com/New%20PDF's/EZ4AXIS/EZ4AXIS_EZ_Start.pdf

Basic move commands to Axis 1

These are the basic move commands:

P	Move motor to relative position in positive direction (microsteps).
D	Move motor to relative position in negative direction (microsteps).
A	Move motor to absolute position in microsteps.
Z	Move motor to home position.

1. Move Axis 1 motor to relative position in positive direction (the *P* command).

NOTE: *Relative* position refers to movement measured from the current position of the motor.

Send this command string: */1aM1P1000R*

Result: The motor on Axis 1 rotates 1000 microsteps in the positive direction from its current position. It then stops and holds its new position until another command is received.

Command string breakdown:

/1	Start character; select address 1 on the EZ bus.
aM1	Select Axis 1 on the board.
P1000	Move 1000 microsteps in positive direction from current position.
R	Run the command.

2. Move Axis 1 motor to relative position in negative direction (the *D* command).

Relative position refers to movement measured from the current position of the motor.

Command string breakdown:

/1 Start character; select address 1 on the EZ bus.

aM1 Select Axis 1 on the board.

D1000 Move 1000 microsteps in negative direction from current position.

R Run the command.

3. Move Axis 1 motor to absolute position (the *A* command)

On power up the Absolute Position is set to zero. The absolute position will also be set to zero when using the Home (*Z*) command at the point when the Home is triggered. The absolute position is a measure of the total distance moved from the point at which the absolute position is set to zero.

Send this command string: */1aM1A1000R*

Result: The motor on Axis 1 rotates to absolute position 1000 microsteps. It then stops and holds its new position until another command is received.

Command string breakdown:

/1 Start character; select address 1 on the EZ bus.

aM1 Select Axis 1 on the board.

A1000 Move (rotate) to absolute position 1000.

R Run the command.

Note that issuing this command again will not make the motor move because it is already at absolute position 1000. The current absolute position can be read back by issuing */1?0.*

4. Home the Axis 1 motor (the *Z* command)

This command causes the motor to turn in the negative direction until the home sensor is tripped or, once the sensor is tripped, the position is set to zero. This allows the drive to initialize a mechanism to a known position. Details are located in "Homing to opto/switch (default *N1* mode)" beginning on page 52.

Example: Set up a switch between the home input and the ground input on the 6-pin Axis 1 Home connector.

Send this command string and push the switch while it's running: */1aM1Z10000R.*

Result: The motor on Axis 1 Drive 1 rotates to the home position until the switch changes state, and then the position for that axis is set to zero.

Command string breakdown:

/1 Start character; select address 1 on the EZ bus.

aM1 Select Axis 1 on the board.

Z Move to home position.

10000 Maximum number of microsteps or encoder counts that the motor is allowed to move toward home in search of the home flag before the program declares an error.

R Run the command string.

NOTE: From this point onward, command string breakdowns will not always be shown.

Send commands to other axes

To send any command to Axes 2, 3, or 4, simply change the *aM1* in the command string to one of the following:

aM2	Axis 2
aM3	Axis 3
aM4	Axis 4

Example:

*/1**aM2**A1000R* goes to Axis 2.

*/1**aM3**A1000R* goes to Axis 3.

NOTE: The axis command is not to be used in the same command string as query commands.

Send commands to multiple axes (multi-axis commands)

Overview

Some commands can be issued to one, some, or all four axes on the drive simultaneously. Thus they are “multi-axis” commands and can be issued by eg:

/1L8768,1432,3000,2345R sets all 4 axes

/1L1000,,1000R only changes axes 1 and 4

These are the multi-axis commands:

L	Set acceleration (sets same value all axes).
V	Set velocity (sets same value all axes).
h	Set hold current (sets same value all axes).
m	Set move current (sets same value all axes).
P	Move forward to relative position.
D	Move backward to relative position.
A	Move to absolute position.

Starting with version 7.61+ The following have been added o multi axis capable command*s*.

F	*Motor direction considered positive*
K	*Backlash compensation steps*
aL	*Decel in negative direction*
aaL	*Decel when limits are crossed.*
z	*Set current position and encoder position.*
az	*Set encoder position*
Z	*Init (sequential)*
a	*Start Speed*
c	*Stop Speed*
aC	*Set correction value for n8 mode*
ad	*Set deadband for potentiometer based moves*
ao	*Set adc offsets*
f	*Set home flag polarity*
ae	*Set encoder to follow*
n	*Set n modes*
an	*Set an modes*

All other commands require individually selecting the axis and issuing the command. */1aM2P1000R* etc.

Send a move command to all four axes

Send this command string: */1P1000,1000,1000,1000R*

Result: All four axes move 1000 microsteps in the positive direction.

You may send different values to different axes. For example: */1P1000,300,1000,300R* moves Axis 1 and 3 1000 microsteps and Axes 2 and 4 300 microsteps.

NOTE:

- Negative numbers would designate negative movement for the otherwise positive-direction *P* command. If the *D* command (negative move) were used, negative numbers would designate positive movement. Example: */1P1000,-500,1000,-500R* would move Axes 1 and 3 1000 microsteps positive, and Axes 2 and 4 500 microsteps negative.
- When several multi-axis commands are placed in a string one after the other, by default each motor will wait until all have completed their motion before responding to the next command. I.e., they all go to the "4-axis coordinate" given by each command prior to starting the next command. Example of such a string: */1A1000,200,300,10A200,500,200,900A200,300,500,78R.*

  See "Motor sequencing in multi-axis commands" on page 28.
- When a multi axis command is issued, it will reset the default single axis command destination to Motor 1. (Inherent *aM1* command)
- The target position can be changed using an "immediate" command even while a move is being executed. (See "Making on-the-fly parameter changes" on page 29.)

Send a move command to just two axes

NOTE: This function requires firmware version 7.04 or higher.

Omit values for the non-addressed axes, but retain commas.

Send this command string: */1P1000,,1000,R*

Result: Axes 1 and 3 move 1000 microsteps in the positive direction. Axes 2 and 4 do not move. The commas marking the positions of Axes 2 and 4 are retained. Note that motors can be started at different times by issuing commands while some motors are moving via *immediate computer command.*

Set velocity, acceleration, and current

The following commands control velocity, acceleration, and motor current.

V Maximum velocity (speed): This sets the maximum velocity for a move, which is reached after an acceleration period set by the *L* command.

Single Axis Example: */1aM1V1000R*

Multi Axis Example: */1V100,200,200,300R*

Or /1V100,,100,R to affect motors 1 and 3only

L Acceleration (acceleration factor): This sets the acceleration factor, which controls the amount of time required for the motor to reach the maximum velocity (acceleration ramps). The EZAXIS equation for acceleration is: Acceleration (in microsteps / sec^2) = (L value) x (100,000,000/65536). For example, if V=10000 and L=1, it will require 6.5536 seconds to reach final velocity. For the EZ4AXIS17XR the equation is TBD

Single Axis Example: */1aM1L100R*

Multi Axis Example: */1L100,200,200,300R*

Or /1L100,,100,R to affect motors 1 and 3only

m Maximum move current: This sets the current level when the motor is moving. More current provides more force and more acceleration. Move current is given as a percentage of the maximum output drive current for the device (m100 = 2A for EZ4AXIS and m100 = 0.5A for EZ4AXIS17XR).

Single Axis Example: */1aM4m30R*

Multi Axis Example: */1m10,20,50,30R*

h Hold current: This sets the current when the motor is stationary. The hold current prevents the motor from slipping against any disturbance when not moving. Hold current is expressed as a percentage of the maximum output drive current for the device (h50 = 1A for EZ4AXIS). (50% is max allowed for hold current)

Single Axis Example: */1aM3h20R*

Multi Axis Example: */1h10,20,20,30R*

Store and recall programs

Overview

Command strings for later recall can be stored in the EEPROM on the EZ4AXIS board.

1. Store a command string (the *s* command)

Store specific command string in designated EEPROM location. the s command is followed by a number ranging from 0 to 63, indicating an EEPROM location.

Example: */1s2P1000R*

Result: The command *P10000* is stored in EEPROM location 2 as specified by the *s2* command, and may be referred to as program 2.

2. Recall (run) a stored command string (the *e* command)

Run the command string stored in designated EEPROM location.

Example: */1e2R*

Result: Executes (recalls) the command string stored in EEPROM location 2.

3. Erase a specific EEPROM location

To erase a location, use the store command without any commands indicated.

Example: */1s2R*

Result: EEPROM location 2 is erased.

4. Erase a stored command string.

To erase a location, use the store command without any commands indicated.

Example: */1s2R*

Result: EEPROM location 2 is erased.

5. Automatically run a stored program on power-up

The command string in location *0* is always executed on power-up. If we used *0* instead of *2* in the above example, this program would execute automatically on power-up.

Example: */1s0A0P10000R*

Result: The command *A0P10000* is stored in EEPROM location 0. Cycling the power will cause *A0P10000* to be executed and the drive to go forward 10000 steps on power-up.

NOTES

- Programs cannot be running while programming the EEPROM. Terminate any strings or loops with */1T* prior to issuing a store command.
- Program storage takes approximately one second to execute. The drive will not respond during this time.
- Each of the 0-63 memory location can accept up to 25 full commands per string, or 256 characters, whichever is less.

  Example: */1s0A0A100gP1000m1000G5e1R*
- Excessive characters will overwrite the 256th character repeatedly until the R (run) command, which is not overwritten because it is the final character in the string.
- Programs can call each other.

  Example:

  /1s0A0e1

  /1s1A1000e0R

  Will cause the motor to go between *A0* and *A1000* on power-up.
- Single axis commands will go to whichever motor was selected with the last */1aM2R* etc motor selection command. This command can be stored in the EEPROM to ensure the correct motor moves. */1s0A0aM2P1000R* will move motor #2 1000 steps on power-up.

  NOTE: There is no relationship between the “Send String” numbers in the EZCommander Windows application and the storage locations in EEPROM specified by the *s* command.

Reading a stored program from EEPROM

To read the contents of a memory location, first execute the command in that memory location, then read the currently running or most recent command.

Example:

1. Issue */1s13aM1A1000A0R* to store command in location 13.
2. Issue */1e13R* to execute the command in location 13.
3. Issue */1$* to read the currently-running or most recent command string.

   Example result: *aM1A1000A0 No Error*.

NOTES

- Do not include the execute and read commands in the same command string.
- The *$* command may not be able to read very long command strings. On older firmware, attempting to read very long command strings may kill board operation. If this happens, power cycle the board.

When a string length exceeds memory location capacity

Each EEPROM location has a capacity of 256 characters, including the run (*R*) command. If the command string exceeds this number, it can be broken into two smaller strings that reside in two different memory locations. At the end of the string that runs first, a command to execute the contents of the second memory location is inserted just before the *R* command. If, for example, the second string is in location 7, *e7* (execute the contents of EEPROM location 7) would be inserted.

NOTE: When a command string exceeds 256 characters, the last character is repeatedly overwritten by the next character in the string until, finally, the R (run) character is written. Thus, such a string will always attempt to execute.

Create loops

One or more commands can be looped, by placing a lower case *g* at the beginning of the and an upper case *G* at the end of the command(s), a number after the upper case G sets the number of times the loop is to be repeated.

The following examples describe how to make two basic types of loops.

NOTE: The example also introduces the *M*, or wait, command.

1. Create a loop that repeats a specific number of times

Example: */1aM2gP1000M500D1000M500G10R*

Command breakdown:

/	Start character. Tells the EZSteppers® that a command is coming in.
1	Device address, (set on address switch on device).
aM2	Axis address, in this case Axis #2.
g	Start a loop.
P1000	Move 1000 microsteps in the positive direction.
M500	Wait for 500 milliseconds.
D1000	Move 1000 microsteps in the negative direction.
M500	Wait for 500 milliseconds.
G10	Repeat 10 times beginning at the location of the *g* command.
R	Run the command.

Result: The command string following the *g* command executes and ends when the *G* command has repeated 10 times.

Issue */1T* to terminate the loop at any time.

2. Create an endless loop

Change *G10* in the preceding example to *G0* (Gzero).

Result: The loop starts and continues forever unless a *T* command is issued. To terminate this loop, issue */1T*. (Do not use */1T2*, */1T3* etc. to terminate a *G* loop since the behavior is undefined and may change in the future.)

Note that if a loop is running a /1T must be issued before making any changes or sending a new command. The only exception is a single immediate command which will be inserted into the loop, one time, at the time of sending.

3. Exit a loop upon input level change method 1.

Example:

/1s1R—store nothing in program 1 in the EEPROM.

1aM1gP1000M1000S02e1GR—loop of motion and wait.

Result: With switch 2 input high the loop executes normally. When Switch 2 is brought low the program executes the *e1* command and jumps out of the loop.

4. Exit a loop upon input level change method 2.

Example:

1aM1gP1000M1000S02G0R—loop of motion and wait.

Result: With switch 2 input high the loop executes normally. When Switch 2 is brought low the program skips the *G* command and stops.

This mode also works for the following strings:

1aM1gP1000M1000S02G0A10000R

where *A10000* executed upon switch closure or even

1aM1ggP1000M1000S02G5A0GR

where the inner loop is exited upon switch closure.

5. Halt a loop pending level change.

Example: Send the following command strings.

1aM1gH02A1000A0GR

Where loop only runs when Switch 2 is low.

1aM1gH02H12A1000A0GR

Where loop runs once for every low/high transition of Switch 2.

NOTE: More complex loops are described in Section 4, “Advanced programming operations,” page 26.

Terminate a program during execution

To immediately terminate any executing command or string on the board, issue */1T*.

Note that the string is still in the command buffer, and may be executed from the beginning by issuing */1R*.

If a multi-axis command is in progress, one axis at a time may be terminated by using */1T1, /1T2, /1T3, or /1T4.*

NOTE: The *T1*, *T2*, *T3*, and *T4* commands should only be used to terminate a single multi-axis command. The behavior in a loop or multi-command string is undefined and may change.

Power Drivers (solenoid drivers) and LVTTL Outputs

The EZ4AXIS has two power drivers for actuating solenoids or any device requiring a relatively large current (2A peak; 1A continuous).

Hookup

- Make hookups to the Power Driver Connector as shown below. There is a + and – connection for each device.

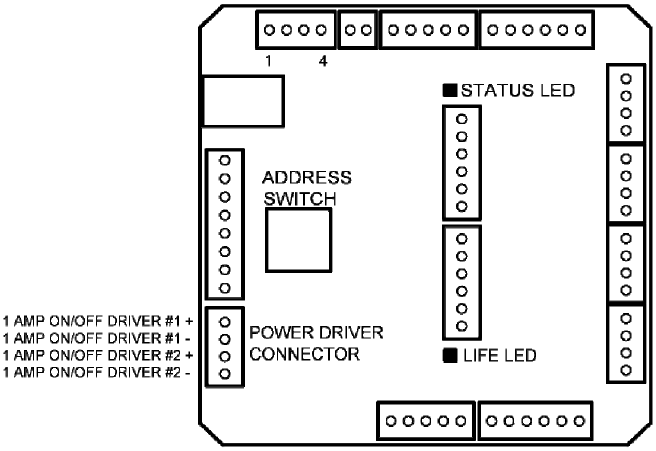


Figure 1   Power Driver Hookups

CAUTION: Do not disconnect inductive loads while power is on. The resulting spark will damage the drivers. This includes loose connections.

Programming Power Driver Outputs

- To actuate a driver, issue the *J* command, e.g., */1J1* (Driver 1 ON).

  Digits following the *J* command are interpreted as 2-bit binary equivalents:

  3 = 11 = Both drivers ON, 2 = 10 = Driver 2 ON Driver 1 OFF,
  3 = 01 = Driver 1 ON Driver 2 OFF. 0 = 00 = both drivers OFF.

  So, to turn Driver 1 off without turning on any other driver, issue *J0.*

  Example: */1gJ0M200J1M200J2M200J3M200GR*

  This turns drivers off and on in a binary counting pattern.

LVTTL Outputs

- LVTTL outputs are avalable on Pin 85 and Pin5 of the 100 Pin SQFP device and these can be wired to an unused INPUT pin on any connector.   These are controlled by the J0-7 Command and the “k” command . For further details please see the “J” and “k” command in the table on page 81.

4. Advanced programming operations

Essential setup information

Motor direction of rotation considered positive

It is recommended that the positive and negative directions be set up by suitable connection of the motor wire leads. Typically if the motor does not turn in the desired direction, switch the A+ and A- leads on the motor.

Alternatively the direction can be switched by using the F command. For example */1aM2F1R* will reverse the direction considered positive for Motor 2 and */1F1,0,1,1R* will set directions for all 4 axes. This should be done once on power up only. This command requires firmware version 7.60+.

Do not use this command to change direction during normal operation. Instead use the *P* and *D* commands. (Using this command during normal operation will result in loss of position because it instantly inverts the drive to one of the phases). Do not use this command if using feedback mode.

Changing communication baud rate

The baud rate can be adjusted with the *b* command. Enter the command followed by the desired baud rate, which can be 9600, 19200, or from 38400 to 230400. Default baud rate is 9600.

Example: */1b19200R* for 19200 baud

Result: The baud rate of Drive 1 is set to 19200 baud.

NOTES

- The baud rate command will usually be stored as program zero and executes on power-up, so that the drive starts talking at a different baud rate. To store as program zero, add *s0 to* the command string: */1**s0**b19200R.* However do NOT store a high baud-rate command in program zero until communication has been tested at the higher baud rate using the non stored /1b192000R etc command.
- Contact factory for instructions on stopping the EEPROM readback on power up, if somehow communication is lost with the drive due to programming with high baud rate in program zero.
- Note that orrect termination and strict daisy-chaining is required for reliable operation at the higher baud rates.

Readback of parameters from the drive:

Reading firmware version

Example: */1&*

This reads the firmware version on Drive 1.

Reading motor positions

To read the position of the currently selected motor, use the */1?0* command:

Example: */1aM4R* then issue */1?0* separately. This retrieves the motor position of Axis 4.

If a command has just been sent to Axis 4, only */1?0* is necessary.

/1?aA reads back the position of all four motors simultaneously.

Similarly use:

/1?V, */1?aV*

/1?L, */1?aL*

Reading currently running or most recent command

To read the currently-running or most recent command string, use the *$* command.

Example: Issue */1P1234P4321R*; then issue */1$* to retrieve the currently-running or most recent command.

Response will be *P1234P4321 No Error*.

Default axis selection

- If *aM* (axis selection command) is omitted in a command string, the command will go to Axis 1 by default or the last axis selected if other than Axis 1.
- If a multi-axis command has just been issued, the default for the next command will always be Axis 1.

Designating negative relative move in otherwise positive-move multi-axis command strings

Example: Use negative numbers to indicate negative relative movement.

/1P10000,-10000,10000,10000

Moves Axes 1, 3, and 4 positive 10000 microsteps, and Axis 2 negative 10000 microsteps.

Designating positive relative move in otherwise negative-move multi-axis command strings

Example: Use negative numbers to indicate positive relative movement.

/1D10000,10000,-10000,10000

Moves Axes 1, 2, and 4 negative 10000 microsteps, and Axis 3 positive 10000 microsteps.

Pre-select axis and send commands subsequently

Once an axis has been selected, subsequent single-axis commands and queries will be directed to that axis until another axis is selected or a multi-axis command is issued (multi-axis commands reset default axis to Axis 1).

Example:

/1aM4R	Selects Axis 4, then:
/1A1000R	Moves Axis 4 to absolute position 1000
/1?0	Retrieves Axis 4 motor position
/1L10R	Sets Axis 4 acceleration to 10.

Motor sequencing in multi-axis commands

By default, motors responding to multi-axis commands executed from EEPROM will wait until all have completed their motion before responding to a new command.

This contrasts with the *linear interpolation* mode, in which two of the motors are coordinated to reach the same point at the same time for drawing lines (the *an65536* command).

The *an0* command, e.g., */1an0*, returns the EZ4AXIS to default motor sequencing any time it is issued. Refer also to “Linear interpolation” on page 101.

Making on-the-fly parameter changes (*Immediate* Commands)

Overview

Some parameters can be changed “on the fly” (i.e. while another command is executing) using Immediate commands. This can be done for one axis (currently selected axis) or for all four axes on the EZ4AXIS.

NOTE: The run command (*R*) is not required for on-the-fly commands, but does not affect operation if added.

Examples

- */1V2000* (no *R* required if in motion) will change the velocity of the currently selected axis.
- */1V1000,2000,3000,4000* will change the velocities of all four axes while in motion.
- */1A1000,2000,3000,4000* will change the targets of all four axes while in motion.
- */1A1000,,1000* will change the target position for axes 1 and 3 while in motion.

On-the-fly changes allow truly independent control of the motors, as opposed to a stored program mode where axes will wait for each other to reach a coordinate.

Note that these commands must be issued one at a time. So, for example, */1V1000V3000* will ignore the *V3000* if the unit is running.

Immediate Command list

A	Absolute position
P	Positive relative move
D	Negative relative move
V	Velocity
L	Acceleration factor
n	Select various modes
J	Turn power output drivers on/off (typically used for solenoids)

The Immediate commands are also listed and described in Table 1, Command Set, which begins on page 72.

Analog and digital Inputs

The EZ4AXIS has twelve analog inputs which can be read back as analog values or be interpreted as digital 1/0 based on a user programmable threshold. Further, the three A, B and Index signals from each encoder can be read back as digital values, giving an additional six digital inputs.

The inputs are:

- **Four analog inputs on the 8-pin blue connector**

  This connector also has provision to drive two LEDs.

  These are read back with:

  /1?aa as analog values

  /1?4 as digital values

  With the *at* command setting the thresholds for 1/0.

- **Two analog inputs x 4 as limits for the four axes**

  These inputs are on the 6-pin blue connectors.

  These connectors also have provision to drive two LEDs.

  These are read back with:

  /1?aa1

  /1?aa2

  /1?aa3

  /1?aa4

- **Six digital inputs from encoder**

  /1?a4 reads back the same as */1?4* above but adds encoder 1 ABI inputs as three MSBs and will in future add the Encoder 2 ABI as three MSBs at a later date. Please be sure to read this number bit wise with masking to allow for the addition of more MSBs in the future.

Below are examples of basic programming that makes use of the input signals on the Analog/Digital IO and Limit/Home connectors. More examples may be found in “Single-Axis programming supplemental examples” beginning on page 38.

Read back digital IO input values (*?4* command)

The On/Off values of all four 8-pin IO inputs can be read back by issuing the *?4* command. Example: */1?4*

The result is a number ranging from 0-15, representing a 4-bit binary pattern in which:

Bit 0 = Input 1 (Switch 1)	Bit 1 = Input 2 (Switch 2)
Bit 2 = Input 3 (Opto 1)	Bit 3 = Input 4 (Opto 2)

Example: Readback number is 9, which is equivalent to digital 1001. This indicates Opto 2 high. Opto 1 low; Switch 2 low; Switch 1 high.

Read back analog IO input values (the *?aa* command)

The *?aa* command reads back analog values on the 8-pin Digital/Analog IO connector inputs in this order: 4, 3, 2, 1 which are input 4 (Opto 2), input 3 (Opto 1), input 2 (Switch 2), and input 1 (Switch 1) respectively.

Example: */1?aa*

Response: *8767,6544,6943,10720 No Error*. These are the values of inputs 4, 3, 2, and 1 respectively, expressed by a number from 0-16368 that represents a linear scale of 0-3.3V.

Additional */1?aa1* or */1?aa2* or */1?aa3* or */1?aa4* commands read back the analog values on the Limit/Home inputs for the respective axis.

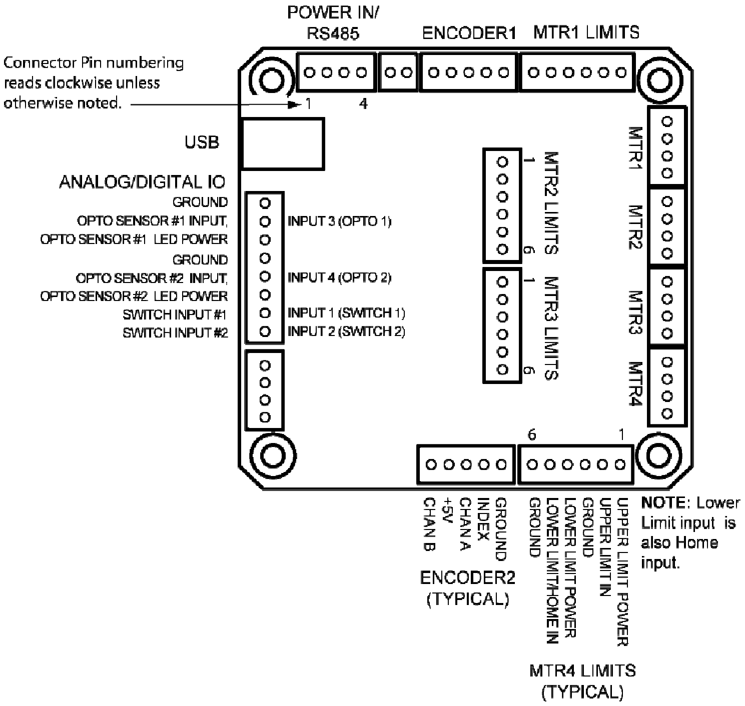


Figure 2 EZ4AXIS Connections

Input-dependent basic operations

Halt and wait for IO or Limits (the *H* command)

Motors may be halted, to wait in response to the status of either the Digital/Analog IO switches or the Limit switches before executing a command.

For this purpose, the *H* command is followed by a two- or three-digit operand, depending on which inputs are involved. The operands specify which input and what polarity the axis will wait for after halting.

- Two-digit operands apply to the 8-pin Digital/Analog IO connector. The first digit is polarity (high or low), and the second digit is the input number (1 through 4):

01	low on input 1 (Switch 1)
11	high on input 1 (Switch 1)
02	low on input 2 (Switch 2)
12	high on input 2 (Switch 2)
03	low on input 3 (Opto 1)
13	high on input 3 (Opto 1)
04	low on input 4 (Opto 2)
14	high on input 4 (Opto 2)

NOTE: If an edge detect is desired, a look for low and a look for high can be placed adjacent to each other, e.g., *H01H11* is a rising-edge detect.

- Three-digit operands apply to the inputs on the 6-pin Limit connectors. The most significant digit is axis, second digit is polarity (high or low), and the third digit is limit 1 or 2:

101	low on Axis 1 limit 1 (lower)
111	high on Axis 1 limit 1 (lower)
102	low on Axis 1 limit 2 (upper)
112	high on Axis 1 limit 2 (upper)
201	low on Axis 2 limit 1 (lower)
211	high on Axis 2 limit 1 (lower)
202	low on Axis 2 limit 2 (upper)
212	high on Axis 2 limit 2 (upper)
301	low on Axis 3 limit 1 (lower)
311	high on Axis 3 limit 1 (lower)
302	low on Axis 3 limit 2 (upper)
312	high on Axis 3 limit 2 (upper)

401	low on Axis 4 limit 1 (lower)
411	high on Axis 4 limit 1 (lower)
402	low on Axis 4 limit 2 (upper)
412	high on Axis 4 limit 2 (upper)

NOTE: If an edge detect is desired, a look for low and a look for high can be placed adjacent to each other, e.g., *H301H311* is a rising-edge detect.

Examples:

/1H101P100R Halt and wait for low on Axis 1 Limit input 1 (lower limit), and then move positive 100 microsteps.

/1gH211P100GR (Looping example) Halt and wait for high on Axis 2 Limit input 1 (lower limit), then move positive 100 microsteps. This repeats infinitely due to the loop created by *g* and G.

NOTE: Issuing */1R* will also break through a halt.

Skip and branch on IO or Limits (the *S* and *e* commands)

You can program the EZ4AXIS to skip an instruction within a command string and branch to another command string stored in EEPROM.

Overview

- Skipping is implemented using the *S* command, which is accompanied by a two- or three-digit operand (as described for the *H* command, above), indicating the condition at one of the inputs.

  For example, *S13* means “Skip next instruction if there is a high on input 3.”

  Or, *S112* means “Skip next instruction if there is a high on Axis 1 limit 2 (upper limit).”

- Branching is implemented with the *e* or execute command, which tells the drive to run the command string in a specific memory location (0-15). For example, *e2* means run the string residing in location 2.

Example

The following example stores two command strings in EEPROM locations 0 and 1. The program skips an instruction and switches from one string to the other depending on the state of input 3.

Send these command strings:

/1s0gA0A10000S12e1G0R (stored string 0, executed at startup)

/1s1gA0A1000S02e0G0R (stored string 1)

Stored string 0 command breakdown:

/1	Talk to device number 1 on the EZ bus (Drive 1).
s0	Store following in memory location 0 (executes on power-up).

g	Start loop.
A0	Go to absolute position 0.
A10000	Go to absolute position 10000.
S12	Skip next instruction if 1 (high) on input 2 (Switch 2).
e1	Jump to string 1 (execute command string stored in memory location 1.) (This is the branch operation.)
G0	End of loop (*0* indicates infinite loop).
R	Run.

Stored string 1 command breakdown:

/1	Talk to device number 1 on the EZ bus (Drive 1).
s1	Store what follows in memory location 1.
g	Start loop.
A0	Go to absolute position 0.
A1000	Go to absolute position 1000.
S02	Skip next instruction if 0 (low) on input 2 (Switch 2).
e0	Jump to string 0 (execute command string stored in memory location 0.) (This is the branch operation.)
G0	End of loop (0 indicates infinite loop).
R	Run.

Result: At power-up, the code will cycle the motor between position *A0* and *A10000* if input 2 is high, and between *A0* and *A1000* if input 2 is low.

NOTE: Loops can be exited by storing nothing in a memory location and skipping to that location.

For example, the command */1s14R* stores nothing in memory location 14, and a skip to that location will exit the loop.

Advanced looping techniques

Create a nested loop

The following example shows how to construct a nested loop, or loop within a loop. Nested loops can be up to four levels deep.

Send this command string:

/1aM2gA1000A10000gA1000A10000G10G100R

Command breakdown:

/1	Talk to device at Address 1 on the EZ bus.
aM2	Talk to Axis 2.
g	Start outer loop.
A1000	Go to absolute position 1000.
A10000	Go to absolute position 10000.
g	Start inner loop.
A1000	Go to absolute position 1000.
A10000	Go to absolute position 10000.
G10	Repeat inner loop 10 times. (end of Inner loop).
G100	Repeat outer loop 100 times. (end of outer loop).
R	Run.

Result: The first *g* (lower case) command starts the outer loop, and the second *g* command starts the inner loop. The first *G* (upper case) command terminates the inner loop and specifies how many times it is run, while the second *G* command does the same for the outer loop.

To create an endless nested loop, change the second *G* command from *G100* to *G0* (zero). The nested loop will now run until interrupted by the *T* command, e.g. */1T.* (Do not use */1T2*, */1T3* etc. to terminate a loop since the behavior is undefined and may change in the future.)

Set up standalone operation

Standalone operation is implemented by storing the appropriate command string in EEPROM memory location 0. The command string in this location runs automatically at power-up. Examples of this are shown on pages 38 and 39.

Readjusting velocity, acceleration, and current

If the motor behavior is problematic using the standard values for the EZ4AXIS provided in Section 3, here are some tips for making corrective adjustments to velocity, acceleration, and current.

Command Description

V Velocity: reduce velocity if the motor stalls, or try adjusting *L* or *m* as described below. Maximum achievable velocity depends on the available supply voltage. Also, move current may need to be adjusted to obtain a desired velocity. Standard setting is *V1000*.

L Acceleration (acceleration factor): depends on adequate supply power and voltage. If available power is insufficient, back off acceleration. Increase voltage, if possible, to overcome the motor's back emf. Standard setting is *L10*.

The EZAXIS equation for acceleration is: Acceleration (in microsteps / sec^2) = (L value) x (100,000,000/65536). For example, if V=10000 and L=1, it will require 6.5536 seconds to reach final velocity. The EZ4AXIS17XR equation for acceleration is TBD.

m Maximum move current: more current provides more force and more acceleration. If motor stalls, try increasing this value. Given as a percentage of the maximum output driver current, which is 2A for the EZ4AXIS and 0.5Afor the EZ4AXIS17XR. Standard setting is *m30* (30% of 2A).

h Hold current: increase if motor is slipping when attempting to hold a position. Given as a percentage of the maximum output driver current, which is 2A for the EZ4AXIS and 0.5Afor the EZ4AXIS17XR. Standard setting is *h10* (10% of 2A). (50% max allowed)

For example, if a motor doesn't move and makes a hammering sound, it is stalled. Decreasing *V* or *L* may be needed. Move current (m) may also need to be increased or supply voltage may need to be increased.

Single-Axis programming supplemental examples

The following single-axis programming examples are provided to supplement the preceding instructions.

Example #1 (loop: moves with waits)

/1aM2gA10000M500A0M500G10R

Command breakdown:

/	Start character. Tells the EZSteppers® that a command is coming in.
1	Drive 1 (device address, set via address switch on device).
aM2	Axis 2
g	Start a repeat loop.
A10000	Turn to absolute position 10000.
M500	Wait for 500 milliseconds.
A0	Turn to absolute position 0.
M500	Wait for 500 milliseconds.
G10	Repeat string 10 times beginning from the location of the *g* command.
R	Run the command.

NOTE: To terminate the above loop while in progress, issue the *T* command, e.g*., /1T2* for Axis 2. This terminates any programs running on the drive card. (Do not use */1T2*, */1T3* etc. to terminate a loop since the behavior is undefined and may change in the future.)

Example #2 (loop: set current, wait for Switch 2 closure, go home)

NOTE: This is a standalone operation example.

/1s0aM1m75h10gJ3M500J0M500G10H02A1000A0Z10000R

Command breakdown:

/1s0	Stores the program that follows in EEPROM location 0 (string 0 is executed on power-up).
aM1	Select Axis 1.
m75	Set move current to 75% of max.
h10	Set hold current to 10% of max.
g	Start a loop.
J3	Turn on both on/off drivers for Axis 1.
M500	Wait 500 ms.
J0	Turn off both on/off drivers for Axis 1.

M500	Wait 500 ms.
G10	Repeat loop above 10 times.
H04	Halt and wait for switch 4 input to go low.
A1000	Move to absolute position 1000.
A0	Move to position 0.
Z10000	Home the stepper. Maximum steps allowed to find opto is set to 10000.
R	Run.

Example #3 (loop: monitor four switches and execute four different programs depending on which switch input is pushed)

NOTE: This is a standalone operation example, which stores five command strings for an endless loop. This loop runs automatically at startup, because it begins at the program *0* location.

Setup

/1s0aM3gS11e1S12e2S13e3S14e4G0R
Stores command string in EEPROM location 0 (string 0 is executed on power-up). (S11= skip next instruction if high on input 1.)

/1s1A1000e0R	Stores command string in EEPROM location 1.
/1s2A2000e0R	Stores command string in EEPROM location 2.
/1s3A3000e0R	Stores command string in EEPROM location 3.
/1s4A4000e0R	Stores command string in EEPROM location 4.

Execution

- At power-up, string *0* automatically executes on Axis 3 and loops around sampling each switch one by one (S11, etc.), and skipping the subsequent instruction if it is not depressed.
- If a switch—for example Switch 1—is depressed, string 1 is executed, which moves the stepper to absolute position 1000.
- Execution then returns to string 0, due to the *e0* command at the end of the string.
- If the switch is still depressed it will jump to string 1 again, but since the motor is already at that position there will be no visible motion.
- If another switch is closed, the program will also jump to that stored string.

To terminate this endless loop, issue */1T*. This stops all commands executing on device with address 1.

NOTE: Using an *e* command to go to another program is more of a “GOTO” than a “GOSUB” since execution does not return to the original departure point.

Example #4 (loop: move 1000 steps forward on rising edge of Switch 2)

```
/1aM2gH01H12P1000G0R
```

The endless loop halts and first waits for a 0 level on Switch 1, then waits for a 1 level on Switch 2.

Then a relative move of 1000 steps is issued, and the program returns to the beginning to look for another rising edge.

NOTE: To terminate the above loop while in progress, issue */1T*.

Example #5 (loop: use threshold setting to regulate pressure)

It is possible to regulate pressure by turning a pump on or off depending on an analog value read back, by designating the threshold of the one/zero call as the regulation point.

```
/1at308000gS03P1000G0R.
```

This command first sets a threshold level using the *at* command. Then it starts an endless loop during which it responds to a high on input 3 by moving the motor 1000 microsteps positive. As long as input 3 remains low, it skips the move command (*P)*.

Multiple-axis/multiple drive supplemental examples

The following examples utilize multi-axis commands.

Example #5: coordinated motion with all axes on a bus performing same motion

This example also shows how to address all drives and all axes on a bus.

```
/_A1000,1000,1000,1000R
```

Command breakdown:

/_ (Slash then underscore) Select all drives on bus.

A1000 Go to absolute position 1000. The four comma-delineated positions above represent the same command applied to the four axes on the drives.

R Run. All motors on all drives go to absolute position 1000.

Example #6: coordinated motion between two separate drive cards.

This example also shows how to set up commands and send a Run command separately so that multiple motors/drives run at the same time.

NOTE: The following are multi-axis commands.

/1A1000,200,300,400 Set up drive card 1 Axis 1 to absolute position 1000; Axis 2 to position 200; Axis 3 to position 300; and Axis 4 to position 400.

/2A200,300,400,1000 Set up Drive card 2 Axis 1 to absolute position 200; Axis 2 to position 300; Axis 3 to position 400; and Axis 4 to position 1000.

/AR Run current commands in buffer for all axes on Drive card 1 and Drive card 2. The /A command addresses a bank defined as Drives 1 and 2. (Banks are described in Appendix 1, Addressing Methods Reference.)

Example #7: synchronized motion among different drives

Synchronized motion can be achieved by issuing commands to individual axes in a bank of drives without the *R* (Run) command, which sets up the command without executing it. At the proper time, the *R* command is sent to the bank of drives to start several actions in concert.

/1aM3A1000 Set up Drive 1 Axis 3 to move to absolute position 1000.

/2aM1A100 Set up Drive 2 Axis 1 to move to absolute position 100.

/AR Run commands on Drive 1 Drive 2. The */A* command addresses a bank defined as Drives 1 and 2. (Banks are described in Appendix 1, Addressing Methods Reference).

Example #8: select drives in bank, then issue command to bank

If no axis is indicated in any command, the command is issued to the last axis specified on each drive in the addressed bank. So axes can be preselected prior to issuing the bank command, for example:

/1aM3R Select drive card 1 Axis 3.

/2aM1R Select drive card 2 Axis 1.

/AP1000R Move drive card 1 Axis 3 and drive card 2 Axis 1 relative 1000 microsteps positive. The /A command addresses a bank defined as Drive cards 1 and 2. (Banks are described in Appendix 1, Addressing Methods Reference.)

5. Limits (*n2*)

Overview

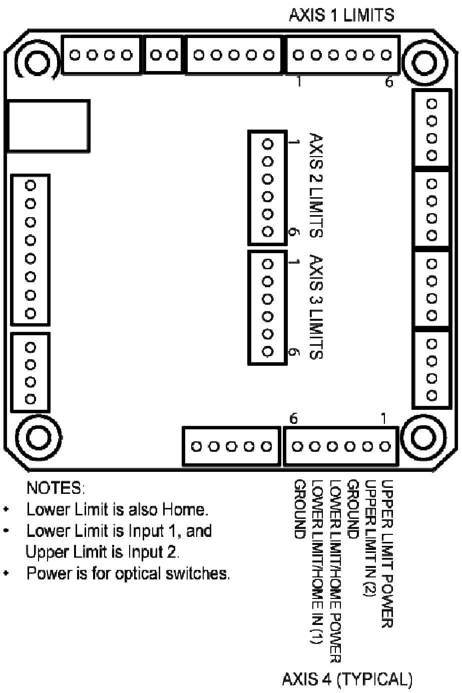
Each axis can be set up to stop motor rotation when a mechanical limit is signaled by a switch closure or opening. Limits are not active by default, and must be specifically turned on. */1n2R* or */1n2,2,2,2R*

When a limit is engaged, the motor will not respond to a move command in the direction in which the limit is engaged, but will perform a move in the direction that backs out of the limit.

NOTE: It is necessary to turn off limits while homing, because the limits will inhibit a correct homing position from being achieved.

Hookup

Make connections at the Limit/home connector for the relevant axis (see figure below). Each 6-pin limit/home connector provides two inputs: an upper limit and a lower limit. The upper limit operates in the positive movement direction, while the lower limit operates in the negative movement direction. The lower limit is also the homing input, as determined by programming.



NOTES:
- Lower Limit is also Home.
- Lower Limit is Input 1, and Upper Limit is Input 2.
- Power is for optical switches.

Figure 3 Limit Connections

The inputs may use either optical or mechanical switching devices, and include outputs for power LEDs. These outputs are internally connected to +5V through 200-ohm resistors. For sensors such as Hall sensors that need direct access to +5V the 200-ohm resistors may be shorted across.

200mA total is available across all 5V connections.

NOTE: The inputs are relatively high impedance at 10K ohms and will pick up noise if bundled with the motor wires, etc. For long cable runs, each input line should be shielded. The addition of a 0.1µF ceramic capacitor from the input to ground at the board connector may be an alternative to shielding, but could slow the response.

Basic limits setup

As needed, refer to "Commands for limits," below, for additional clarification.

1. Set up mechanical assembly with limit switch or switches placed in desired location(s).

2. Activate limits on desired axis by issuing the *n2* command, e.g., */1aM2n2R*, or /1n2,2,2,2R in multi axis format.

3. Ensure that a positive move, e.g. */1aM1P1000R,* moves toward the upper limit and away from the lower limit. If the motor moves in the wrong direction, reverse the connections to only one of the windings of the motor.

4. Set limit polarity if necessary (requires V7.60+ code):

The default condition expects the limit switch to be low when away from the limit (as is the case when an optical switch is used). If the limit switch is to be high when away from the limit (as with a normally-open switch), issue the command *f1* to reverse the polarity that is expected. This can be done per axis; for example, */1aM1f1aM2f0R* selects different polarities for the limits of Axes 1 and 2. So *f1* = normally open, and *f0* = normally closed. This command also works in multi axis format /1f1,0,1,1R etc

5. Set limit input threshold if needed with the *at* command (for example, because some sensors will not pull to a TTL low level when closed).

To calculate the threshold number to be used in the command: (Desired threshold voltage/3.3) x 16368 = threshold number. Example for 2.00 volts: */1at3209920R,* where *22* indicates Axis 2 input 2 (upper limit) and *09920* is the threshold number for 2.00 volts according to the formula above (a zero is added at the beginning because this must be entered as five digits).

Confirm thresholds with the *?aat* command.

6. Issue move commands and confirm that the motor stops when it reaches the limit or limits that have been set up.

Commands for limits

n2 Makes limits active on a per-axis basis, e.g., */1aM3n2R* activates limits on Axis 3.

f Set limits polarity. Set expected limit switch to be normally open or normally closed. Normally open is *f1* and normally closed is *f0*. The default is normally closed. Normally closed is generally preferable because opening a switch can interrupt current to terminate motion immediately.

at Adjust thresholds, if needed. For example, the sensor used for limit switching may not pull to a full TTL level, as is the case with a reflective sensor. The default threshold is 1.24V.

Thresholds are expressed as five-digit numbers in a range from 00000-16368, which linearly represents the 0-3.3V input. The default threshold value is 06144 (1.24V).

Example: */1at3209999R.* This sets the threshold on Axis 3 input 2 (upper limit) to 09999 (2.02 volts). Key components:

at	Threshold command
32	Axis/input identifier, in this case Axis 3 and Limit Input 2 (upper limit). The full range is 11,12,21,22,31, 32,41,42.
09999	Threshold value, 00000–16368, representing 0–3.3V. (Threshold value = (desired threshold voltage/3.3) x 16368.)

The threshold value for limits must always be entered as five digits. Thus it is necessary, in this example, to insert a leading zero after the axis/input identifier to reach the required number of digits.

To set multiple thresholds, repeat the *at* command for each threshold to be set:

1at1105952at2105952at1211904at2211904R. This sets the lower limit (input 1) thresholds of Axes 1 and 2 to 1.2V, and the upper limit (input 2) thresholds to 2.4V. (Threshold voltage = (threshold number/16368) x 3.3.)

NOTE: In previous firmware versions, all limit thresholds were set when input t 4 on the 8-pin Digital/Analog IO connector was set using the *at4XXXX* command.

?aat (Requires firmware version 7.50 or higher.) Read thresholds of all home/limit inputs on the drive. The order of readback (in terms of the axis/input identifiers explained above) is 12, 11, 22, 21, 32, 31, 42, 41.
Example readback:
6144,6144,6144,6144,9999,6144,6144,6144 No Error

NOTE: Input 1 is Lower Limit/Home, and input 2 is Upper Limit.

6. Motion sequencing modes

Immediate commands

Issue /1A1000,2000,3000,4000R

And before the move is done issue

/1A-1000,-2000,-3000,-4000R

The first command will be overwritten by the second command and the motors will move to the new coordinate, smoothly stopping and changing direction if necessary

Move command execution sequence "coordinate mode"

In a string with multiple commands, command execution starts in the left most command and moves to the right in sequence.

/1A1000,2000,3000,4000A-1000,-2000,-3000,-4000R

The default mode is coordinate mode. Where all motors must reach the first "4 point coordinate" 1000,2000,3000,4000 before they go to the second coordinate -1000,-2000,-3000,-4000

Move command execution sequence "non coordinate mode"

In the "an16 non coordinate mode" the 4 motors will not wait for each other to get to a coordinate. And will look ahead to the next command. Each motor will start the next command before all motors reach the first coordinate.

So /1an16A1000,2000,3000,4000A-1000,-2000,-3000,-4000R

Motor 1 will reach its target first and reverse towards -1000 while all the other motors are still going forwards.

This look ahead is for just ONE command ahead only. So if commands 1 2 and 3 are in a sequence ALL motors must be done with command 1 before command 3 starts.

/1an16A100,200,300,400A-100,-200,-300,-400A100,200,300,400R

The third command will not start until Motor 4 reaches 400 in the first command and command 1 is completely finished. The addition of any command in between these commands will stop the look ahead to the next command. Eg in the below command the M1 makes command 2 complete for all 4 motors before the final move command starts.

/1an16A100,200,300,400A-100,-200,-300,-400M1A100,200,300,400R

7. Digital Inputs (switch-controlled) applications

The EZ4AXIS can respond to on/off states applied to the Analog/Digital IO 8-pin connector. A switched input can be used to notify an axis when a specific mechanical position is reached, or for any other practical purpose requiring an on/off signal, such as:

- Halt; then move or execute another program stored in memory
- Skip the next step
- Wait for another change in status of the input
- Monitor an input using an endless loop, or base an action on the status of an input while running the loop a specified number of times.

Hookups

The 8-pin Analog/Digital IO connector provides a set of four multipurpose inputs, accessible by any of the four axes via programming. All inputs operate on TTL-level signals, although thresholds can be adjusted to accommodate non-TTL level switch closures.

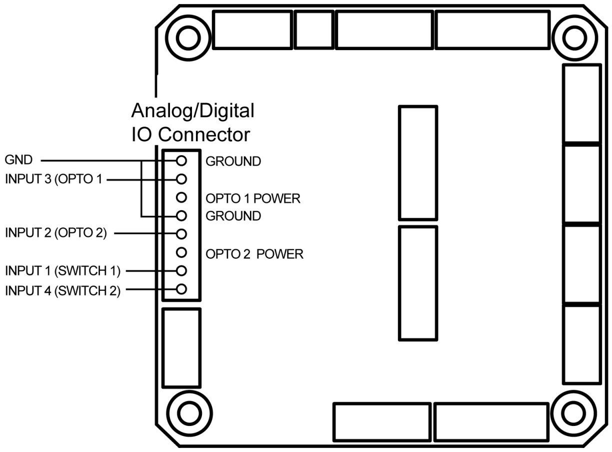


Figure 4 Switch inputs for the EZ4AXIS

The inputs may use either optical or mechanical switching devices, and include outputs for power for two LEDs. These outputs are internally connected to +5V through 200-ohm resistors. For sensors such as Hall sensors that need direct access to +5V, the 200-ohm resistors may be shorted across.

200mA total is available across all 5V connections.

Optical or mechanical switches may be used on any input. If four optical switches are desired for the IO connector, power for the additional optical switches can be drawn from the 5V supply pin on one of the encoder connectors. This power may require an external resistor in series with the LED in the optical switch.

NOTE: The inputs are relatively high impedance at 10K ohms and will pick up noise if bundled with the motor wires, etc. For long cable runs, each input line should be shielded. The addition of a 0.1µF ceramic capacitor from the input to ground at the board connector may be an alternative to shielding, but could slow the response.

Commands

?aa Read back ADC values (values after analog/digital conversion) on specified input *(/1?aa1*= Axis 1*, /1?aa2*=Axis 2, etc.*)*. These values are on a scale of 0 - 16368 as the input varies from 0–3.3V. The inputs as shipped have a resolution of about 7 bits, but can be improved to exceed 10 bits with the removal of the input overvoltage protection circuitry (call AllMotion for details).

at Adjust thresholds. Thresholds can be set for on/off detection, since IO connector inputs are essentially analog. The default threshold value is 6144 (1.24V).

Example: */1at309999R*. This sets the threshold on input 3 to 09999 (2.02V).

3 Input identifier, in this case Input 3 (Opto 1).

09999 Threshold value, 00000–16368, representing 0–3.3V. (Threshold value = (desired threshold voltage/3.3) x 16368.)

Note that it is necessary to insert a leading zero after the input identifier (3), since the threshold value must always be entered as five digits (00000-16368).

NOTE: In prior firmware versions, all thresholds were simultaneously programmed when input 4 on the 8-pin IO connector was set using the */at4XXXXXR* command.

?at Read back thresholds for all four inputs on the 8-pin connector. The readback order is inputs 4, 3, 2, 1.

Example response: 6144,6144,6144,6144 No Error (1.24 volts, expressed as number from 0-16368 representing the 0-3.3V range at the inputs)

H Halt

S Skip next command

M Wait

e Execute command string stored in specified EEPROM memory location. Used for branching in conjunction with halts, skips, and waits. E.g., */1e2* means “execute contents of memory location 2.”

Examples

For programming examples, see “Input-dependent basic operations” beginning on page 33 and “Single-Axis programming supplemental examples” beginning on page 38.

8. Analog control applications

This section describes analog control applications that use one or more of the inputs on the 8-pin Analog/Digital IO Connector.

These applications utilize potentiometers as the input devices. However, any input ranging from 0–3.3V will be accepted.

Analog inputs

The four inputs on the 8-pin connector are all ADC inputs.

The ADC values, representing the potentiometer positions, can be read using the *?aa* command which reads the inputs on the 8pin connector.

Each of the 6 Pin limit connectors also have ADC inputs which can be read *(/1?aa1 =* axis 1*, /1?aa2* = axis 2, etc.*)*.

These values are on a scale of 0 - 16368 as the input varies from 0 - 3.3V. The inputs as shipped are good to about 7 bits, but can be made to be better than 10 bits with the removal of the input overvoltage protection circuitry (contact AllMotion for instructions).

These inputs will report voltages above 3.3V as the max value of 65536.

Noise considerations

The inputs are relatively high impedance at 10K ohms and will pick up noise if bundled with the motor wires, etc. For long cable runs, each input line should be shielded. The addition of a 0.1µF ceramic capacitor from the input to ground at the board connector may be an alternative to shielding, but could slow the response.

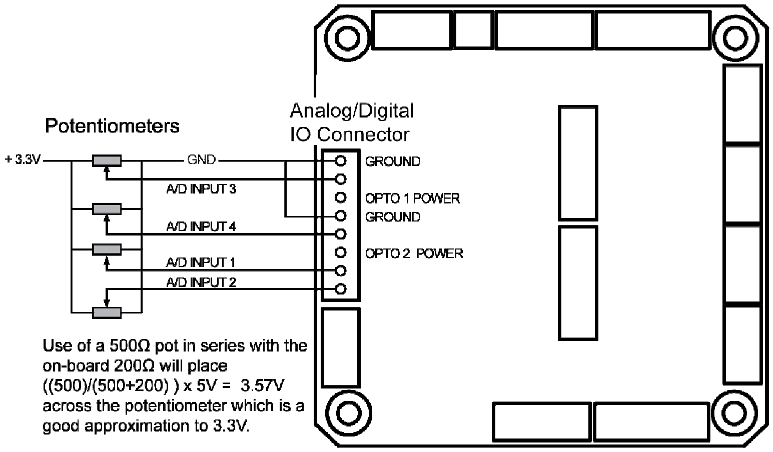
Potentiometer hookups

Potentiometer hookups may be made at the 8-pin analog/digital IO connector, shown below. The inputs digitize on a scale of 0-3.3V is 0-16384 readback. It is necessary to provide a 3.3V supply for the potentiometer(s) to ensure the proper voltage range.

The power for optical sensor LEDs can be used for powering the potentiometers. These outputs have a 200 Ohm resistor in series with them which can be replaced with zero ohm resistors to give direct access to the 5V power on the board. These resistors are on the bottom side of the board, next to the LED and have a trace from the resistor to the LED pin. A series resistor added to one end of the potentiometer can make the output of the potentiometer 0-3.3V. The encoder supply can also be used to power the potentiometer.

Internally the drive has 10KΩ pullups on the inputs, which will interfere with the linearity of the potentiometer. To overcome this 10K use a low impedance potentiometer such as 500Ω or remove these pullup resistors (contact factory for details).

As shipped these inputs are accurate to 7 bits. There is an input protection circuits which will need to be removed if an accuracy of 10 bits is to be reached (contact factory for details).



Use of a 500Ω pot in series with the on-board 200Ω will place ((500)/(500+200)) x 5V = 3.57V across the potentiometer which is a good approximation to 3.3V.

Potentiometer Velocity Mode (Joystick Mode)

This is available in firmware version 7.60+

Hook up the potentiometers as shown in the diagram above.

Issue the command /1ad100,100,100,100am256,256,256,256n65536,65536,65536,65536z0,0,0,0R to enable all 4 axes for joystick mode.

The ratio of motion between the potentiometer read value and the motion is given by.

Velocity in microsteps/sec = +/- [(potentiometer value(0to16368) – (potentiometer zero value from "z" command) - ("ad" deadband value/2)] x (am/256)

In this mode a voltage on the 4 inputs of the 8 pin Input connector is used to command the velocity of the 4 motors. The value read back on the potentiometer , from 0-16368, is multiplied by the multiplier "am" and then divided by 256. The motor uses this number just as if it had been commanded by a V command. To see the commanded velocities issue /1?aV

The /1n65536 command above enters joystick velocity mode. Once in this mode, /1z0R will set zero velocity to the current position on the potentiometer. (Important to issue the z0 AFTER entering this mode). The P0 command then starts an endless move based on the velocity as read from the potentiometer.

Instead of using z0 which zeros to the current position of the potentiometer, an exact value can be set which defines the zero value. For example /1z8192,8192,8192,8192R sets the mid position (ie 3.3V/2) to be zero

To terminate this mode, first issue /1n0,0,0,0R then issue /1T

To Enable limits while in this mode issue limit in addition to joystick mode 65536 + 2 = 65538 . So /1n65538R etc

Note also that there is a 10K pullup on the PCB that will affect the linearity of any value from a high impedance potentiometer. Contact factory for instructions on removing these.

Potentiometer Position Mode

Potentiometers hooked up to the 8 pin connector may also be used to command position proportional to voltage.

Issue the command /1ao100,100,100,100ad100,100,100,100am256,256,256,256n8192,8192,8192,8192R

Stepper position = ((analog value from potentiometer(0 to16384)/ 256) x (“am” multiplier)) + (“ao” offset value)

The inputs digitize on a scale of 0-3.3V is 0-16384 readback. It is necessary to provide a 3.3V supply for the potentiometer(s) to ensure the proper voltage

Further, there is a “deadband” command, “ad”, which sets a dead band on the 0-16368 potentiometer value read back such that a value outside this deadband must be seen before a command is issued to cause a move.

Note also that there is a 10K pullup on the PCB that will affect the linearity of any value from a high impedance potentiometer. Contact factory for instructions on removing these.

The LED supply pin is a connection to 5V through 200Ohm which may be shorted across to gain access to 5V, which can then be dropped down through a resistor in series with the potentiometer ends to get 3.3V at the ends of the potentiometer.

9. Homing

Overview

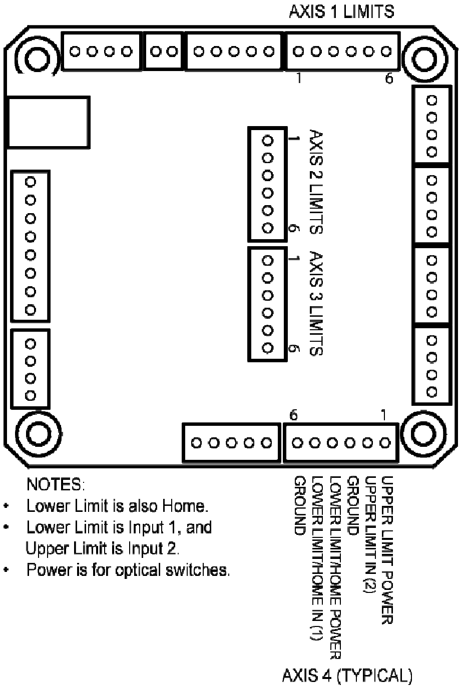
Homing provides a known starting point for each motor, from which each operation can begin, and from which absolute positions are calculated. There are two homing modes:

- N1 Mode, homing to a TTL input on the 6-pin Home/Limit connector for that axis. This is the default homing mode. Typically a mechanical or optical switch is set up to open or close when the motor reaches the home position. See "Homing to opto/switch (default *N1* mode)," below.
- N2 Mode, homing to an index. Version requires 7.60B+ . In this mode, the index pulse from an encoder is used for homing. For details, see "Homing to encoder index (N2 mode)," below. /1aM1N2Z10000R or /1aM2N2Z100000R etc

Homing to opto/switch (default *N1* mode*)*

Hookups

Each axis on the drive has its own set of limit/home inputs on 6-pin connectors, as shown below. The lower limit input is also the home input.



NOTES:
- Lower Limit is also Home.
- Lower Limit is Input 1, and Upper Limit is Input 2.
- Power is for optical switches.

Figure 5 Home/Limit Connections

These connections can be used with any device that sends out TTL level signals. Typically optical or mechanical switching devices, and include power outputs for optical LEDs. The High Low threshold can also be changed using the “*at”* command. Further since each input has a pullup resistor built into the board, a simple switch to ground can be used as a home switch. See the wiring diagram on the AllMotion website EZ4AXIS product page, for more detail if needed.

Noise considerations

The inputs are relatively high impedance at 10K ohms and will pick up noise if bundled with the motor wires, etc. For long cable runs, each input line should be shielded. The addition of a 0.1µF ceramic capacitor from the input to ground at the board connector may be an alternative to shielding, but could slow the response.

Homing behavior

The *Z* command initializes the motor to a known position, called Home (the Home position is usually aligned with a switch closure or opening). This is position 0. All absolute positions are relative to the Home position. When the *Z* command is issued, the motor turns toward position 0 until the home switch is interrupted. If the switch is already interrupted, the motor will back out and return until the switch is re-interrupted.

Basic homing setup

Refer to “Commands for homing to opto/switch,” below, as needed for additional clarification.

NOTE: Homing occurs at the speed currently set by the *V* (velocity) command. For accuracy and reliability, it is important to home at a slow speed. If high-speed homing is desired, home at high speed first and then home again at low speed.

1. Make sure switch and flag are set up to be unambiguous. For example, when the motor is at one end of travel, the home flag should interrupt the switch; and when at other end of travel, the home flag should not interrupt the switch. There should be only one zero-to-one transition possible on the home input in the whole range of motor rotation.
2. **FIRST ensure that a positive move, e.g. */1aM1P1000R*, moves away from home and the home flag.** If the motor does not move away from home on a positive move, reverse the connections to only one of the windings of the stepper motor.
3. Set home flag polarity if necessary. Again, before doing this step make sure the *P1000* command moves away from home.

   The default condition expects the home flag to be low when away from home (as is the case when an optical switch is used). If home flag is to be high when away from home (as in the case of a normally-open switch), issue the command *f1* to reverse the polarity that is expected of the home flag. This can be done per axis; for example, */1aM1f1aM2f0R* selects different polarities for the home flags of Axes 1 and 2. So *f1* = normally open, and *f0* = normally closed. Or use multiaxis command E.g. /1f1,0,1,1R

NOTE: If the home flag polarity is set incorrectly, the motor may move in the wrong direction when attempting to home.

4. Set home input threshold if needed with the *at* command; confirm with the *?aat* command: (Desired threshold voltage/3.3) x 16368 = threshold number. Example for 2.00 volts: */1at3109920R,* where *31* indicates Axis 3 input 1 and *09920* is the threshold number for 2.00 volts according to the formula above (a zero is added at the beginning because this must be entered as five digits).

5. Issue the *Z* command with the desired maximum number of steps, for example */1aM1Z100000R*. Or with the home flag polarity setting included, for example */1aM1f1Z100000*. Observe motor behavior.

Commands for homing to opto/switch

N1 Enter the Homing to Switch mode. This is the default mode, so it is not usually necessary to issue this command.

Z The homing command. The maximum number of steps allowed to go toward home is defined by the *Z* command operand, e.g., /1*Z40000R*.

f Set Home polarity. Set expected home switch to be normally open or normally closed. Normally open is *f1* and normally closed is *f0*. The default is normally closed. Normally closed is generally preferable because it is “fail safe” in case of disconnection of the sensor..

NOTE: If the *f* command is not set correctly, the motor may move in the wrong direction when homing.

at Adjust thresholds, if needed. The default is 1.24V.

For example, consider a home sensor that doesn’t fully pull to a TTL low level (e.g., a reflective sensor). The threshold can be adjusted to accommodate the sensor’s output level without external signal conditioning.

Thresholds are expressed as five-digit numbers in a range from 00000-16368, which linearly represents the 0-3.3V input. The default threshold value is 06144 (1.24V).

See example next page.

Example: */1at3109999R.* This sets the threshold on Axis 3 input 1 (lower limit/home) to 09999 (2.02 volts). Key components:

31 Axis/input identifier, in this case Axis 3 and Input 1. The Home input is always Input 1.

09999 Threshold value, 00000–16368, representing 0–3.3V. (Threshold value = (desired threshold voltage/3.3) x 16368.)

The threshold value for home/limits must always be entered as five digits. Thus it is necessary, in this example, to insert a leading zero after the axis/input identifier to reach the required number of digits.

?aat (Requires firmware version 7.50 or higher.) Read thresholds of all home/limit inputs on the drive. The order of readback (in terms of the axis/input identifiers explained above) is 12, 11, 22, 21, 32, 31, 42, 41.
Example readback:
6144,6144,6144,6144,9999,6144,6144,6144 No Error

These are numbers on a 0-3.3V scale = 0-16384

so the default value of 6144 is 1.24V for the hi/lo threshold

NOTE: Input 1 is Lower Limit/Home, and input 2 is Upper Limit.

Homing to encoder index (*N2* mode)

NOTE: Homing should be done at a slow speed, especially if homing to a narrow index pulse on an encoder, which could be missed at high speeds.

Overview

In this mode, the specified axis (Axis 1 or 2) will home to the index of the encoder associated with the axis. Note that the index is sampled at a 20kHz rate, and may be missed if motor velocity is too high. Velocity must be such that the index is at least 100µs in width. Implemented on firmware V7.60B and later.

Hookup

For encoder hookup, refer to Section 10, "Using encoders," page 57.

Commands

N2	Enter the Home to Encoder Index mode.

Example

/1aM1N2Z10000R	Home Motor1 to Encoder1 Index
./1aM2N2Z10000R	Home Motor2 to Encoder2 Index.

10. Using encoders

Overview

Encoder input connectors are provided for Axis 1 and Axis 2. Encoders may be used in the following ways:

- **Encoder Following:** Motor follows index pulses from non-coupled encoder. The encoder that is to be followed can be moved by hand or can be an encoder coupled to a different motor.
- **Eelectronic gearing:** Motors can be electronically geared to an encoder and will follow it in real time. The encoder that is to be followed can be moved by hand or can be an encoder coupled to a different motor.
- **Position Correction:** Motor position is automatically corrected based upon an encoder that is coupled to the motor. Coupling can be directly on the motor shaft or at the other end of a gear train or mechanism, so as to position the end effector correctly.
- **Auto recovery in Position Correction mode:** auto recovery scripts are run if Position Correction cannot correct a motor position. S n modes n512
- **Overload report mode:** overloads are reported but there is no position correction or auto recovery.
- **Homing:** provide a starting point for the motor using encoder index pulses. This mode is explained in “Homing to encoder index (N2 mode)” on page 56.

Encoder hookup

There are two encoder input connectors, one for Axis 1 (Encoder 1) and the other for Axis 2 (Encoder 2). The connectors accept index and AB quadrature pulses, and provide 5V power to the encoders. See Figure 6 below.

Electrical Notes:

- The encoder(s) + Optos must draw total current of <200mA from the 5V pin.
- Encoders must have 0.2V low and 4V high swing at the connector.
- Refer to wiring diagram also.

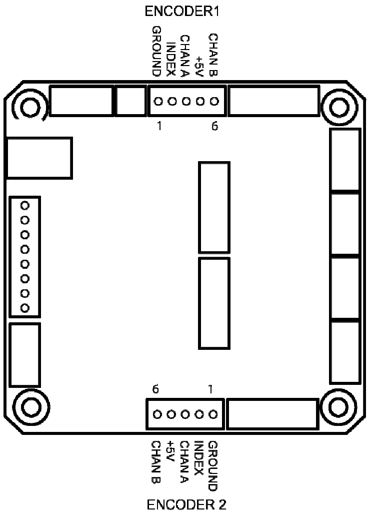


Figure 6 Encoder Connectors

NOTE: Cable from encoders should be shielded, especially in environments with significant noise. They will pick up noise if bundled with motor wires, etc. For long cable runs, each input line should be individually shielded.

Encoder following mode (*an64*)

Overview

Starting with Firmware V7.65 any of the motors can be made to follow a value read from an encoder. This mode is similar to the potentiometer position mode. The encoder can be turned either by hand or by a secondary mechanism/motor. This mode reads the encoder value and uses it as a target position for the motors that are following it. This value is continuously entered as a continuously varying target position for the drive to follow. The target position is automatically entered and continuously updated similar to computer commanded "A" commands and is subject to acceleration and velocity parameters set for each axis and may result in lags. (Note: For exact real-time electronic gearing use n64 mode).

Motor position = [encoder_value * (am/256)] + [ao].

Note that the Deadband = +/-(ad)/2 (where "ad" is the number entered via the deadband command)

Related commands for this mode are:

/1ae1,2,2,1R sets which motor the encoders follow 1 or 2

/1az0,55,0,1234R initializes just encoder counts (only 1 and 2 have meaning since only encoders on this board)

/1z32,22,44,0R initializes encoder and motor position as desired

/1ao200,300,44,89R offset added to encoder count after multiplying by am (Default is zero)

/1am256,512,300,22R (default is 256) sets multiplier

/1ad10,10,10,10,10R sets deadband . (So it does not hunt.)

Example

Wire up two encoders and 4 motors. Issue the command:

/1z0,0,0,0ae1,2,1,2am256,256,4096,4096an64,64,64,64R

Motors 1 and 3 will follow encoder 1 with different speeds. And motors 2 and 4 will follow encoder 2 with different speeds.

Electronic gearing mode (*n64*)

Overview

Starting with Firmware V7.65 electronic gearing mode is available. The electronic gearing happens at a 20Khz rate and it essentially “real-time”. This mode is similar to the an64 mode described above but does not allow offset “ao” or deadband “ad”.

/1?aA reflects the current position. /1?a8 reads back the encoders

Eg: /1z0,0,0,0ae2,2,2,2am512,256,128,128n64,64,64,64R makes all 4 axes follow encoder 2 with different gear ratios. (Note commands executed sequentially from left to right so enable mode n64 as final command after setting up all parameters)

This mode is also useful for moving to a position under computer command A200,300,400,500R etc and then panning around that position. Then moving to a new position, and panning around the new position.

Eg XY panning mode: /1ae,1,2,1,2am512,256,128,128n64,64,0,0R

Motors 1 and 2 are slaved to encoders 1 and 2 which can be on a joystick.

Note that any motion of the encoder to be followed is added/subtracted from the *current* position. So position ratios being a multiple of the encoder readback is only maintained if the axes are started from zero (z0,0,0,0) . Position commands (A,P,D) if issued subsequent to this mode starting will break the numerical ratio between the axes, but upon reaching a coordinate given by A,P,D the encoder following can be used to seamlessly pan around the new location. Physical position locations and readbacks /1?aA are maintained.

Encoder position correction mode (*n8*)

NOTE: This function requires firmware version 6.7 or higher.

Overview

Position correction mode moves the motor until the quadrature encoder count (not microsteps) correctly represents the commanded position. If the motor stalls during a move, the move will be re-attempted until the encoder reads the correct number. If the move cannot be completed, an error message is issued.

There are two main types of encoder feedback arrangement: the first is where the encoder is placed on the motor shaft. The second is where the encoder is placed on the component that is finally positioned, and may be only loosely coupled to the motor due to backlash, etc. The position correction mode will work with either feedback arrangement.

Functional description

In position correction mode, the EZStepper® determines a stalled or overload condition by checking to see if the encoder is tracking the commanded trajectory. If the encoder is not following the commanded trajectory within the error specified by *aC*, a stall is determined. The drive will automatically retry any stalled moves up to the number of times set by the *au* command. If the motor remains stalled, an overload condition is determined. The EZ4AXIS will NOT halt any strings or loops upon detection of a stall.

When an overload condition is detected, it is reported back as an upper or lower case "*I"* (Error 9). Status messages are explained in Appendix 4. This status can be used by an external computer to execute a recovery script (or alternatively, the drive can be configured to execute stored recovery scripts as described in "Auto recovery in position correction mode *(n512, n1024, n1536)*," page 66.)

The position correction mode utilizes a correction algorithm, which operates to bring the motors to within the deadband value set by the *aC* command. This algorithm runs continuously while the stepper motor is in motion and will detect a motor that is stalled or lagging by more than *aC* during a move. At that point the axis will stop and reissue the move starting from zero velocity so as to slowly spin up a motor that may have stalled at high speed. It is important to set the *aC* value to a reasonable minimum number (for example, *50,* the default value) or the drive will always be attempting to correct.

Subsequent disturbances greater than *aC* will result in the correction algorithm being engaged and busy status being asserted.

Commands for encoder position correction mode

n8 Enters position correction mode.

aE Sets encoder ratio, the ratio between encoder movement and stepper motor movement. Default is 1000. Range is 1000-10^6.

NOTE: If the encoder ratio (*aE* command) has been set, the units of the move and velocity commands change to microstep-equivalent encoder counts/second.

au (optional) Sets overload timeout, the number of times that a move will be retried in case of a stall before an overload error notification is sent. Default is 10. Range is 1-64999.

aC (optional) Sets position correction deadband, the distance (in encoder counts) that the stepper is allowed to be in error before position correction using encoder feedback is applied. Default is 50 encoder counts. Range is 1-64999.

?8 Reports encoder count on currently selected axis (1 or 2)

?a8 Reports encoder position (count) on both encoder-capable axes, Axis 1 and Axis 2, in comma-delimited format, e.g., 1000,2000 with Axis 1 followed by Axis 2.

NOTE: It is sometimes required to set hold current (the *h* command) at least equal to move current (the *m* command) so that there is no reduction in torque at the end of a move. Lower holding torque allows the detent torque to influence the position of the motor.

Setting Up encoder position correction mode

For this procedure, the encoder must be mounted in the position in which it will be used, and wired to the EZ4AXIS.

1. Make sure motor goes in the direction you intend

FIRST ensure /1P100R moves away from home in the direction you want to be positive. If not flip the connections to one phase of the motor. THEN confirm that the encoder count increases when the motor moves in the positive direction using the *?8* command, e.g., */1?8*. If not, switch either the AB lines from the encoder, which will reverse the count direction .

2. Calculate encoder ratio and set (*aE*)

Do this if the encoder is on the motor shaft, or if you know that the motor and encoder are coupled so that they turn at exactly the same speed. Otherwise skip to the next step, "Automatically compute encoder ratio and set (aE)."

NOTES

- If the encoder ratio is changed from its default of 1000, the allowed maximum position will be decreased from +2^31 by the same ratio as the change. The count will roll over from positive to negative range when this limit is exceeded.

- Once the encoder ratio has been set, the units of the move and velocity commands change from microsteps to microstep-equivalent encoder counts/second.

Procedure:

1. Move the motor to zero (starting) position. Typically this is the home position.
2. Calculate the encoder ratio:

   Encoder ratio = (motor microsteps per rev/quadrature encoder counts per rev) X 1000.

   For example, a motor with 200 steps/rev operating on the EZ4AXIS, which is always in the 1/16 microstep mode, would have 200 X 16 = 3200 microsteps/rev.

   A 400-line quadrature encoder would have 400 X 4 = 1600 encoder counts per rev.

   So, (3200/1600) X 1000 = 2000 for the encoder ratio, if the encoder is mounted on the motor shaft.
3. Issue the encoder ratio command *aE* with the calculated ratio, e.g., in the preceding example, */1aM2aE2000R* for Drive 1 Axis 2.

   NOTE: Preferably, the calculated ratio will be a whole number. If it is not, use the nearest whole number. Later, the *aC* value will need to be adjusted as discussed below.
4. Confirm the calculated encoder ratio by running the next step and comparing it with the automatically computed encoder ratio. Afterwards it will be necessary to re-enter the ratio using the *aE* command.

3. Automatically compute encoder ratio and set (*aE*)

Use this method when the encoder is not placed on the motor shaft and the movement ratio of the shaft to the encoder is unknown. Also use it to confirm an encoder ratio that you have calculated, as above.

NOTE: If the encoder ratio is changed from its default of 1000, the allowed maximum position will be decreased from +2^31 by the same ratio as the change. The count will roll over from positive to negative range when this limit is exceeded.

Procedure:

1. Issue the *n0* command to the axis. This clears any special modes, e.g., */1aM2n0R*.
2. Move the motor to zero (starting) position. Typically this is the home position.
3. Issue the *z0* command to the axis. This zeroes both the motor and the encoder positions.

4. Move the motor 100,000 microsteps by issuing the command *A100000* to the axis. Confirm that the move completes at a velocity that does not stall.
5. If the motor stalls, the velocity will probably need to be reduced using the *V* command. The current programmed velocity can be read by issuing *?2* to the axis.
6. Issue the command *?0* to the axis, which reads back the current position of the motor. If it has not stalled, the number will be 100000.
7. Issue the command *?8* to the axis, which reads back the encoder position (count).
8. Issue the command *aE0* to the axis, which divides these two numbers to arrive at the encoder ratio.
9. Issue the command *?aE* to the axis, which reads back the computed encoder ratio.
10. The value read back is not the precise ratio, but is a very close approximation with an error of a few counts. The actual ratio will be apparent to someone familiar with typical encoder ratios (for example, if the number is read back value is 2557, the actual ratio would be 2560). Use the actual ratio in the next step.
11. Or, if using this procedure to confirm a ratio calculated in the preceding instructions, compare readback with calculated value; they should be approximately the same.
12. Issue the command *aE* with the actual ratio to the axis, e.g., */1aM2aE2560R* from the example above. This overwrites the automatically computed ratio set with the *aE0* command.

NOTE: Overwriting is a crucial step in preventing accumulative error and "shuffling" that would result as the error was repeatedly corrected.

4. Optional: set correction deadband (*aC*)

This value represents the error in quadrature encoder counts allowed before a correction is issued. Default is 50.

- Recommend leaving at default unless operation requires changing. Refer to “Troubleshooting” on page 65 and the “Functional description,” above.
- If calculated ratio is not an even number, set *aC* to cover at least the difference between the calculated ratio and nearest full number.
- Example: */1aM2aC75R*

5. Optional: Set the Overload Timeout Value (*au*)

This is the number of retries allowed under a stall condition. Once this number is reached and the motor remains stalled, the motor is in an overload state. Default is 10.

Example: */1aM2au10000R*

6. Enable the position correction mode (*n8*)

1. Zero positions just prior to enabling position correction mode by issuing the *z0* command to the axis, with the motor in the zero position (typically home).

   Example: */1aM2z0R*

2. Enable position correction mode by issuing the *n8* command to the axis, e.g., */1aM2n8R*

   Example of full command string:

   /1aM2z0aC50h40m40au100aE2000L100n8R

   This command string starts the position correction mode on Axis 2 on Drive 1 and sets parameters discussed above including, in addition, hold current, move current, and acceleration (*h*, *m,* and *L*). (If you want to test moving the motor off position set h low)

   Remember that the motor should be moved to its zero position (typically the home position) before issuing the command string, because it includes the zero command (*z*).

To terminate position correction mode

To terminate, issue the following (Axis 2 used for example):

/1aM2n0R	Exits current mode.
/1T2	Terminates any commands in process on the axis (Axis 2).

Troubleshooting

- If motor consistently stops during a move:

  If a very fine line count encoder is used, such that for example, the encoder ratio is around 2000, or if the encoder is decoupled from the motor shaft, or if the encoder ratio is non integer, increase the error (*aC*) allowed, for example, set *aC* to *2000*. This way a move that is in progress will not be halted and restarted because the correction algorithm detects that the position error is too large.
- Typical reasons that the position error is too large:
  - *m* value (move current) set too low.
  - *L* value (acceleration) set too high for torque available from motor. Use *?L* to read back the current acceleration setting for the axis, e.g., */1?LR*.
  - *V* value (velocity) set too high for torque available from motor. Use *?aV* to read back the current velocity setting for all axes, e.g., */1?aV* (requires v7.50 and higher firmware). Results are displayed in order of axis numbers, e.g., 1000,50000,1000,10000 lists the velocity settings for axes 1 through 4 respectively.
  - Physical obstruction or excessive friction
  - Inadequate voltage from power source

Auto recovery in position correction mode (*n512*, *n1024*, *n1536*)

NOTE: This function requires firmware version 6.997 or higher.

Overview

In the Position Correction mode, an error message (upper or lower case *I* —Error 9) is issued if a stalled motor cannot be corrected within the number of retries set by the *au* command. This message indicates an overload status, and can be used by an external computer to execute a recovery script. For information regarding status messages, see "Appendix 4, Device Response Packet," page 90.

However, it may be desired that the drive recover by itself in the case of a stand-alone application. The *n512*, *n1024*, and *n1536* auto recovery modes allow the EZ4AXIS to execute stored recovery scripts when an overload is detected.

These scripts, provided by the user, are stored in EEPROM locations 13, 14, and/or 15. In addition, a last-resort script is stored in location 12.

Depending on which auto recovery mode is selected, the drive will execute stored program 13, 14, or 15 when an overload is detected. The number of times the recovery script can run is set by the *u* command (see below). If the selected recovery script cannot auto recover within the number of retries specified by the *u* command, program 12 is run.

An overload error on any motor, if position correction is enabled, will execute error recovery.

Commands

n512 Enters Auto Recovery mode and designates the program stored in location 13 as the recovery script.

n1024 Enters Auto Recovery mode and designates the program stored in location 14 as the recovery script.

n1536 Enters Auto Recovery mode and designates the program stored in location 15 as the recovery script.

When issuing the commands above, it is necessary to combine them with the position correction mode command *n8.* For example, *n512+n8 = n520*, *n1024 + n8 = n1032*, or *n1536 +n8 = n1544*. This includes position correction with auto recovery. Otherwise position correction will be disabled when auto recovery is enabled.

u Sets number of times the recovery script may run before executing the last-resort recovery script stored in location 12 , e.g., *u5* = 5 times.

Example: */1aM2u5n1032R*. This sets up auto recovery on Drive 1 Axis 2, using Program 14 for the initial recovery script (*n1032*, which combines *n1024* with *n8*) to run up to 5 times (*u5*).

The user will need to provide the recovery scripts and store them in program locations 13, 14, and/or 15, and 12.

Example (exercise)

(Axis 2 is used in the example command string):

1. Enter */1s13p1202R*. This stores an error recovery script in memory location 13 that simply sends the number 1202 to the bus, each time the recovery script is run.
2. Enter */1s12p1201R*. This stores a recovery script in memory location 12, which simply sends the number 1201 to the bus. This is the final "last resort" script.
3. Move the motor to its starting position (usually the home position).
4. Enter */1aM2m5h5z0aC50au5u3aE2000L100n520R*.

   This does the following:

   *m*5 and *h5* Sets move current and hold current low so the motor can be stalled easily.

   z0 Zeroes encoder and motor position counter with the *z0* command.

   aC50 Sets correction deadband at 50 encoder counts.

   au5 Sets retries allowed via encoder feedback to a maximum of 5.

   u3 Specifies that recovery script is run a maximum of three times.

   aE2000 Sets encoder ratio to 2000 (encoder ratio setup is described in "Calculate encoder ratio and set (aE)" on page 62.

   n520 Enters position correction mode and specifies that stored program 13 will be executed on overload error condition. *n* = 520 = *n8* + *n512*.
5. Now manually move the motor shaft so that the drive tries to correct five times and then gives up.

   After the fifth retry, the overload error will be issued and the drive will execute stored program 13 up to three times, sending the number 1202 to the bus each time. If the motor is manually held so that it remains stalled, the number 1202 will be sent 3 times followed by the number 1201 as the final recovery script, stored program 12, is run.

Troubleshooting

See "Troubleshooting" on page 65.

Encoder Overload Report mode (*n16*)

In position correction mode (*n8*), the drive will automatically correct any stalled moves up to the limit given by "*au*." Only then will it report Error 9, the overload error indication.

However, it may be desirable to detect a stall but not correct it. The Overload Report Mode does just this. The encoder value is continuously compared against the commanded position and Error 9 is set when these do not match to within the error band specified by the *aC* command (default 50 encoder counts). When this error occurs, the axis will exit from any loops or multiple command strings it may be executing.

This mode requires the encoder ratio to be entered correctly via the *aE* command. Enter encoder ratio and zero the encoder and motor position counter prior to issuing the *n16* command (see instructions below).

Overload Report mode commands

z0 Zero encoder and motor together. First move motor to zero position (typically home).

aE Encoder ratio. Set according to instructions in "Calculate encoder ratio and set (aE)" on page 62.

aC Specifies correction deadband. Default is 50.

n16 Enters overload report mode.

Example command string:

/1aM2z0aE2000n16R—This sets up Overload Report Mode on Axis 2 on Drive 1. Before issuing this command string, send the motor to the zero position (typically home).

Setting arbitrary measurement units via the *aE* command

It may be desired to use inches, for example, as measuring units in a particular setup that controls the depth of a drilling apparatus.

If the motor movement vs. drill depth is known, this information can be used to set the encoder ratio to a value that allows movement in units that reflect the desired precision, e.g., thousandths of an inch.

It is not necessary to use position correction mode or even have an encoder, in order to set the encoder ratio */1aE32000R* etc. Setting the encoder ratio thus allows positioning in any units of the user's choice.

Appendix 1. Addressing methods reference

Addressing individual drive cards

NOTE: The following addresses correspond to the settings of the address switches on the individual drive cards (Not to be confused with different axes on the same card).

Addressing drives 1-9

Use */1*, */2*, etc. with address switch on board set accordingly.

Addressing drives 10-16

Use the ASCII characters on a standard keyboard:

Bus address	Type this:	Set address switch to:
10	/: (colon)	A
11	/; (semi colon)	B
12	/< (less than)	C
13	/= (equals)	D
14	/> (greater than)	E
15	/? (question mark)	F
16	/@	0 (zero)

(So these addresses 1 to 16 map to hex 30 to hex 3F on the ASCII chart)

Addressing one axis (motor) within a single drive card

NOTE: If no axis is selected, any command issued is addressed to the default axis. Any multi-axis command will reset the default axis to Axis 1. Otherwise the default axis is the last axis addressed in a command.

NOTE: Use the *aM* command to address the axes, *aM1* through *aM4* for axes 1 through 4.

Select axis and issue command at the same time

Example: */1aM1A1000A0R* for Axis 1 (*aM1*)

Pre-select axis and send commands subsequently

Once the axis is selected, subsequent single-axis commands and queries are directed to that axis until another axis is selected or a multi-axis command is issued.

Example:

/1aM4R	Selects Axis 4, then:
/1A1000R	Moves Axis 4 to absolute position 1000
/1?0	Retrieves Axis 4 position
/1L10R	Sets Axis 4 acceleration

Addressing multiple axes on a drive card simultaneously

This function is available with multi-axis and interpolation commands. Please refer to "Send commands to multiple axes (multi-axis commands)" on page 16 and "Drawing circles and lines" on page 99 (Appendix 9).

Addressing banks of drive cards

Up to 16 drive cards can be addressed in banks of 2, 4, or “all,” increasing versatility and ease of programming. These are physically separate cards, not to be confused with different motors on the same drive.

Addressing banks of two drives

Drives 1 and 2	*/A*
Drives 3 and 4	*/C*
Drives 5 and 6	*/E*
Drives 7 and 8	*/G*
Drives 9 and 10	*/I*
Drives 11 and 12	*/K*
Drives 13 and 14	*/M*
Drives 15 and 16	*/O*

Addressing banks of four drives

Drives 1, 2, 3, and 4:	*/Q*	
Drives 5, 6, 7, and 8:	*/U*	
Drives 9, 10, 11, and 12:	*/Y*	
Drives 13, 14, 15 and 16:	*/]*	(close square bracket)

Addressing all drive cards at once

Use the global address /_ (underscore) to select all drives. To address all axes on the drives, insert the command four times separated by commas.

To select all drives on bus: /_

Appendix 2. Command set reference

Introduction

The following table lists the commands available for the EZ4AXIS at the time of publication. It indicates the command, possible operands, and brief descriptions with examples.

NOTE: The EZ4AXIS is always in 1/16th step mode, meaning that there are always 16 microsteps per step.

Command list

Table 1. Command Set

Command (case sensitive)	Operand/ (default)	Description
		AXIS SELECTION

`aM`	`1, 2, 3, or 4`
	`(1)`
		Designate target axis for command.
		/1aM1R selects Axis 1. From then on, all commands are sent to Axis 1.
		/1aM2R selects Axis 2, and so on.
		As part of a complete move command:
		e.g., */1aM2A1000R*. Move Axis 2 to absolute position 1000.

		POSITIONING
`A`	`0-2^31`	**Move motor to absolute position.** microsteps (or if in encoder feedback mode quadrature encoder counts, 32-bit positioning). E.g. */1aM3A10000R* (Axis 3 specified) Works in Multi Axis Mode E.g. /1A100,200,300,345R
`P`	`0-2^31`	**Move motor relative in positive direction.** microsteps (or if in encoder feedback mode quadrature encoder counts)E.g. */1aM2P10000R* (Axis 2 specified) A value of zero will cause an endless forward move at speed V. (i.e., enters into velocity mode) The velocity can then be changed on the fly by using the *V* command. Also /1P1000,2000,2000,1000R etc Endless moves can be terminated by issuing a *T* command or by a falling edge on the Switch 2 Input. See *T* command. Works in Multi Axis Mode E.g. /1P100,200,300,345R
`D`	`0-2^31`	**Move motor relative in negative direction.** microsteps (or if in encoder feedback mode quadrature encoder counts) E.g. */1aM2D10000R* (Axis 2 move) A value of zero for the operand will cause an endless backwards move at speed *V*. (i.e. enter into Velocity Mode). The velocity can then be changed on the fly by using the *V* command. Also /1D1000,,,300R moves just axes 1 and 4. Also /1D1000,200,200,100R etc. Endless moves can be terminated by issuing a */1T*

Command (case sensitive)	Operand/ (default)	Description
F	0 or 1	**Set direction of rotation considered positive to default or specified axis.** **Requires V7.60+ Firmware** E.g. */1F1R or /1aM2F1* with axis (Axis 2) specified /1F1,1,10R Only do this once on power up use, (do not use with encoder feedback). For feedback mode swap motor wires of just one phase.
r	NA	**Set current position to be same as encoder position.** E.g. */1aM2rR* (Axis 2 specified)
INTERPOLATION COMMANDS (Axes 1 and 2)		
aaA	0–90000	**Set diameter of circle. (circular interpolation)** Units are micro6steps.
aaI	0-1024	**Set beginning phase of circle (circular interpolation).** Units are such that 360 degrees = 1024.
aaW	1-20000	**Set speed at which circle is drawn (circular interpolation).** Units are microsteps/second.
aaC	1-1024	**Specifies how much of a circle is drawn and initiates circle drawing process (circular interpolation).** Units are such that 100% = 1024 = 360°. Note: *aaC2048* will draw two circles on top of one another.
an65536	NA	**Places axes 1 and 2 into linear interpolation mode.** This mode draws straight lines. Requires V7.50 or higher firmware. In this mode, the speed of the faster axis is slowed such that both axes arrive at the destination at the same time. This mode is active only with the *A* command. Issue commands as in multi-axis programming, while always omitting axes 3 and 4. E.g., */1an65536A1000,2000R*
HOMING		
f	0 or 1 (0)	**Set Home Flag and Limit polarity,(V7.60+ firmware)** Sets polarity of limits/home sensor. Each axis has own set of limit/home flags; these are on the 6-pin connectors. The polarity of each limit/home flag can be changed individually. E.g. */1aM3f1R* sets Axis 3 limit/home flag polarity to 1. 1=high (normally closed) 0=low (normally open) or use multi axis format /1f1,1,0,1R etc

Command (case sensitive)	Operand/ (default)	Description

`Z`
`(upper case)`
	`0-(2^31)`
	`(400)`
		Home/initialize motor.
		Initializes motor to known position. When issued, motor will turn toward 0 until the home sensor is interrupted. If already interrupted, motor will back out from interrupted position and come back in until re-interrupted. This sets motor position to zero.
		The value after the Z is the max number of microsteps allowed to be sent , within which the home sensor must be crossed. Else an error is declared.
		E.g. */1aM3Z300000R* (Axis 3 specified, 300000 microsteps allowed to find home)
		Works in multi-axis format in V7.60+ firmware. /1Z1000,1000,1000,1000R etc. Motors are homed in sequence 1,2,3,4 , any failure of any axis to find a home flag will abort the command and subsequent motors will not home.

`z`
`(lower case)`
	`--`	1. When used with encoder: *z0* zeroes motor and encoder at current position. zXXX sets current position to XXX. /1z2000R etc
		2. In voltage positioning (potentiometer positioning), voltage-velocity (joystick), and position correction modes: sets zero point to current motor position.
		E.g., */1aM2z0R* sets zero point to current motor position. Absolute positions are computed in reference to this point.
		Works in multi-axis format in V7.60+ firmware. /1z1000,6000,4000,3300R etc. sets all 4 motor positions to values specified.

`az`
`(lower case)`
	`--`	**1. Zeros or sets encoder only to value**
		E.g., */1aM2az0R* zeros or sets encoder count to this value. Also works in multi axis mode. /1z200,300,100,100R
		Issue in normal multi axis format but encoders 3 and 4 do not exist.

SET VELOCITY		

`V`	`1-59900`
	`(568)`
		Set max/slew speed (velocity) of default or selected motor. (positioning mode)
		Sets microsteps per second. Max V is 59900.
		NOTE: The EZ4AXIS is always in 1/16th step mode.
		E.g. */1aM2V10000R* sets max. velocity of Axis 2 motor. Or send /1V1000,1000,1000,1000R
		NOTE: If the encoder ratio (*aE* command) has been set, the units of velocity change to encoder counts/second.

Command (case sensitive)	Operand/ (default)	Description
v	0-900 (0)	**Set start velocity for selected motor.** Units are microsteps/second. **Note set v<V** Only or applications where it is desired to have motor accelerate suddenly from zero to a specific velocity. Else do not use, causes jerky motion. E.g. */1aM2v100R* sets start velocity of Axis 2 motor to 100. Works in multi-axis format in V7.60+ firmware. E.g. /1v100,100,200,300R etc.
c	0-900 (0)	**Set stop velocity for selected motor.** Units are microsteps/second. **Note set c<V** Only for applications where it is desired to have motor stop suddenly from a specified velocity rather than follow the more sloping deceleration curve. Else do not use, causes jerky motion. E.g. */1aM2c400R* sets stop velocity of Axis 2 motor to 400 microsteps/second. Works in multi-axis format in V7.60+ firmware. E,g, /1c100,100,200,300R etc
SET ACCELERATION		
L aL aaL	0-64999 (10)	**Set acceleration factor.** Acceleration factor = *L** (*V* in microsteps / sec^2) = (*L* value) x (100,000,000/65536). For example, if *V*=10000 and *L*=1, it will require 6.5536 seconds to reach final velocity. /1L100,1000,200,250R **NOTE:** Acceleration does not scale with encoder ratio. E.g., */1aM21L1200R* (Axis 2 specified) /1L100,100,300,55R (Multi Axis) In Firmware V7.06D1+ aL sets decel to be different from accel aaL sets decel when a limit is hit (n2 mode) note any change of L will reset aL and aaL to be same as L value, so set aL and aaL after setting L Multi Axis format available for aL and aaL in V7.65+
LOOPING AND BRANCHING		
g	NA	**Beginning of loop marker.** E.g. */1aM2gP10000M1000G10R.* (Axis 2 specified) This loop begins with the *P* command following the *g* marker. It continues until the *G* marker (described below).
G	0-30000	**End of loop marker and repeat designator.** G marks the end of a loop. The operand following the G specifies how many times to repeat the loop. A value of 0 causes the loop to repeat until terminated. (Requires *T* command to terminate). If no value is specified, 0 is assumed. E.g. */1aM2gP10000M1000G10R*. This loop repeats 10 times (shows Axis 2 specified). NOTE: Loops can be nested up to 4 levels. E.g. */1aM2gA1000A10000gA1000A10000G10G100R* is an example of a two-level nested loop.

Command (case sensitive)	Operand/ (default)	Description
`H`	`01-14`	**Halt current command string and wait until input or limit switch condition specified to resume operation. Resume causes the last command issued to be run** **NOTE:** The *H* command with no number after it waits for low on Switch 2 to resume operation. **Halt and wait for status of inputs:** *01* Wait for low on input 1 (Switch 1) *11* Wait for high on input 1 (Switch 1) *02* Wait for low on input 2 (Switch 2) *12* Wait for high on input 2 (Switch 2) *03* Wait for low on input 3 (Opto 1) *13* Wait for high on input 3 (Opto 1) *04* Wait for low on input 4 (Opto 2) *14* Wait for high on input 4 (Opto 2) E.g. */1gH02P10000G20R*. Waits for low on Switch 2 (loop). If halted, operation can also be resumed with the *R* command, e.g., */1R.* If an edge detect is desired, a look for low and a look for high can be placed adjacent to each other, e.g., *H01H11* is a rising edge detect. **Halt and wait for status of limit switches:** Operand is extended to three digits, the most significant digit being the I/O block/axis number. e.g., */1H101P100R* Halt and wait for low on Axis 1 Limit input 1 (lower limit). */1H211P100R* Halt and wait for high on Axis 2 Limit input 1 (lower limit). (16 possibilities for Halt)

Command (case sensitive)	Operand/ (default)	Description
`S`	`01-14`	**Skip next instruction depending on input or limit switch status.** **Skip on status of inputs:** *01* Skip next instruction if low on input 1 (Switch 1) *11* Skip next instruction if high on input 1 (Switch 1) *02* Skip next instruction if low on input 2 (Switch 2) *12* Skip next instruction if high on input 2 (Switch 2) *03* Skip next instruction if low on input 3 (Opto 1) *13* Skip next instruction if high on input 3 (Opto 1) *04* Skip next instruction if low on input 4 (Opto 2) *14* Skip next instruction if high on input 4 (Opto 2) Program branching to a complex subroutine can be implemented by making the next instruction a stored string execution. Loops can be escaped by branching to a stored string with no commands. E.g. */1gS02A10000A0G20R* - skips if low on Switch 2. **Skip on status of limit switches:** Operand is extended to three digits, the most significant digit being the I/O block/axis number. E.g., */1S101P100R* Skip for low on Axis 1 limit input 1. */1S211P100R* Skip for high on Axis 2 limit input 1. (16 possibilities for Skip)
PROGRAM STORAGE AND RECALL		
`e`	`0-15`	**Executes program stored in specified EEPROM location 0-15.** E.g. */1e1R* executes stored program 1 (the program stored in EEPROM location 1).
`s`	`0-15`	**Stores a program to specified EEPROM location 0-15.** E.g. */1s1A10000A0R* stores command string to location 1. This command takes approx 1 second to write to EEPROM. NOTES: 25 full commands max. per string, 256 characters. Program 0 is executed on power-up. If no command string is included, content of memory location is erased,
PROGRAM EXECUTION		
`R`	`NA`	**Run the command string that is currently in the execution buffer of the default or selected motor.** E.g. */1R* or */1aM2R* (Axis 2 specified) Can be used to resume operation after a halt (*H*) or termination (*T*). Resume causes the last command issued to be run.

Command (case sensitive)	Operand/ (default)	Description
SET MAX MOVE / HOLD CURRENT		

`h`	`0-50`
	`(10)`
		Sets hold current within a scale of 0 to 50% of max current.
		100% = 2A E.g. */1aM2h15R = 15%* (Axis 2 specified). Multi Axis format available in V7.65+ /1h10,15,19,9R

`m`	`0-100`
	`(25)`
		Set max move current within a scale of 0 to 100% of max current.
		100% = 2A E.g. */1aM2m40R = 40%* (Axis 2 specified) . Multi Axis format available in V7.65+ /1m19,12,13,9R

N MODE COMMANDS		

`N`	`1-3`
	`(1)`
		Initiates designated mode determined by operand.
		1 = Encoder with no index or no encoder (default). Homes to opto or switch.
		2 = Encoder with index. Homes to index.
		3 = Uses potentiometer as an encoder on specified axis.
		E.g., */1aM1N3*
		Applies to specific axis.

Command (case sensitive)	Operand/ (default)	Description
n MODE COMMANDS		
n	0-128000 (0)	**Background "n" modes** These mode bits enable functions that run in the background. Bit0 (LSB) - */1n1R* Not used in EZ4AXIS. Bit1 - */1aM1n2R* Enable limits on an axis-by-axis basis. Limits are enabled for Axis 1 in this example. The polarity of the limits is set by the *f* command. Bit2 - */1n4R* Not used in EZ4AXIS. Bit3 - */1n8R* enables Encoder Position Correction mode, with the two encoder (AB) inputs being used for feedback. Axes 1 and 2 only. (Requires firmware version 6.7 or higher.) Bit4 - */1n16R* Enables Encoder Overload Report mode. Axes 1 and 2 only. Bit5 - */1n32R* Not used in EZ4AXIS. Bit6 - */1n64R* Mode not implememnted Bit7 - */1n128R* Not used in EZ4AXIS. Bit8 - */1n256R* Not used in EZ4AXIS. Bit9 and Bit10 - These bits will execute one of the stored recovery script programs 13, 14 or 15 whenever the position correction feedback shuts down the drive due to an overload. (That is, the number of retries specified by the au command has been exhausted. See Position Correction Commands in this table.) Axes 1 and 2 only. Position Correction must run concurrently. (Requires firmware version 6.997 or higher.) */1n512R* will execute recovery program 13. */1n1024R* will execute recovery program 14. */1n1536R* will execute recovery program 15. Bit11 - */1n2048R* Reserved. Bit12 - */1n4096R* Reserved. Bit13 - */1n8192R* Enters Voltage Positioning mode for Axis 1 only. Uses potentiometer or other variable voltage input to command the position of the motor. Bit14 - Reserved Bit15 - Reserved Bit16 - */1n65536R* Enables joystick (voltage-velocity) mode, in which a potentiometer or other varying voltage between 0 and 3.3V can be used to control the velocity of Axis 1. Multi Axis format available in V7.65+ E.g. /1n65538,65538,65538,65538R (Example shows Joystick with limits enabled on all 4 axes, 65536 + 2)

Command (case sensitive)	Operand/ (default)	Description
an MODE COMMANDS		
an	**0** **16** **64** **65536**	**Background "an" modes** These mode bits enable functions that run in the background. *an0* – e.g., */1an0R.* an16 Coordinate mode or semi independent mode . See appendix 6 an64 encoder following mode. In this mode the encoder selected by the ae command is followed by the motor with a deadband of ad and a multiplier of am and encoder to follow set by ae *an65536* – e.g., */1an65536R.* When set, places Axes 1 and 2 into linear interpolation mode for drawing
POSITION CORRECTION COMMANDS		
aC	1-64999 (50)	**Set position correction value (deadband).** When in position correction mode, sets distance (in quadrature encoder counts) from commanded position allowed before the drive corrects using encoder feedback. E.g. */1aM2aC100R* (Axis 2 specified) Multi Axis format available in V7.65+
aE	1000-10^6 (1000)	**Set encoder ratio.** This sets the ratio between the encoder counts/rev and the microsteps/rev for the specified motor. E.g. */1aM2aE12500R* (Axis 2 specified) Encoder ratio = (motor microsteps per rev/quadrature encoder counts per rev) X 1000. (Note:NOT Multi Axis)
ae		**Assign encoder following.** Starting with version 7.61+ this command /1ae1,2,1,1R sets each of the axes to follow encoder 1 or 2 /1z0,0,0,0ae2,2,2,2am65536,65536,65536,65536 n64,64,64,64R
au	1-64999 (10)	**Set overload timeout.** This sets the number of times the move is retried in case a move stalls. E.g. */1aM2au10000R* (Axis 2 specified) When the *au* retries are exhausted, the drive will drop out of position correction mode (*n8*) and report Error 9 (overload). . (Note:NOT Multi Axis) Also see the auto recovery n mode commands *n512*, *n1024*, and *n1536R*.
u	1-64999 (0)	**Sets the number of times error recovery scripts 13, 14, or 15 are run prior to calling upon final recovery script 12.** (Requires firmware version V6.99 or higher.) Also see the auto recovery n mode commands *n512*, *n1024*, and *n1536R*. . (Note:NOT Multi Axis)

Command (case sensitive)	Operand/ (default)	Description
POWER DRIVER CONTROL AND LVTTL OUTPUTS		
J	0-3 (0)	**Turn driver On/Off** (Digits interpreted as 2-bit binary equivalent expression.) 3=11= Both drivers on, 2=10=Driver 2 on Driver 1 Off, etc. e.g., */1J1* (Driver 1 ON) NOTE: If total current input to the board exceeds 2A, it will be necessary to change the input fuse to up to 4A. NOTE: Sufficient time must be allowed between solenoid turn-on and turn-off to allow the solenoid to respond. A delay may be inserted if needed, with the *M* (wait) command. Starting with firmware version 7.60D1, one extra output is available on Pin 85 of the 100-pin SQFP part, which can be jumpered typically to an unused INPUT pin, and can be addressed J0-7 (extension of above J command to an extra 3rd bit) . Caution Max 3.3V; use 332Ω series resistor for some added protection. /1gJ0M10J7M10G100R
k (lower case)	65000,65000	**Extra LVTTL Output** Starting with firmware version 7.61 Pin 5 of the 100 Pin SQFP part will output a LVTTL signal on this pin . This signal can be wired to an unused INPUT pin and then can act as an extra output. Use a series resistor of say 332 Ohm so as to provide some protection against miswires/static. The numbers set ON,OFF time in increments of 50uS e.g., */1k10,10R* creates a 1KHz square wave /1k0,0 turns the output solid low .
POTENTIOMETER POSITION COMMANDS		
These commands apply to the Potentiometer Positioning mode (*n8192*).		
ad	0-16368 (50)	**Sets a deadband (in microsteps) around the potentiometer value used for the last move.** This deadband must be exceeded before a new move command is issued. The deadband is defined in terms of the reading from the potentiometer after A/D conversion, a number ranging from 0–16368 which represents 0–3.3V. E.g. */1aM2ad100R* (Axis 2 specified) Multi Axis format available in V7.65+
am	0-20000 (256)	**Set A/D multiplier.** The potentiometer output value is multiplied by this value and divided by 256 to get the preliminary commanded position. E.g. */1aM2am512R* (Axis 2 specified). Multi Axis format available in V7.65+
ao	0-20000 (0)	**Specify positioning offset.** After multiplication by the *am* value, this offset is added to obtain the final commanded position. E.g. */1aM2ao1228R* (Axis 2 specified) Multi Axis format available in V7.65+

Command (case sensitive)	Operand/ (default)	Description
MISCELLANEOUS COMMANDS		
aP	0-30000 (5)	**Response delay** (Available in V6.79+) Units are milliseconds. This command sets the delay from the drive receiving the command to the response being sent out. E.g. */1aP1000R* sets the delay to 1000 milliseconds.
ap	0-15	**Inverts polarity of inputs on 8-pin connector as seen by *?4*, *S*, and *H* commands.** (Available in firmware version 7.60G4+) Example: */1ap3R* will invert the polarity of inputs 1 and 2. Value is decimal number seen as combination of 4 binary bits.
b	9600 19200 38400 to 230400 (9600)	**Adjust baud rate** E.g. */1b19200R* This command will usually be stored as program zero and executes on power-up. Default baud rate is 9600. *Do not store in program zero until reliable operation is ensured by issuing command without storing it.* NOTE: correct termination and strict daisy chaining required for reliable operation at higher baud rates.
K	0-64999 (0)	**Set backlash compensation.** Units are number of steps. For when a non-zero value of K is specified, the drive will always approach the final position from a direction going more negative. If going more positive, the drive will overshoot by an amount K and then go back. By always approaching from the same direction, the positioning will be more repeatable. Multi Axis format available in V7.65+
M	0-29999	**Wait for specified period.** Units are milliseconds.
p **(lower case)**	0-64999	**Ping Command** Sends a numeric message back to the host, when that point in the command string is reached. E.g. */1aM2gA1000p3333A0G0R* (Axis 2 specified). Will send the number 3333 every time through the loop. Example: /0@3333ÿ/0@3333ÿ/0@3333 *No Error* **Note:** Care must be taken when using this command because it can tie up the 485 bus.

Command (case sensitive)	Operand/ (default)	Description
IMMEDIATE QUERIES / COMMANDS		
The following are “Immediate” queries and commands, which can execute while other commands are running, allowing on-the-fly programming. • These commands cannot be cascaded in strings or stored. • These commands must each be sent individually, and separate from axis selection commands. (Note axis selection must be issued separately **prior** to query /1aM2R<CR> then /1?2<CR> etc) – (<CR> means hit “enter” on the keyboard which sends ASCII CR LF to the drive. • These commands do not require an “R” at the end. • In firmware version 7.02 and above, it is possible to query *some* parameters by using the same letter that set the parameter. E.g., */1?A* returns current position; /1?2 returns slew speed and */1?V* returns instantaneous velocity of a moving motor. • Some other commands may be executed as immediate commands.		
`$`		**Reports the command string currently executing, or most recently executed on drive.** E.g., */1$* Example response: *P1000P1200P1300P1400 No Error* **Note:** The $ command may not be able to read very long command strings. On older firmware, attempting to read very long command strings may kill board operation. If this happens, power cycle the board.
`&`		**Reports the current firmware revision number and date.** E.g., */1&* Example response: *EZController AllMotion V7.50h5 12-18-12 No Error*

`?0`
`(?zero)`
		Reports the current commanded position for last commanded axis.
		E.g. */1aM2R* */1?0* (e.g., for Axis 2)
		Example response: *10000 No Error*

`?aA`		**Reports positions of all four motors (requires V7.50 or higher firmware).** E.g., */1?aA* Example response (Axes 1 through 4 in order): *102000,35000,35000,5000 No Error*
`?aV`		**Reports programmed velocities of all four motors (requires V7.50 or higher firmware).** E.g., */1?aV* Example response: *568,568,568,568 No Error*
`?1`		**Reports start speed for default or selected motor.** E.g., */1aM2R* */1?1* (Axis 2 specified)
`?2`		**Reports the current Slew/Max speed for Position mode for default or selected motor.** E.g., */1aM2R* */1?2* (Axis 2 specified)
`?3`		**Reports stop speed for default or selected motor set with the *c* command.** E.g., */1aM2R* */1?3* (Axis 2 specified)

Command (case sensitive)	Operand/ (default)	Description
`?4`		**Digital Input Query. Reports the high/low status of all four Digital/Analog IO inputs** /1?4 reads the 8 Pin I/O connector 0-15 represents a 4-bit binary pattern: Bit 0 = Switch1 (input 1) Bit 1 = Switch 2 (Input 2) Bit 2 = Opto 1 (input 3) Bit 3 = Opto 2 (Input 4) Example: 11 = all high except input 3 (bit 2)
`?5`		**Reports the current velocity mode speed for selected axis.** E.g., */1aM2R /1?5* (Axis 2 specified)
`?8`		**Reports encoder position for currently selected motor.** *E.g., /1aM1R /1?8* (Motor/encoder 1 specified) */1aM2R /1?8* (Motor/encoder 2 specified) Example response: *1000*
`?a8`		**Reports encoder position for all motors.** V7.60+ Firmware */1?a8*
`?10`		**Reports encoder 2 position.** *E.g., /1?10* Example response: *250* (depends on encoder count for current position.)
`?aa`		**Reports analog values on all four inputs on 8 Pin Digital/Analog IO connector.** E.g. */1?aa* Example response: *16368,15,16368,16368 No Error* Readback order is inputs 4,3,2,1 These numbers represent the voltage range 0-3.3V available at each input, as expressed by a number from 00000-16368.

`?aa1`
`?aa2`
`?aa3`
`?aa4`
	`1-4`	**Reports analog value of limit/home inputs on designated axis. (Six pin limit connectros)**
		/1?aa1 reads back Axis 1 Limits
		/1?aa2 reads back Axis 2 Limits
		/1?aa3 reads back Axis 3 Limits
		/1?aa4 reads back Axis 4 Limits
		Example response: 15648,526 No Error
		Readback order is Upper Limit, Lower Limit/Home.
		These numbers represent the voltage range 0-3.3V available at each input, as expressed by a number from 00000-16384.

Command (case sensitive)	Operand/ (default)	Description
?aat		**Reports thresholds for all four axes on Limit/Home connections.** Requires firmware version 7.50 or higher. E.g. */1?aat* Readback order is 12, 11, 22, 21, 32, 31, 42, 41, where 21, for example, indicates Axis 2 input 1. Input 1 is Lower Limit and Home, and Input 2 is Upper Limit. Example response: *6144,6144,6144,6144,6144,6144,6144,6144 No Error* The response 6144 is 1.24V as expressed by a number from 00000-16368, which represents the 0-3.3V range available at each input.
?at		**Reports the thresholds for all four inputs on 8 pin Digital/Analog IO connector**. E.g. */1?at* The readback order is inputs 4, 3, 2, 1. Example response: 6144,6144,6144,6144 No Error The response 6144 is 1.24V as expressed by a number from 00000-16368, which represents the 0-3.3V range available at each input.
?aE		**Reports encoder ratio for default or selected axis.** e.g., */1aM2R /1?aE* (with Axis 2 specified. Only Axes 1 and 2 accommodate encoders.)
?h		**Reports hold current** For currently selected motor with last issued /1aM2R<CR> then /1?h<CR> etc
?m		**Reports move current** For currently selected motor with last issued /1aM2R<CR> then /1?m<CR> etc
?L ?aL		**?L Reports acceleration for default or selected axis.** e.g., */1aM2R<CR> then /1?L<CR>* **?aL Reports acceleration for all 4 axes** e.g., */1?aL<CR>*
?2 ?V		**/1?2 Reports programmed velocity (slew rate) for default or selected axis. /1?V reports instantaneous velocity** e.g., */1aM2R<CR> then /1?V* (Axis 2 specified)
?aC		**?aL Reports auto correction value for encoder feedback mode for all 4 axes** e.g., */1?aC<CR>*

Command (case sensitive)	Operand/ (default)	Description
Q		**Reports current status of EZ4AXIS board (drive).** E.g., */1Q* Reports the Ready/Busy status as well as any error conditions in the status byte of the return string. The return string consists of the start character (/), the master address (0) and the status byte. Bit 5 of the status byte is set when the drive is ready to accept commands. It is cleared when the drive is busy, ie any axis is moving. The least significant four bits of the status byte contain the completion code. List of codes: 0 = No Error 1 = Initialization error 2 = Bad Command 3 = Operand out of range Errors in opcode will be returned immediately, while Errors in operand range will be returned only when the next command is issued. See Appendix 4, Device Response Packet, page 90.
?aQ		Sends busy status of All 4 motors as 0 = not running , 1 = running (Firmware V7.65) /1?aQ<CR> returns 0,1,1,0 etc
General Immediate Query Syntax		In firmware version 7.02 and above it is possible to query *some* parameters by using the same letter that set the parameter. E.g. */1?A* reports current position; /1?aA reports all 4 motor positions.
T		**Terminate current command or loop for an axis.** /1T terminates all loops and commands. */1T1* = terminate Axis 1 */1T3* = terminate Axis 3 */1T2* = terminate Axis 2 */1T4* = terminate Axis 4 NOTE: Do not use /1T2, /1T3 etc. to terminate a loop since the behavior is undefined and may change in the future.

Command (case sensitive)	Operand/ (default)	Description
Other Immediate Commands		The following other commands may be issued as immediate (on-the-fly): A L D J V P These commands can be sent while the motors are moving and will change the motion “on the fly”. Typically issue in multi axis format to affect any motor. Eg /1P1000,,1000,R will change target position of axes 1 and 3 while moving. Eg issue /1A10000,10000,10000,10000R then while running issue /1A,,-10000,R reverses motor 3 while moving. Note that these commands must be issued one at a time. Ie no multi command strings. If drive is running a sequence of commands in a loop then this command will affect the currently running command instantly, and then the loop will continue, but with cganged velocity etc in case that was changed. By using multi axis on the fly commands any motor can be started at any time, further by using /1T1 /1T2 etc and motor can be stopped at any time.

<table>
<tr><th colspan="3">ANALOG INPUT (ADC) COMMANDS</th></tr>
<tr><td colspan="3">The Analog/Digital IO and Limit/Home inputs are all ADC.</td></tr>
<tr><td>at</td><td>100000 to 116368
200000 to 216368
300000 to 316368
400000 to 416368
(6144)</td><td><b>Sets thresholds for “one” and “zero” on Digital/Analog IO connector and the four Limit/Home connectors.</b>
<b>Setting IO Connector thresholds</b>
The number consists of the input number followed by a 5-digit number ranging from 00000-16368, which represents the threshold on a scale from 0-3.3V. The default value is 6144 (1.24V) for all four inputs.
Note: threshold value= (threshold voltage/3.3) x 16368
Changing the threshold allows the H (Halt) and S (Skip) commands to work on a variable analog input value which essentially allows the program to act upon an analog level. This can be used, for example, to regulate pressure to a given level by turning a motor on/off at a given voltage.
E.g. <i>/1at106144R</i> sets the threshold of input 1 to 6144. Note that leading zeros are required for the threshold value, which is always 5 digits plus the channel number.
IO connector thresholds can be read back with the <i>?at</i> command. See the <i>?at</i> command for details.
<b>Setting Limit/Home Connector thresholds</b>
Simply add the axis number and a specific limit to the beginning of the command described above. For example, to set Axis 4 upper limit to 10000, issue <i>/1at4210000R</i> (note seven numerical digits). The numeral 4 specifies Axis 4, and the numeral 2 specifies the upper limit.
Note that on the Limit/Home connectors, Input 1 is the lower limit/home input, and Input 2 is the upper limit.
NOTE: in prior firmware versions, all thresholds were simultaneously programmed when input 4 on the 8-pin IO connector was set using the /at4XXXXXR command.
Limit/Home thresholds can be read back with the <i>?aat</i> command. See the <i>?aat</i> command for details.</td></tr>
<tr><td colspan="3"><b>RESPONSE PACKET</b>
<b>See Appendix 4, Device Response Packet</b></td></tr>
</table>

Appendix 3. Step loss detection using opto

For some applications that operate without encoder feedback, it may be necessary to detect loss of steps due to the mechanism stalling for any reason.

Step loss is easily detected by following these steps:

1. Home the stepper to the opto using the *Z* Command.
2. Move out of the flag a little by issuing, for example, an *A100* command.
3. Figure out the exact step on which the flag gets cut by issuing *D1* commands followed by *?4* commands to read back the opto. Let's call this value Y. (This only needs to be done once during initial set-up).
4. Execute the move sequence for which step loss detection is needed.
5. Issue a command to go back to absolute position Y+1.
6. Check the opto; it should not be cut (read opto back with the *?4* command).
7. Now issue a command to go to position Y-1.
8. Check the opto; it should be cut (read opto back with the *?4* command). If the opto was not at the state expected, steps may have been lost.

Step loss detection can also be done by looking for changes on the other inputs.

Appendix 4. Device response packet

Introduction

EZSteppers® and EZServos® respond to commands by sending messages addressed to the “Master Device.” The master device (which is typically a PC) is always assumed to have address zero (0). The master device should parse the communications on the bus continuously for responses starting with */0*. (It should NOT, for example, look for the next character coming back after issuing a command, because glitches on the bus when the bus reverses direction can sometimes be interpreted as characters.)

Response packet structure

After */0,* next comes the “Status Character” which consists of 8 bits:

Bit7	Reserved
Bit6	Always set
Bit5	Ready bit. Set when the EZStepper® or EZServo® is ready to accept a command.
Bit4	Reserved

Bits 3 through 0. These form an error code N from 0-15:

N	Function
0	No Error
1	Init Error
2	Bad Command (illegal command was sent)
3	Bad Operand (Out of range operand value)
4	N/A
5	Communications Error (Internal communications error)
6	N/A
7	Not Initialized (Controller was not initialized before attempting a move)
8	N/A
9	Overload Error (Physical system could not keep up with commanded position)
10	N/A
11	Move Not Allowed
12	N/A
13	N/A
14	N/A
15	Command overflow (unit was already executing a command when another command was received)

Note that in the RS485 bus, devices must respond right away, after the master sends a command, before the success or failure of the execution of the command is known. For this reason, some error messages that come back are for the previous command. An example of this is “failure to find home.”

Example initialization error response

Note that the upper nibble typically only takes on values of 4 or 6 (Hex).

An initialization error response has 1 in the lower nibble. So the response is 41 Hex or 61 Hex which corresponds to ASCII character upper case “A” or lower case “a,” depending on whether or not the device is busy.

Example invalid command response

Note that the upper nibble typically only takes on values of 4 or 6 (Hex)

An invalid command response has 2 in the lower nibble. So the response is 42 Hex or 62 Hex, which corresponds to ASCII character upper case “B” or lower case “b,” depending on whether or not the device is busy.

Example operand out of range response

Note that the upper nibble typically only takes on values of 4 or 6 (Hex).

An operand out of range response has 3 in the lower nibble. So the response is 43 Hex or 63 Hex, which corresponds to ASCII character upper case “C” or lower case “c,” depending on whether or not the device is busy.

Example overload error response

Note that the upper nibble typically only takes on values of 4 or 6 (Hex).

An overload error response has 7 in the lower nibble. So the response is 47 Hex or 67 Hex, which corresponds to ASCII character upper case “I” or lower case “i,” depending on whether or not the device is busy.

Example response to command “/1?4”

FFh: RS485 line turn around character. It is transmitted at the beginning of a message.

2Fh: ASCII “/” Start character. The DT (Data Terminal) protocol uses the ‘/’ for this.

30h: ASCII “0” This is the address of the recipient for the message.

In this case ASCII zero (30h) represents the master controller.

60h: This is the status character (as explained above).

31h: These two bytes are the actual answer in ASCII.

This is an eleven which represents the status of the four inputs.

The inputs form a four-bit value. The weighting of the bits is:

Bit 0 = Switch 1

Bit 1 = Switch 2

Bit 2 = Opto 1

Bit 3 = Opto 2

03h: This is the ETX, or end-of-text character. It is located at the end of the answer string.

0Dh: This is the carriage return.

0Ah: This is the line feed.

Appendix 5. Microstepping primer

First consider a full stepping driver.

A stepper motor moves by having two windings that are orthogonal to each other and sequencing the current in these windings.

When full stepping, a typical sequence is:

- A+ (Only winding A current applied in positive direction)
- B+ (Only winding B current applied in positive direction)
- A- (Only winding A current applied in negative direction)
- B- (Only winding B current applied in negative direction)

(A full electrical cycle consists of four steps.)

It can be seen that if the windings are not physically placed orthogonally, the four steps may not be of equal size, and the difference in motion will be a constant only if the number of steps is divisible by four, even when in full step mode.

Now consider microstepping:

Microstepping is achieved by placing two sinusoidally varying currents that are 90 degrees apart in the windings of the stepper. This causes a torque vector of equal length to rotate, causing smooth inter-step motion of the rotor.

However, in order to get even motion in every step it is necessary:

- That the windings be mechanically orthogonal
- That the windings produce equal torques for equal currents
- That there is no other “detent torque” acting upon the rotor in the absence of current. (This detent torque is easily felt by rotating the stepper with windings disconnected and not shorted. A motor that is good for microstepping will feel smooth when rotated by hand—somewhat like a DC motor—with little tendency to detent.)
- That the current not be so small that the driver cannot regulate it to the microstepping accuracy desired

In general, most inexpensive stepper motors cannot microstep with accuracy. Typically, a motor designed especially for microstepping must be run at a significant current in order to get even microsteps. When accuracy is required, the move current must generally be set equal to the hold current. This is because if the current is reduced at the end of the move, the motor will fall back into a detent position.

Appendix 6. Stepper motor electrical specification

The EZStepper® will work with most stepper motors. However, the performance achieved will be a function of the motor used.

A stepper motor moves by generating a rotating magnetic field, which is followed by a rotor. This magnetic field is produced by placing a sine wave and a cosine wave on two coils that are spaced 90 degrees apart. The torque is proportional to the magnetic field, and thus to the current in the windings.

As the motor spins faster, the current in the windings needs to be changed faster in a sinusoidal fashion. However the inductance of the motor will begin to limit the ability to change the current. This is the main limitation on how fast a motor can spin.

Each winding of the motor can be modeled as an inductor in series with a resistor. If a step in voltage is applied, the current will rise with time constant L/R. If L is in Henrys and R is in ohms, then L/R is the time it takes in seconds for the current to reach 63% of its final value. (NOTE: there is also the back EMF of the motor, which essentially subtracts from the applied voltage.)

The current *I* for a step function of voltage *V* into a coil is given by:

I = (V/R) (1-^(tR/L))

This equation is a standard response of a first-order system to a step input. The final value of current is seen to be V/R. (This system is similar to a spring (L) in parallel with a damper (R) being acted upon by a step in force (V) giving a resulting velocity (I).)

Maximizing speed at which current can be changed

There are two methods by which the current can be made to change faster:

1. Reduce the inductance of the motor.

2. Increase the forcing function voltage V.

For (1) it is seen that for high performance, a motor with low inductance is desired.

For (2) the trick is to use a motor which is rated at about ¼ of the supply voltage (V). This minimizes the time it takes to ramp the current to a given value. (Once the current reaches the desired value, the “chopper” type drive used in the EZSteppers® will “chop” the input voltage in order to maintain the current—so the current never actually gets to the final value of V/R, but the advantage of “heading towards” a higher current with the same time constant is that the current gets to any given value faster.) In addition, using a lower voltage motor results in less back EMF, and does not subtract as much from the applied voltage.

So, for example, for a 24V supply, use a motor rated at around 6V, and then use the *m* and *h* commands to set the current regulation at or below the rating for the motor. The default values on power-up are *h*=10% and *m*=25%, and should be safe for most motors.

EZ4AXIS operation

The EZ4AXIS will drive at 1A per phase when *m*=50 (peak of sinusoidal drive move current waveform) with no restrictions.

However, at 2A per phase (peak of sine wave) when *m*=100, the drive can only be operated at about 25% move time with rests in between at a low hold current. Typically the move is limited because of thermal considerations to a maximum of approximately one minute continuous.

Maximizing power to motors on EZ4AXIS

In order to exploit the full capability of the EZ4AXIS, the motors must be of a low resistance (less than 5Ω or so) and the supply voltage—as mentioned above—should be about 4X the motor voltage. So use a 6V motor with a 24V supply. This is necessary not only for the reasons described above, but also because the maximum input current from the power supply is restricted to 4A. So input power is about 30V x 4A = 120W. The drive will step down the voltage and step up the current, much like a switching supply. So when using 6V motors, a total of 120W/6V= 20A is available to drive the eight phases of the four motors. Thus it is possible to get two amps per phase on four motors with the input current being only four amps at 24V or 30V. It is not possible, likewise, to run four 24Ω coil resistance motors at 1A because this would require a total of 8A input current at 24V, so motor selection is critical for optimizing the capability of the drive.

See also Appendix 7, “Heat Dissipation (EZStepper® products with motor drives)” beginning on page 96.

AllMotion® provides a heat sink for this drive. Please see stepper accessories on the AllMotion® website: http://www.allmotion.com/stepperaccessories.htm

Summary

Motor/supply voltage requirements are affected by inductance, resistance, and back emf. In order to obtain maximum current rise and available power, the following are recommended:

- Use motors with low inductance and resistance (5Ω or less).
- Use motors with low voltage rating (e.g., 6V).
- Use power supply at 4X motor voltage (e.g., with 6V motors use a 24V supply).
- Set move and hold current values using *h* and *m* commands if change from default is needed.

Appendix 7. Heat dissipation (EZStepper® products with motor drives)

Overview

Most stepper applications require intermittent moving of the motor. In the EZStepper®, the current is increased to the move current, the move is performed, and the current is then reduced to the hold current (automatically). The dissipation in the drive is proportional to the current flowing in the drive, and therefore the dissipation occurs primarily during the move.

When the drive generates heat, the heat first warms the circuit board and heat fin (ordered separately if needed)

Only then does the heat transfer to the surroundings. For intermittent moves that are less than one minute in duration, the drive primarily cools using this thermal inertia of the board and heat fin, and not by steady state dissipation to the surrounding ambient.

Running at high current/duty cycle

The electronics for EZSteppers® are fully capable of running at the rated voltage and current. However, due to the small size of the boards, which limits the steady state heat transfer to the ambient, care must be taken when the drive is used in high duty cycle and/or high current applications. For conservative operation, it is recommended that the duty cycle be reduced linearly, from 100% duty at 50% of rated current, to 25% duty at 100% of rated current. (Duty cycle means the percentage of the time that the drive is moving the load, averaged over 5 minutes). Conservatively, the maximum continuous run at 100% current is about one minute. An on-board thermal cutout typically trips after about two minutes at 100% current. (This cutout is self-resetting when the drive cools). Of course, at 50% of current, the drive will run continuously with no time limit.

Most “intermittent move” applications will NOT require derating of the drive.

Typically if using the motor at high current and high duty cycle (move time), please purchase the additional heat sink.

In addition, if running high current on two motors, select non-adjacent channels (1 and 3, for example) to distribute the heat load within the board.

EZSteppers® are designed with parts rated at 85° C or better. This means the PCB copper temperature must remain below 85° C. The ambient air temperature allowed depends on the airflow conditions.

MTBF is 20,000 hr. at 85° C PCB copper temperature, and doubles for every 10° C under 85° C.

Appendix 8. OEM Protocol with checksum

Introduction

The protocol described in the majority of this manual is DT (Data Terminal). There is, however, a more robust protocol known as OEM that includes checksums. AllMotion, Inc. drives work transparently under both protocols, and switch between the protocols depending on the start transmission character detected.

The OEM protocol uses 02 hex (Ctrl B) as the start character, and 03 Hex (Ctrl C) as the stop character. The 02 Hex start character is equivalent to the / character in DT protocol.

OEM Protocol example 1

/1A12345R in DT protocol is equivalent to

(CtrlB)11A12345R(Ctrl C)# in OEM protocol.

Name	**Typed**	**Hex**
Start Character	*Ctrl B*	02
Address	*1*	31
Sequence	*1*	31
Command	*A*	41
Operand	*1*	31
Operand	*2*	32
Operand	*3*	33
Operand	*4*	34
Operand	*5*	35
Run	*R*	52
End Character	*Ctrl C*	03
Checksum	#	23

The checksum is the binary 8-bit XOR of every character typed, including the start and end characters. (The sequence character should be kept at 1 when experimenting for the first time.) Note that there is no need to issue a carriage return in OEM protocol.

OEM Protocol example 2

/1gA1000M500A0M500G10R in DT protocol is equivalent to *(CtrlB)11gA1000M500A0M500G10R(CtrlC)C* in OEM protocol.

The C at the end is Hex 43, which is the checksum (binary XOR of all preceding bytes).

Sequence Character:

The Sequence Character comes into effect if a response to a command is not received from the drive. In this instance the same command can be resent with bit 3 (repeat bit) of the sequence byte set, and bits 0-2 representing the sequence number.

When the repeat bit is set consecutive commands received by the drive must have a different sequence number in order to get executed. Only the sequence number is looked at—not the command itself—in determining whether the command should be executed. So, if the drive has already seen this command sequence (the value in bits 0-2), it will not execute it again, but will acknowledge (again) that the command was received.

This covers both possibilities that (a) the drive didn’t receive the command, and (b) the drive received the command but the response was not received.

The sequence number can take the following values:

- 31-37 without the repeat bit set
- 39-3F with the repeat bit set

(The upper nibble of the sequence byte is always 3.)

Appendix 9. Linear and circular interpolation

Drawing circles and lines

The EZ4AXIS is capable of coordinated motion among axes. Interpolation commands directly coordinate the motion of multiple axes for specific tasks, and are available for drawing circles and straight lines.

Overview

Interpolation commands control Axes 1 and 2 simultaneously. To implement interpolation commands, Axes 1 and 2 drive an X-Y type mechanism such as shown here:

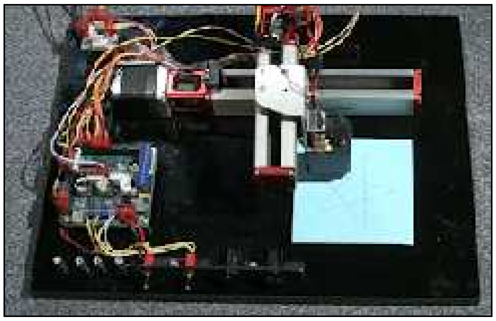


Figure 7 X-Y Mechanism for Interpolation Commands

You can see this mechanism in action in the demo video located at http://www.allmotion.com/Flash_Video_Pages/Example_Videos/demos_examples_4AXIS_Linear_flash.html

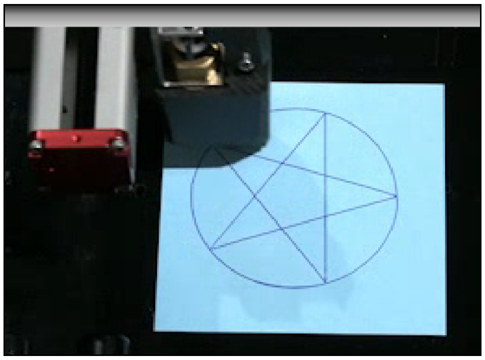


Figure 8 Circular and Linear Interpolation

Circular interpolation

There are four commands associated with circular interpolation:

aaA Sets the diameter of the circle in microsteps (0 – 90000 microsteps)

aaI Sets beginning phase of the circle (0-1024) (degrees/360*1024)

aaW Sets the speed at which the circle is drawn in microsteps/second (1-20000). Note: speed needs to be lower for larger diameter circles.

aaC Sets arc (how much of a circle is drawn) and initiates the circle drawing process (1-1024) (degrees/360*1024). Note: *aaC2048* will draw two circles on top of one another.

The following figure illustrates how the commands define the circle.

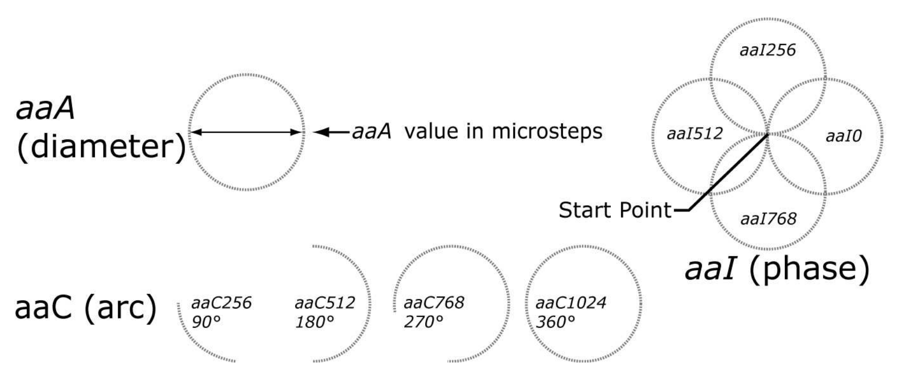


Figure 9 Circular Interpolation Command Effects

To draw a circle, issue a command such as:

/1aM1A40070,35200aaW1000aaI0aaA14000aaC256R

This results in an arc, or part of a circle, that is drawn at a speed of 1000 microsteps/second (*aaW1000*), begins at 0° (*aaI0*), has a diameter of 14000 microsteps (*aaA14000*), and spans an arc of 90° (*aaC256*).

NOTES

- Place commands in the order shown above.
- Do not add commands for axes 3 and 4 when issuing circular interpolation command strings.
- Do not include circular interpolation commands with other commands in the same string.
- Issue the *aaC* command last, since it initiates the circle drawing process.

Linear interpolation

Overview

NOTE: This function requires v.7.50 or higher firmware.

There are two commands associated with linear interpolation:

an65536 Enable linear interpolation. The *an* command uses weighted bit values just as the *n* mode commands do.

an0 Exit linear interpolation mode.

Once linear interpolation has been enabled, use the multi-axis *A* command (move to absolute position), for example:

A1000,2000R (e.g., */1an65536 A1000,2000R*)

This will cause Axis 1 to move to position 1000, and Axis 2 to move to position 2000. The two moves are tied together so that the pen driven by the two axes moves in a straight line. This is also demonstrated in the video referred to above.

To move to multiple interpolated positions, use the A command for each interpolated position. For example, notice *A3500,6000* in this command string:

/1an65536 A1000,2000,A3500,6000R

NOTE: You may issue a multi-axis command addressed to all four axes while the linear interpolation mode is on. In such a case Axes 1 and 2 will move in interpolation fashion, while Axes 3 and 4 will move normally.

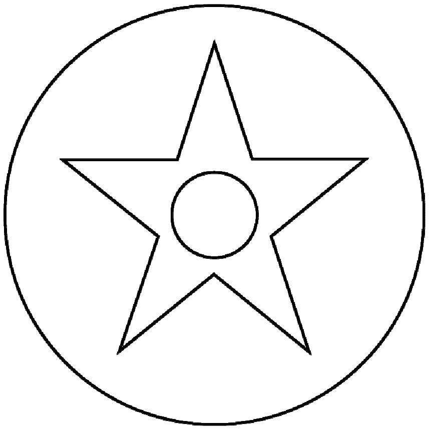
Exiting linear interpolation mode

To exit linear interpolation mode, enter the command *an0* following the move commands, e.g., */1an65536 A1000,2000,A3500,6000an0R* or */1an0R*.

Circle and star example

Introduction

This example describes how an EZ4AXIS was programmed to draw a composite star-circle pattern utilizing a dual-axis stepper motor mechanism equipped with ink pen actuated by a solenoid. Here is the example pattern:



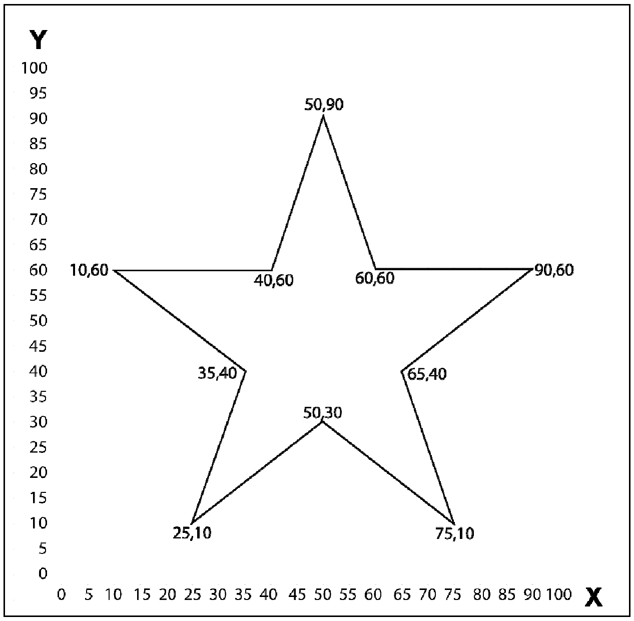
This pattern was implemented by five command strings, each stored in a different memory location in the on-board EEPROM:

- Startup instructions, which set basic operating parameters and begins the sequence when a high appears at Switches 1 and 2. (Memory location 0, which runs automatically at power-up.)
- Draw star pattern utilizing linear interpolation. (Memory location 4)
- Return both axes home. (Memory location 7)
- Draw small circle pattern utilizing circular interpolation, and return both axes home. (Memory location 5)
- Draw large circle pattern utilizing circular interpolation, return both axes home, and then execute the string in memory location zero (startup instructions). (Memory location 6)

  At this point the equipment is ready to draw the pattern again when a high appears at Switches 1 and 2.

The star pattern

The following illustration shows the X-Y coordinates for points on the star in a grid with a scale of 0-100. The X coordinate is written first, then Y. Zero (0) represents the home positions of the two axes.



The coordinates are the starting and stopping points for the pen.

The X-Y numbers are translated proportionally into microsteps according to the desired size of the star. This star was intended to fit into a space of 64000 microsteps, comfortably below the 70000 microstep range of the fixture in use.

So each of the coordinates in a pair becomes a percentage of the 64000 microstep range (coordinate/100*64000 = coordinate in microsteps).

A 3200 microstep offset was then added to each of the coordinates to place the star pattern well out of the way of the home positions of the two axes.

For example, the coordinate 60 would be 60/100*64000+3200=41600.

Command string for star pattern (location 4)

The coordinate pairs in the diagram above are shown in **bold**.

_/1s4aM1V12000aM2V12000_***A60800,35200***_an65536J3_***A41600,28800,A41600,9600,A28800,25600,A9600,19200,A22400,35200,A9600,51200,A28800,44800,A41600,60800,A41600,41600,A60800,35200***_J0an0e7R_

Breakdown:

/1 Select Drive 1.

s4 Store the following commands in memory location 4.

aM1V12000aM2V12000 Set velocities of Axes 1 and 2 to 12000 microsteps/second.

A60800,35200 Move Axes 1 and 2 to absolute positions comprising the starting point for drawing the star.

an65536 Enter the linear interpolation mode.

J3 Turn ON/OFF drivers on, engaging the pen solenoid.

A41600 . . . 35200 Execute moves sequentially to absolute position defined by each coordinate pair (e.g., *A41600,28800*) using the absolute move command (*A*).

J0 Turn ON/OFF drivers off, releasing the pen solenoid.

an0 Exit the linear interpolation mode.

e7 Execute string 7 (the program in memory location 7), the homing command string. Note that this is stored in a separate location from the star pattern to avoid exceeding the capacity of the memory location.

R Run the command string.

Command string for homing after drawing star pattern (location 7)

/1s7aM1V30000f1Z200000aM2V30000f1Z200000e5R

Breakdown:

/1 Select Drive 1.

s7 Store the following commands in memory location 7.

aM1V30000f1Z200000 On Axis 1, set velocity (*V*) to 30000 microsteps/second; set polarity of home flag to normally open (*f1*); and go home (*Z*), allowing 200000 microsteps to reach home.

aM2V30000f1Z200000 Same as above for Axis 2.

e5 Execute the contents of memory location 5 (the small circle pattern).

R Run the command string.

Circle patterns

- The circles are both aligned with the center of the star on the Y axis.
- The radius is the distance, in microsteps, from the center of the star to the desired circumference. Multiplied by two, this is the diameter used in the command string.
- The remaining commands are described on a previous page.
- The circle command string should have commands placed in the order shown and include a command to home both axes. A velocity command is included, noting that the velocity must be lower for successfully drawing larger circles.

Command string for smaller circle (location 5)

/1s5aM1V8000aM2V8000aM1A40070,35200J3aaW1000aaI256
aaA14000aaC1024J0aM1V30000f1Z200000aM2V30000f1Z200000e6R

Breakdown:

/1 Select Drive 1.

s5 Store the following commands in memory location 5.

aM1V8000aM2V8000 Set velocities of Axes 1 and 2 to 8000 microsteps/second.

aM1 Select Axis 1.

A40070,35200 Move Axes 1 and 2 to absolute positions comprising the starting point for drawing the circle.

J3 Turn ON/OFF drivers on, engaging the pen solenoid.

aaW1000 Set speed of drawing to 1000 microsteps/second.

aaI256 Set beginning phase of circle to 90 degrees.

aaA14000 Set diameter of circle to 14000 microsteps.

aaC1024 Draw a full 360 degree circle. This command also starts the circular interpolation mode.

J0 Turn ON/OFF drivers off, releasing the pen solenoid.

aM1V30000f1Z200000 On Axis 1, set velocity (*V*) to 30000 microsteps/second; set polarity of home flag to normally open (*f1*); and go home (*Z*), allowing 200000 microsteps to reach home.

aM2V30000f1Z200000 Same as above for Axis 2.

e6 Execute the contents of memory location 6 (larger circle pattern).

R Run the command string.

Command string for larger circle (location 6)

```
/1s6aM1V12000aM2V12000aM1A33070,67200J3aaW1000aaI0
aaA64000aaC1024J0aM1V30000f1Z200000aM2V30000f1Z200000e0R
```

Breakdown:

/1 Select Drive 1.

s6 Store the following commands in memory location 6.

aM1V12000aM2V12000 Set Axes 1 and 2 velocities to 12000 microsteps/second.

aM1 Select Axis 1.

A33070,67200 Move Axes 1 and 2 to absolute positions comprising the starting point for drawing the circle.

J3 Turn ON/OFF drivers on, engaging the pen solenoid.

aaW1000 Set speed of drawing to 1000 microsteps/second.

aaI0 Set beginning phase of circle to 0 degrees.

aaA64000 Set diameter of circle to 64000 microsteps.

aaC1024 Draw a full 360-degree circle. This command also starts the circular interpolation mode.

J0 Turn ON/OFF drivers off, releasing the pen solenoid.

aM1V30000f1Z200000 On Axis 1, set velocity (*V*) to 30000 microsteps/second; set polarity of home flag to normally open (*f1*); and go home (*Z*), allowing 200000 microsteps to reach home.

aM2V30000f1Z200000 Same as above for Axis 2.

e0 Execute command string stored in memory location 0 (startup command string).

R Run the command string.

Command string for startup (location 0)

This is the command string designed to execute at power-up, since it is stored in memory location 0.

/1s0aM1m30L10V5000f1Z200000aM2m30L10V5000f1Z200000H01H02 M100e4R

Breakdown:

/1 Select Drive 1.

s0 Store the following in memory location 0.

aM1 Select Axis 1.

m30 Set move current to 30% of max (2A).

L10 Set acceleration factor to 10.

V5000 Set velocity (*V*) to 5000 microsteps/second.

f1 Set polarity of home flag to normally open (*f1*).

Z200000 Go home (*Z*), allowing 200,000 microsteps to reach home.

aM2m30L10V5000f1Z200000 Same as above for Axis 2.

H01 Halt and wait for 0 on Switch 1.

H02 Halt and wait for 0 on Switch 2.

M100 Wait 100 milliseconds.

e4 Execute the contents of memory location 4 (the star pattern).

R Run the command string.

Appendix 10. Position Based Trigger Outputs

Starting with Version 7.61+ Trigger outputs based on motor position has been implemented.

The command structure is as follows

/1aJ1,4321,13,10R

The First of the commands has 4 parameters and sets up the trigger table.

Parameter 1: can be 1 or 2 depending on output desired to be computed

Parameter 2: is a position value at which point to trigger the output.

Parameter 3:

Motor 1 software computed position – 1

Motor 2 software computed position – 2

Motor 3 software computed position – 3

Motor 4 software computed position – 4

Encoder count 1

Encoder count 2

Parameter 4: is a duration in increments of 200uS

So in the above command output1 will be triggered on when the position 4321 is crossed (going lower or higher), on the encoder assigned to motor #3, the output will turn on for a duration of 2mS (=200uS x 10).

Note that the encoder is assigned to the motor by the (lower case) “ae” command, described else where in this document.

Further trigger points can be added by using the aJ command with single parameters IMMEDIATELY following the above aJ command with 4 parameters.

Eg: /1aJ1,4321,13,10R

/1aJ550aJ2000aJ5000aJ7000aJ9000aJ22aJ531R etc

Note that each output can only be assigned to one motor. This is done by the 4 parameter long command . It is not possible to mix and match within a single table.

To setup triggers for output 2 use aJ2

Eg: /1aJ**2**,4321,13,10R

/1aJ550aJ2000aJ5000aJ7000aJ9000aJ22aJ531R etc

To read back the trigger table

Issue /1?aJ1 or /1?aJ2

To exit positions triggering the output issue :

/1aJ1,,0R

/1aJ2,,0R

Or issue a normal output control J command eg /1J1R