User Guide

Instructions for EZQuadServo

Manual revision 1.78
May 2018

Preliminary Release

Important Notices

Life and Safety Policy

Without written authorization from the AllMotion company President, AllMotion, Inc. products are not authorized for use as critical components in life support systems, for surgical implant into the body, or other applications intended to support or sustain life or any other applications whereby a failure of the AllMotion, Inc. product could create a situation where personal injury, death or damage to persons, systems, data or business may occur.

AllMotion, Inc.
30097 Ahern Avenue
Union City, CA 94587
USA

Tel: 408.460.1345
Fax: 408.358.4781

Technical Support: 408.460.1345
Sales: 510.471.4000

Website: www.allmotion.com

Table of Contents – page numbers approximate

1. Quick Guide

This EZQUAD SERVO 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** encoder counts. 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 EZQUAD SERVO using the Quick Start guide and the wiring diagram from links at the bottom of this web page:
http://www.allmotion.com/Servo_Pages/EZQUADServoDescription.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 for the drive. If a *new* com port does not appear *and disappears*, then install the windows/mac drivers manually.

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. Ensure correct phasing of hall sensors and encoder per Appendix 6
2. Using the EZCommander windows App, issue the command */1&*. The drive should respond with its firmware version.
3. With the power off plug in Motor #1. Turn on power, issue the command */1P1000R*. The drive should move forward 1000 encoder counts. If the drive spins out of control and then shuts off, this is because of positive feedback, switch the encoder AB lines to fix.
4. Turn off power and plug in up to four motors.
5. Issue the command

   /1aM2P1000R. Motor 2 should move.

   /1aM3P1000R Motor 3 should move.
6. Issue the command

   */1P1000,*1000*,1000,1000,1000R*

   All 4 motors should spin
7. Issue the command

   */1P1000,*1000*,,1000R*

   Motors 1, 2, and 4 will spin.
8. */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 73.

2. Introduction

About this manual

This document describes how to program and operate the EZServo® EZQUAD SERVO (Brushless/Brush Controller + Driver).

These sections are included:

- **Basic Programming Operations**. (Starting page 9) This describes how to set up basic motor moves, first on one axis and then multiple axes.
- **Advanced Programming Operations.** (Starting page TBD **Error! Bookmark not defined.**) 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 70) 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 EZServo® communicates over the RS485 EZ bus at 9600 baud, 1 stop bit, no parity, no flow control.

Obtain needed documentation

Obtain the following for the EZQUAD SERVO via links at the bottom of this web page:
http://www.allmotion.com/Servo_Pages/EZQUADServoDescription.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 servo 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 EZServo® command language

Features

This EZQUAD SERVO 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** encoder counts. 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 EZServo® that a command is coming in.

1 Device address. This is the number set on the rotary mechanical Address switch on the Drive. .

P1000 Command. Move 1000 encoder counts 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.

3. Basic Programming Operations

This section describes how to enter basic commands to the EZQUAD SERVO. A complete listing of commands is contained in Table 1 on page 73.

First Things

Make sure system is connected and operating

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

TBD Use this doc for now (which is for a product with identical motor wiring).

http://www.allmotion.com/New PDF's/SV17_23/EZSV17_23 EZ Start.pdf

Basic move commands to Axis 1

These are the basic move commands:

P Move motor to relative position in positive direction (encoder counts).

D Move motor to relative position in negative direction (encoder counts).

A Move motor to absolute position in encoder counts.

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 encoder counts 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 encoder counts 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 encoder counts 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 encoder counts. 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 Axis1 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 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

For example:

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

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

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. These are the multi-axis commands:

L	Set acceleration . eg /1L100,200,300,400R
V	Set velocity .
h	Set constant torque mode current .
m	Set move current .
P	Move forward to relative.
D	Move backward to relative.
A	Move to absolute position.
u	Set overload timeout in mS.
Z	*Homes all axes in sequence 1,2,3,4 – TBD has problems if one axis fails to home in beta version - do individual homing for now /1aM1Z10000R etc*

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

When issuing a multi-axis command, the axis positions are delimited by commas, beginning with Axis 1 on the left and ending with Axis 4 on the right, as shown in the following examples.

Send a move command to all four axes

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

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

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

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. For example, */1P1000,-500,1000,-500R* would move Axes 1 and 3 1000 encoder counts positive, and Axes 2 and 4 500 encoder counts 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 29.
- 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 30.)

Send a move command to just two axes

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

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

Result: Axes 1 and 3 move 1000 encoder counts in the positive direction. Axes 2 and 4 do not move. The commas marking the positions of Axes 2 and 4 are retained.

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*

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 encoder counts / 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.

Single Axis Example: */1aM1L100R*

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

m Maximum move current: This sets the current level when the motor is moving or stationary holding position. 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 = 5A for EZQUAD SERVO).

Single Axis Example: */1aM4m30R*

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

h Torque Mode: This sets the current in the motor and thus commands Torque, since Torque is proportional to Current. This current is expressed as a percentage of the maximum output drive current for the device (h50 = 2.5A for EZQUAD SERVO). (50% is max allowed for hold current)

Single Axis Example: */1aM3h20R*

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

In this mode the motor will not hold position or look at the encoder for feedback.It will push with a constant force and will accelearate at a constant rate if the shaft is not held. It will stop accelerating and settele at a constant speed only when the resisting force (like friction) becomes equal to the generated torque, or when the back emf = supply voltage (whichever occurs first as it speeds up)

Store and recall programs

Overview

Command strings for later recall can be stored in the EEPROM on the EZQUAD SERVO 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.

Send this command: */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.

Send this command: */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.

Send this command string: */1s0A0P10000R*

Result: The command *P10000* is stored in EEPROM location 0. Cycling the power will cause *P10000* to be executed and the drive to go forward 10000 encoder counts 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 encoder counts on power-up.

  NOTE: There is no relationship between the "String" numbers on the EZCommander Windows app and the storage locations in the EEPROM. The storage location is set by the number defined by the lower-case *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

Send this command string: */1aM2gP1000M500D1000M500G10R*

Command breakdown:

/	Start character. Tells the EZServos® 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 encoder counts in the positive direction.
M500	Wait for 500 milliseconds.
D1000	Move 1000 encoder counts 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.)

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

Send these command strings:

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

1aM1gP1000M1000S102e1GR—loop of motion and wait.

Result: With input 2 high on the channel1 I/O connector the loop executes normally. When input 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.

Send these command strings:

1aM1gP1000M1000S102G0R—loop of motion and wait.

Result: With input 2 high on the channel 1 I/O connector the loop executes normally. When input 2 is brought low the program skips the *G* command and stops.

This mode also works for the following strings

1aM1gP1000M1000S102G0A10000R

where *A10000* executed upon input 2 low or even

1aM1ggP1000M1000S102G5A0GR

where the inner loop is exited upon input 2 low.

5. Halt a loop pending level change.

Send these command strings:

1aM1gH102A1000A0GR

Where loop only runs when input 2 low.

1aM1gH02H112A1000A0GR

Where loop runs once for every low/high transition of input 2 of channel1

NOTE: More complex loops are described in Section **Error! Reference source not found.**, "**Error! Reference source not found.**."

6. Use limits to move smoothly until sensor cut

Send these command strings:

1gaM1n2P0n0P1500gaM2P1000aM1P1000G8aM1P25000GR

Say motor 1 is a conveyor belt that moves a microtiter plate until its under a syringe moved by motor 2. Use a sensor wired to the high limit of motor 1, the P0 moves until the microtiterplate is under the syringe then stops, no limits are turned off, the plate moves forward 1500 until plate e well is under syringe, plate is filled with aM2P1000 eight times. Plate is kicked out with P25000 and cycle repeats

Terminate a program during execution

To terminate any command or string or loop running immediately, 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.

Controlling Power Drivers (solenoid drivers)

The EZ4AXIS17XR has 16 power drivers for actuating solenoids or any device requiring a relatively large current. While each driver is capable of switching in excess of 1A the total current to the board is limited by the current capability of power connector which is 3 max.

Hookup

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

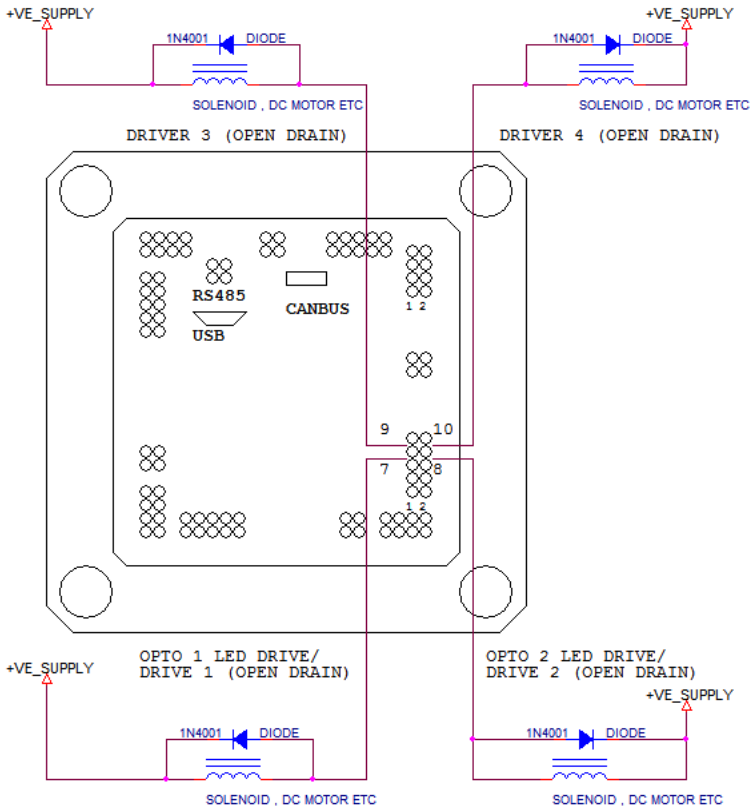


Figure 1 Power Driver Hookups

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

Programming

- To actuate a driver, issue the *J* command:

  Digits following the *J* command are interpreted as 4-bit binary equivalents: 1111 binary = 15 decimal = all drivers on

/1gJ15,15,15,15J0,0,0,0GR will toggle all outputs on and off

/1gJ1,0,0,0J0,0,0,0GR will toggle output 1 on axis 1 on and off

Note that Drive 1 and 2 have a 200 Ohm resistor to the 5V supply on the board, (for driving the optos) . These resistors will interfere with the operation of the output if a +VE supply greater than 5V is used for driving these loads. Please contact the factory for instructions on removing the resistor.

Bitwise On/Off (not implemented yet)

- The legacy J command described above requires shadow registers to be maintained by the user software because the command changes all outputs.

  The aJ and aaJ command address this problem by allowing bitwise set and reset of the outputs.

- The aJ command clears a particular output bit without affecting any other output bit.

  /1aJ1,0,0,0R will turn off Driver 1 on Axis1

  /1aJ0,0,0,4R will turn off Driver 3 on Axis4

- The aaJ command sets a particular output bit without affecting aany other output.

  /1aaJ1,0,0,0R will turn on Driver 1 on Axis1

  /1aaJ0,8,0,0R will turn on Driver 4 on Axis2

PWM of On/Off Ouput (not implemented yet)

- The aK command allows the outputs to be turned on and off at multiples of 10Khz intervals.

  aK Axis, Output, HiTime, LowTime Where the Times are in increments of 100uS increments.

  /1aK1,3,1,1 creates a 100uS On, 100uS Off (5Khz) PWM on axis1 channel 3

Essential Setup Information

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.
- 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.
- Correct termination and strict daisy-chaining is required for reliable operation at the higher baud rates.

Readback of parameters from the drive:

Reading Firmware Version

Issue */1&*

Example: */1&* reads the firmware version on Drive 1.

Reading Motor Positions

To read the commanded position of the currently selected motor, use the */1?0* command, or use /1?8 to retrieve encoder position.

Example: */1aM4R* then issue */1?0* 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 currently commanded position of all four motors simultaneously.

/1?a8 reads back the position of all four encoders simultaneously, ie actual position.

Similarly use:

/1?2 – reads back the max allowed velocity of one motor

/1?V, */1?aV – TBD*

/1? L, */1?aL* – TBD

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 encoder counts, and Axis 2 negative 10000 encoder counts.

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 encoder counts, and Axis 3 positive 10000 encoder counts.

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 EZQUAD SERVO to default motor sequencing any time it is issued. Refer also to “Linear Interpolation” on page 99.

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 EZQUAD SERVO.

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

m Move current

n Select various modes

J Turn power output drivers on/off (typically used for solenoids)

J COMMAND NOT IMPLEMENTED IN BETA

The Immediate commands are also listed and described in Table 1, Command Set, which begins on page 73.

Analog and Digital Inputs

The EZQUAD SERVO has sixteen analog values which can be read back as analog values. Eight of these are parameters of the channel such as current, and the remaining eight of these are routed to the I/O connector as 2 per connector.

Read back digital IO input values on the 10 Pin I/O Connector (*/1?41 /1?42 /1?43 /1?44* command)

?41 reads back the digital values associated with 10 pin I/O connector on channel 1 in order UpperLimit, Home,ADC2,ADC1 where the ADC is considered high or low depending on the threshold set by the "at" command (see "at" command below).

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

Bit 0 = ADC1 (Switch 1) Bit 1 = ADC2 (Switch 2)
Bit 2 = Home (Opto 1) Bit 3 = UpperLimit (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 *?aa1* command)

The *?aa1* command reads back the two analog ADC values on the **10 Pin** IO connector and the two ADC's measuring motor currents and other internal parameters on the drive. inputs in this order 4, 3, 2, 1, which are input 4 (From Drive), input 3 (From Drive), ADC 2, and ADC1 respectively. The intenal drive parameters are as yet undefined, and subject to change and should not be used by the end user. Analog inputs 3 and 4 are unrelated to the digital inputs 3 and 4 .

Example: */1?aa* 1

Response: *8767,6544,6943,10720 No Error*. These are the values of inputs 4, 3, 2, and 1 respectively, expressed by a number from 0-65535 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

Programmable Threshold on Analog Readback (the *at* command)

at Adjust thresholds at which a high or a low is called, for the /?41 comand, on the two analog inputs on the 10 Pin I/O connector..

Thresholds are expressed as five-digit numbers in a range from 00000-65535, which linearly represents the 0-3.3V input. The default threshold value is 24200 (1.22V).

Example: */1at3209999R.* This sets the threshold on Axis 3 ADC2 to 09999 (0.5 volts). Key components:

at Threshold command

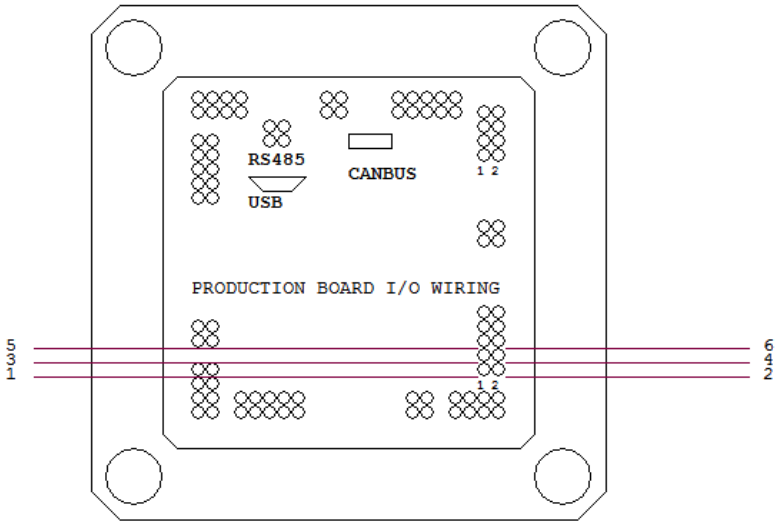
32 Axis/input identifier, in this case Axis 3 and Limit Input 2 (upper limit). The full range is 11,12,21,22,31, 32,41,42.

09999 Threshold value, 00000–65536, representing 0–3.3V. (Threshold value = (desired threshold voltage/3.3) x 65535.)

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.

?aat Read thresholds of all ADCs on the four 10 pin I/O connectors on the drive. The order of readback (in terms of the axis/input identifiers explained above) is

LEFT END Axis1ADC2, Axis1ADC1, Axis2ADC2, Axis2ADC1, Axi3ADC2, Axis3ADC1, Axis4ADC2, Axis4ADC1. *RIGHT END*
Example readback:
6144,6144,6144,6144,9999,6144,6144,6144 No Error



5 GND 6 GND
3 OPTO 1/HOME/LOWER LIMIT/DIGITAL IN 2^2 4 OPTO 2/UPPER LIMIT/DIGITAL IN 2^3
1 SWITCH 1 IN/DIGITAL 2^0/ ANALOG CH1 2 SWITCH 2 IN/DIGITAL 2^1/ ANALOG CH2

Figure 2 EZQUAD SERVO 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 three-digit operand, The operands specify which input and what polarity the axis will wait for after halting.

- Three-digit operands apply to the inputs on the 10-pin I/O connectors. The most significant digit is axis, second digit is polarity (high or low), and the third digit is limit 1 or 2:

  101 wait for low on Axis 1 ADC1
  111 wait for high on Axis 1 ADC1
  102 wait for low on Axis 1 ADC2
  112 wait for high on Axis 1 ADC2
  103 wait for low on Axis 1 limit 1 (lower)
  113 wait for high on Axis 1 limit 1 (lower)
  104 wait for low on Axis 1 limit 2 (upper)
  114 wait for high on Axis 1 limit 2 (upper)

  201 wait for low on Axis 1 ADC1
  211 wait for high on Axis 1 ADC1
  202 wait for low on Axis 1 ADC2
  212 wait for high on Axis 1 ADC2
  203 wait for low on Axis 1 limit 1 (lower)
  213 wait for high on Axis 1 limit 1 (lower)
  204 wait for low on Axis 1 limit 2 (upper)
  214 wait for high on Axis 1 limit 2 (upper)

  301 wait for low on Axis 1 ADC1
  311 wait for high on Axis 1 ADC1
  302 wait for low on Axis 1 ADC2
  312 wait for high on Axis 1 ADC2
  303 wait for low on Axis 1 limit 1 (lower)
  313 wait for high on Axis 1 limit 1 (lower)
  304 wait for low on Axis 1 limit 2 (upper)
  314 wait for high on Axis 1 limit 2 (upper)

401 wait for low on Axis 1 ADC1

411 wait for high on Axis 1 ADC1

402 wait for low on Axis 1 ADC2

412 wait for high on Axis 1 ADC2

403 wait for low on Axis 1 limit 1 (lower)

413 wait for high on Axis 1 limit 1 (lower)

404 wait for low on Axis 1 limit 2 (upper)

414 wait for high on Axis 1 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 encoder counts.

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

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

NOTE: Issue /1T to Terminate

Skip and Branch on IO or limits (the *S* and *e* commands)

You can program the EZQUAD SERVO 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 0-63. For example, *e2* means run the string residing in location 2. Note that e2 is a GOTO, not a GOSUB.

Example

The following example stores two command strings in EEPROM locations 0 and 1, and 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:

/1aM2gA1000A10000gA1000A2000G10G100R

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.
A2000	Go to absolute position 2000.
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 EZQUAD SERVO 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 stops during a move, 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 encoder counts / sec^2) = (L value) x (Needs Number). For example, if V=10000 and L=1, it will require (Needs number) seconds to reach final velocity.
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 5A for the EZQUAD SERVO. Standard setting is *m50* (50% of 5A).

For example, if a motor doesn't move, Decreasing *V* or *L* may be needed. Move current (m) may also need to be increased or supply voltage may need to be increased. Note that "m" is non linear at the low end of current below 25%.

Note that if currents below 25% are desired it is better to change the current sense resistor on the drive which will change the full scale range from say 0-5A to 0-2A for m=0 to100. The current sense resistor is the 2512 size resistor on the bottom side near each of the mounting holes. This is normally 0.04 Ohms . Changing this to 0.1 Ohms for example will change the max current to 2Amps (Max current is reached when 0.2V is present across this resistor).

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 EZServos® 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 small "*g*."
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 encoder counts 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 encoder counts 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 encoder counts 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: Using 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 encoder counts 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 pre-selected 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 encoder counts positive. The /A command addresses a bank defined as Drive cards 1 and 2. (Banks are described in Appendix 1, Addressing Methods Reference.)

4. 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. */1am1n2R* 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.

Status of limits are read back by the */1?41 , /1?42, /1?43* and */1?44* command.

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 10-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. Note Home input wiring pinout is different for production and prototype boards – prototype boards were sold before 7/7/2017..

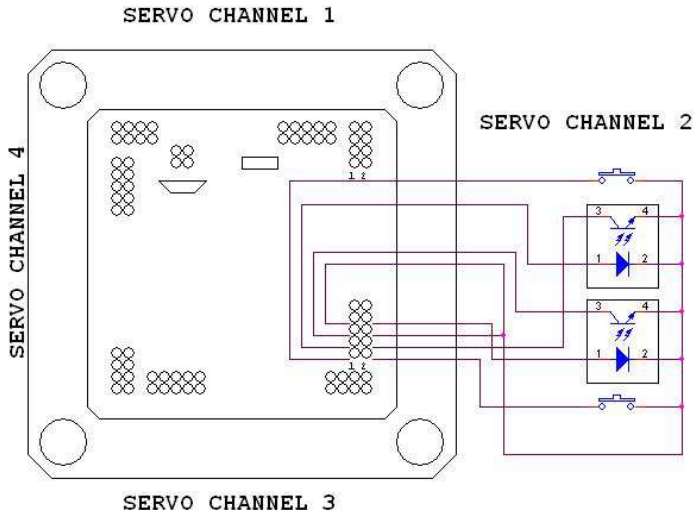


Figure 3 Limit Connections prototype designs

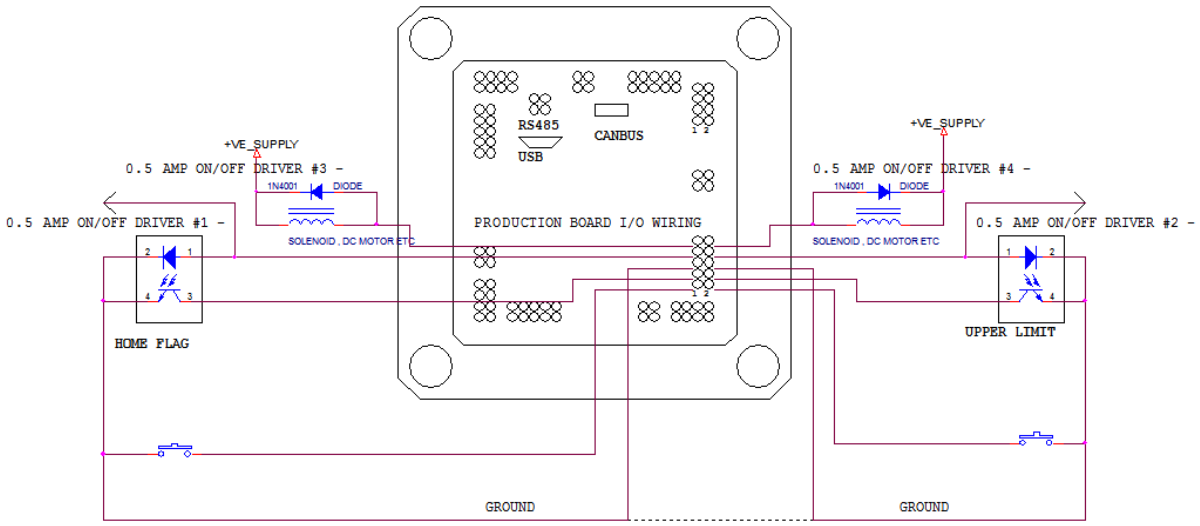


Figure 3 Limit Connections final design

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., */1n2,2,2,2R*. Enables limit mode on all 4 axes
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:

   The default condition expects the limit switch to be low when away from the limit (as is typical 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, */1f1,0,1,1R* selects different polarities for the limits of Axes 1 and 2. So *f1* = normally open, and *f0* = normally closed.

5. Issue move commands and confirm that the motor stops when it reaches the limit or limits that have been set up. For example with nothing plugged into the limit connectors issue: */1f1,1,1,1n2,2,2,2gA1000,1000,1000,1000A0,0,0,0GR* . All motors should spin back and forth, grounding any limit will stop that motor.

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

Commands for limits:

n2 Makes limits active on a per-axis basis, e.g., */1n0,0,2,0R* 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 it will stop motion in case the limit switch gets disconnected.

5. Emergency Stop / Kill Move

Overview

This command not implemented in preliminary release

6. Digital IO (switch-controlled) applications

The EZQUAD SERVO 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 10-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 0 to 3.3V – analog level signals, although Hi/Low threshold can be adjusted to accommodate non-TTL level switch closures or sensors that do not have a high contarast.

Status of digital inputs are read back by the */1?41 , /1?42, /1?43* and */1?44* command.

The four digital inputs consist of 2 analog inputs threholded with the *at* command to give two digital inputs and two LV TTL level digital inputs.

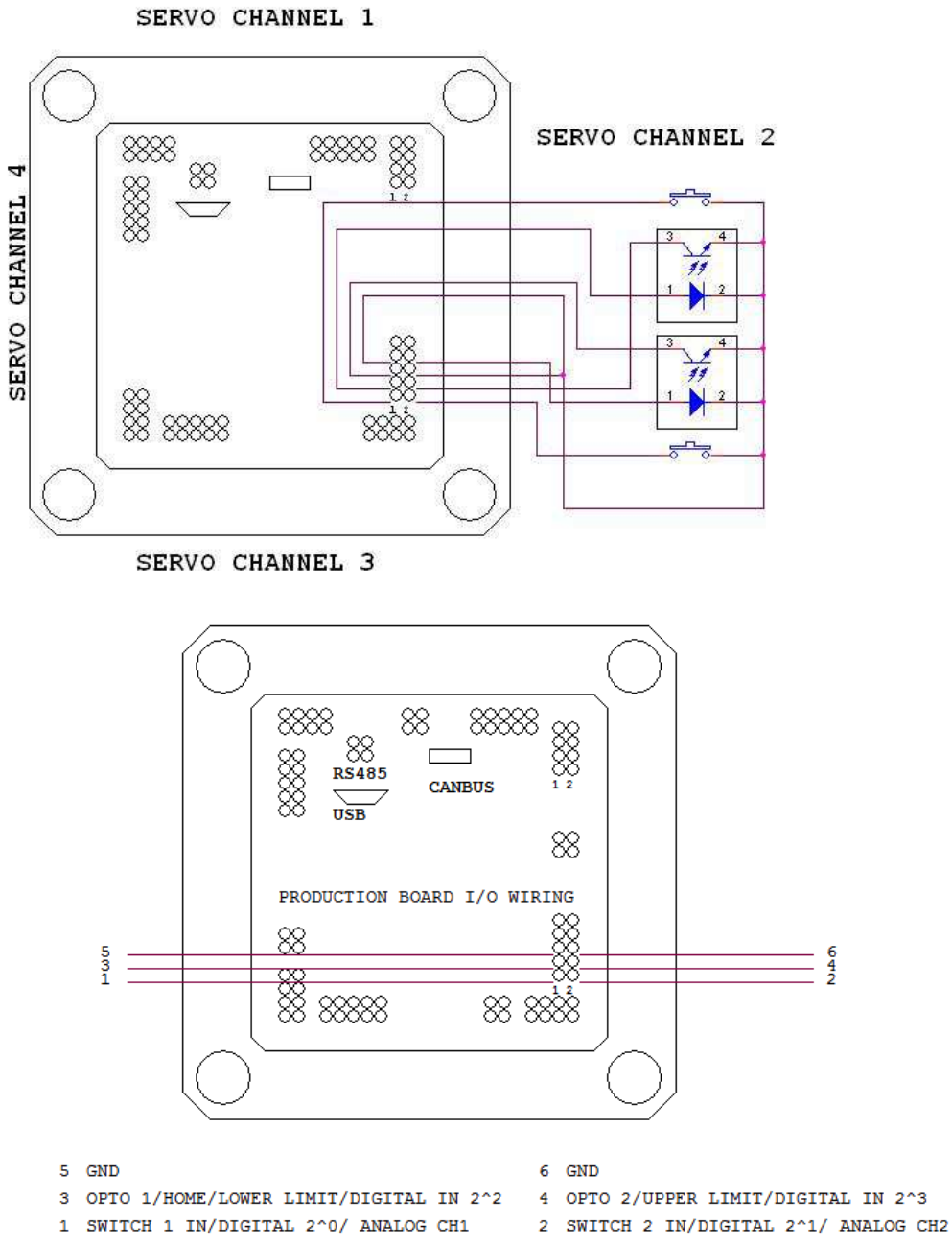


Figure 4 Inputs for the EZQUAD *Prototype(above). Production(below)*

The inputs may use either optical or mechanical switching devices, and include outputs for power for 2 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?aa (/1?aa1*= Axis 1*, /1?aa2*=Axis 2, etc.*)*. These values are on a scale of 0 - 65535 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 20400 = 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, 00000–65535, representing 0–3.3V. (Threshold value = (desired threshold voltage/3.3) x 65536.)

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 (00000-65536).

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 0-65535 representing the 0-3.3V range at the inputs)

?aat Read thresholds of all ADCs on the four 10 pin I/O connectors on the drive. The order of readback (in terms of the axis/input identifiers explained above) is

LEFT END Axis1ADC2, Axis1ADC1, Axis2ADC2, Axis2ADC1, Axi3ADC2, Axis3ADC1, Axis4ADC2, Axis4ADC1. *RIGHT END*

Example readback:
6144,6144,6144,6144,9999,6144,6144,6144 No Error

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.

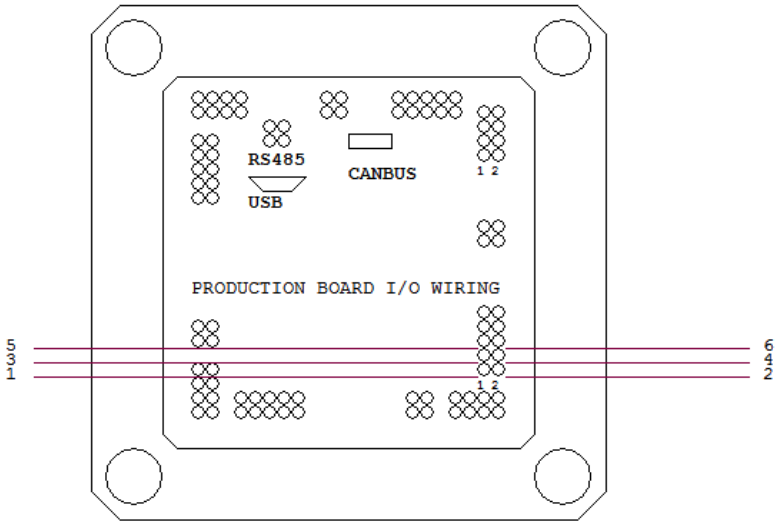
7. Analog Control Applications

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

Two of the 4 inputs on the 10-pin connector are ADC inputs.



5	GND	6	GND
3	OPTO 1/HOME/LOWER LIMIT/DIGITAL IN 2^2	4	OPTO 2/UPPER LIMIT/DIGITAL IN 2^3
1	SWITCH 1 IN/DIGITAL 2^0/ ANALOG CH1	2	SWITCH 2 IN/DIGITAL 2^1/ ANALOG CH2

The ADC values, representing the potentiometer positions, can be read using the *?aa* command *(/1?aa1*= axis 1*, /1?aa2*=axis 2, etc.*)*. These values are on a scale of 0 - 65536as 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). The EZQUAD SERVO reads back 65535 for voltages higher than 3.3V.

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

TBD

Figure 5 Potentiometer Hookup Example

8. 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.
- Homing to an index. In this mode, the index pulse from an encoder is used for homing. For index homing, see "Homing to encoder index (N2)," below.

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

Hookups

Each axis on the drive has its own set of limit/home inputs on 10-pin connectors, as shown below. The lower limit input is also the home input.

Status of home inputs are read back by the */1?41 , /1?42, /1?43* and */1?44* command.

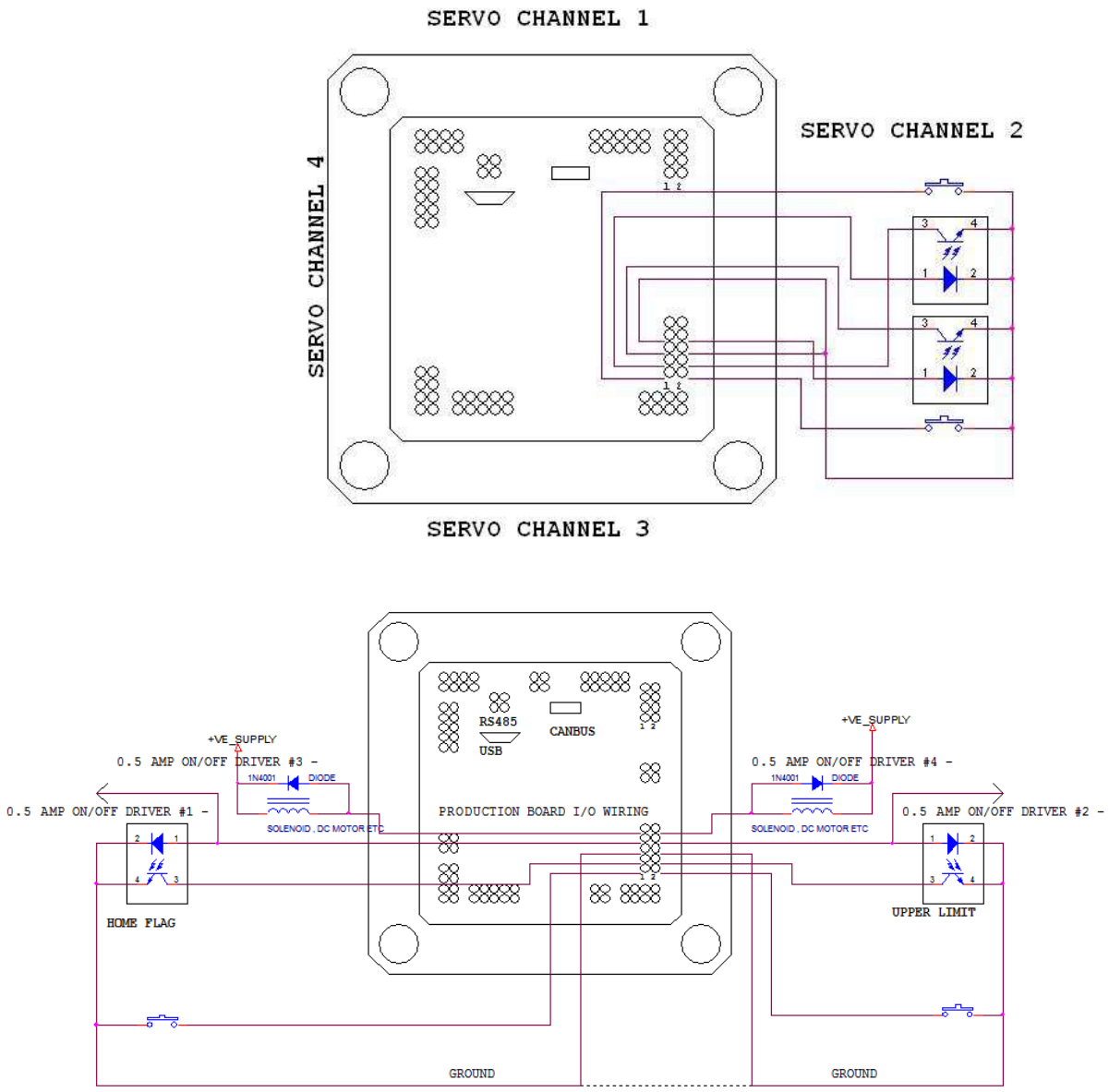


Figure 6 Home/Limit Connections prototype boards

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 EZQUAD SERVO 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. 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.

   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 65535 = threshold number. Example for 2.00 volts: */1at3139718R,* where *31* indicates Axis 3 input 1 and *39718* is the threshold number for 2.00 volts according to the formula above .(Note this 39718 threshold

value must be 5 digits and requires leading zeros if the number is less than 5 digits.*)*

5. Issue the *Z* command with the desired maximum number of encoder counts, 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 encoder counts allowed to go toward home is defined by the *Z* command operand, e.g., *Z4000*.

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 opening a switch can interrupt current to terminate motion immediately.

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 00000-65535, which linearly represents the 0-3.3V input. The default threshold value is 24200 (1.22V).

See example next page.

Example: */1at3109999R*. This sets the threshold on Axis 3 input 1 (lower limit/home) to 09999 (0.5 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, 00000–65535, representing 0–3.3V. (Threshold value = (desired threshold voltage/3.3) x 65535.)

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

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

Homing to encoder index (*N2*)

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 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.

Hookup

For encoder hookup, refer to Section 9, "Using Encoders."

Commands

N2 Enter the Home to Encoder Index mode.

Example

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

Homing to a hard stop

The axis is run against a hard limit and stalled and then recovered and the position ser to zero. Eg */1aM1m10D1000000R* will go negative with a max current of 10% and hopefully will stall and error out when it hits a hard stop. then issue */1r1R* to recover the axis to the current encoder count then issue /1z0R to set the position to zero.

9. Using Encoders

Overview

Encoder input connectors are provided for all axes for feedback . Additionally 2 extra encoder inputs allow encoder following. Encoders may be used in the following ways:

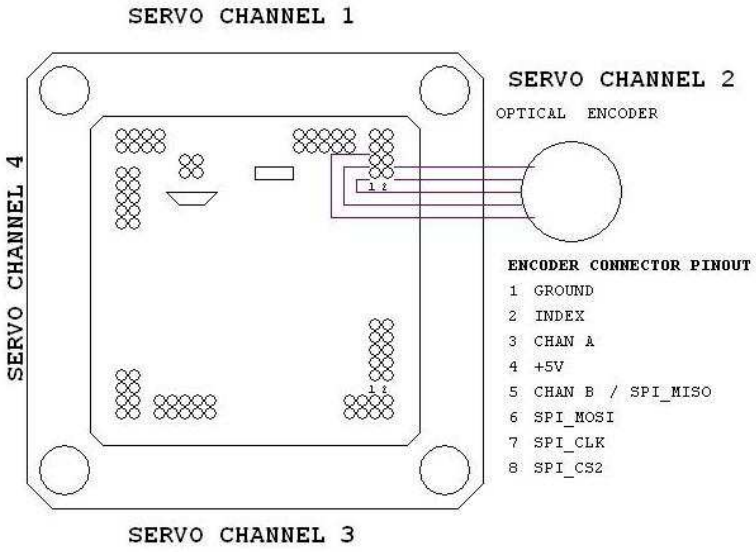
- **Encoder Following:** Motor follows index pulses from non-coupled encoder.
- **Position Feedback** Motor position is fed back for use by the servo algorithm.
- **Homing:** provide a starting point for the motor using encoder index pulses. This mode is explained in “Homing to encoder index (N2)” on page 57.

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 0.

Electrical Notes:

- The encoder(s) must draw total current of <100mA from the 5V pin.
- Encoders must have 0.2V low to 4V high swing at the connector.
- Refer to wiring diagram also.



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 (*n64*) – not yet implemented

This mode can be used with either Axis 1 or Axis 2, which have encoder inputs.

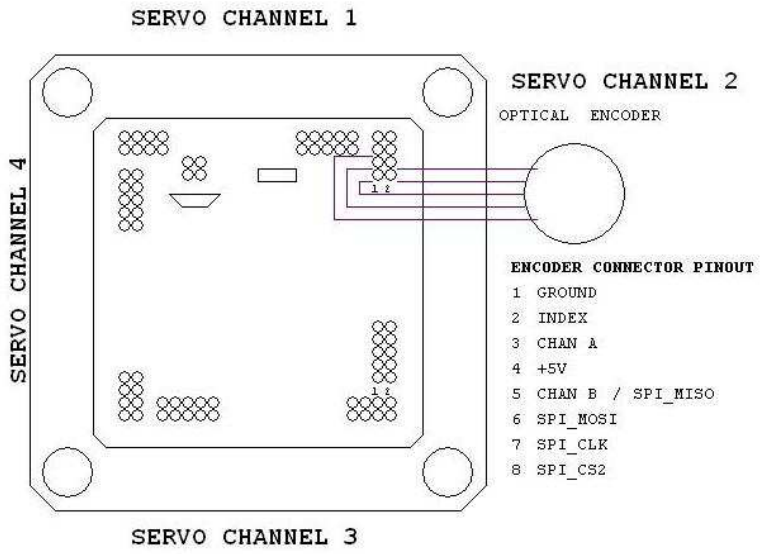
Overview

In this mode, also called "Slave to Counter," the motor takes the AB count from an encoder not coupled to the motor, and uses this count as a commanded position. Motor position and velocity vary with encoder position and velocity.

For example, an encoder might be attached to a turn-knob on a control panel, so that turning the knob causes a stepper motor to turn.

Setting up encoder following mode

1. Set up encoder on shaft with knob or other desired mechanism.
2. Make index, power and ground connections from the encoder on the shaft to the encoder connector for the desired Axis, 1 or 2. Refer to



0
Encoder Connectors, page 59.

3. Turn the shaft to its desired starting position.
4. Move the motor to its desired starting position using move commands such as *P* or *D,* addressed to the axis, e.g., */1aM2D100000R*.
5. Once the shaft and the motor are at the desired starting positions, zero the motor and encoder using the *z0* command addressed to the axis, e.g., */1aM2z0R*.
6. Turn on the encoder following mode by issuing *n64* for Axis 1 or Axis 2, whichever is appropriate. For example, */1aM2n64R* turns the mode on for Axis 2 on Drive 1.
7. Turn the mechanism to which the encoder is attached and observe how the motor moves.

   Example command string (after motor has been moved to desired starting position): */2aM2z0am256n64R*

Commands for encoder following mode

n64 Enters encoder following mode.

z0 Zeroes motor with encoder. Sets encoder count to zero at the current motor and encoder positions. Both the motor and the encoder are to be turned to their desired zero positions before this command is issued. The motor will turn in different directions above and below the zero point, unless it is set at a physical extreme.

am	Multiplier. Sets the ratio of motor movement to encoder movement. If set to 256, the ratio is 1:1; if set to 512 the ratio is 2:1, etc. Default setting is 256.
?10	Read back encoder count at current motor position.

The encoder count is related to the motor position by the following relationship: stepper position = (*am* multiplier / 256) x encoder count. Encoder count starts at zero position set by *z0* command.

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. Use *?m* to read back the move current setting for the axis, e.g., */1aM2?mR*.
  - *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., */1aM2?LR*.
  - *V* value (velocity) set too high for torque available from motor. Use *?2aV* to read back the current velocity setting for all axes, e.g., */1?aV* 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

Intentionally Blank Page

Intentionally Blank Page

Intentionally Blank Page

Intentionally Blank Page

Intentionally Blank Page

Auto Recovery of a Stalled Servo Mode (*n512*, *n1024*, *n1536*)

NOTE: This function is not implementyed yet

Overview

The EZServo determines a stalled or overload condition, by checking to see if is following a commanded trajectory. If the following error is too great for a period given by the "u" command then the servo will shut down and report an error condition.

Typically the following error is great due to the fact that either:

1)"m" value (current) set too low.

2)"L" value (acceleration) set too high, for Torque available from motor.

3)"V" value (Velocity) set too high, for Torque available from motor.

4) Physical obstruction, or excessive friction.

When an overload condition is detected it will be reported back as an upper or lower case I when the status is quizzed. This status can be used by an external computer to execute a recovery script.

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 EZQUAD SERVO 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 these commands, 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*.

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)

Set m=5 so that we can stall a motor easily.

Set u=1000 so the motor overloads after 1 second.

Set au = 10 so that 10 retries max are allowed

Set n =512 so that Stored Program 13 will be issued on error condition.

/1s0m5n512au10u1000e1R

/1s1gA10000A0G0R

/1s13r1e1R

/1s12z333R

Program zero enables Auto-recovery mode and calls program 1 on power up.

Program 1 cycles between 10000 and 0

When a stall occurs while running program 1, program13 is automatically called. This program recovers the servo to the current encoder position and then calls program 1 again. The servo will attempt auto-recovery 10 times as given by the “au” command, then, if no move completes after 100 retries, it will execute stored program 12.

In this example cycle the power and the servo will go between 0 and 10000. Now hold the shaft of the motor and stall it (if safe to do so). The motor can be felt to retry the move 10 times prior to setting its position to 333 and stopping.

Note /1r1R recovers the servo to the current encoder position. Also /1r1,1,1,1R . Note that a stalled servo wil automatically recoder to the current encoder position if a new A, P or D command is received. Note that /1r0,0,0,0R will stop the encoder feedback and free the axes. Default is r1 where encoder feedback is enabled

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 (circular and linear interpolation) on page 97 (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 EZQUAD SERVO at the time of publication. It indicates the command, possible operands, and brief descriptions with examples.

NOTE: The EZQUAD SERVO is always in 1/16th step mode, meaning that there are always 16 encoder counts 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.** (quadrature encoder counts, 32-bit positioning). E.g. */1aM3A10000R* (Axis 3 specified)
P	0-2^31	**Move motor relative in positive direction.** (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. Endless moves can be terminated by issuing a *T* command.
D	0-2^31	**Move motor relative in negative direction.** (quadrature encoder counts) E.g. */1aM2D10000R* (Axis 2 specified) 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. Endless moves can be terminated by issuing a *T* command or by a falling edge on the Switch 2 Input.

Command (case sensitive)	Operand/ (default)	Description
r	0 or 1 (1)	**Set current position to be same as encoder position and turns on encoder feedback if servo was off.** E.g. */1aM2r1R* (Axis 2 specified) /1aM2r0R turns off the channel 2 servo and freewheels the motor. Also works in multi axis mode /1r1,1,1,1R Also /1r0,0,0,0R will turn off feedback and free the axes. Typically r1 is used to recover a stalled servo without losing the encoder position.
INTERPOLATION COMMANDS (Axes 1 and 2)		
aaA	0–90000	**Set diameter of circle. (circular interpolation)** Units are encoder counts.
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 encoder counts/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 and separately axes 3 and 4 interpolation mode.** This mode draws straight lines. In this mode, the speed of the faster axis is slowed such that both axes arrive at the destination at the same time. You may issue a multi-axis command addressed to all four axes to enter linear interpolation mode. In such a case Axes 1 and 2 will move in interpolation fashion, and separately Axes 3 and 4 can move in a linear interpolated fashion. *1an65536,65536,0,0R sets* Axes 1 and 2 into linear interpolation mode for drawing straight lines. */1an0,0,65536,65536R sets* Axes 3 and4 into linear interpolation mode for drawing straight lines. */1an65536,65536,65536,65536R sets* Axes 1 and 2 into linear interpolation mode and separately sets axes 3 and 4 into interpolation mode
HOMING		
f	0 or 1 (0)	**Set Home Flag and Limit polarity, --not implemented in beta** Sets polarity of limits/home sensor. Each axis has own set of limit/home flags; these are on the 10-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)

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. Includes number of encoder counts allowed before reaching home position. E.g. */1aM3 Z300000R* (Axis 3 specified, 300000 encoder counts allowed)
z0 (lower case)	--	**1. When used with encoder: *z0* zeroes motor with encoder at current position.** **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.
SET VELOCITY		
V	1-99999999	**Set max/slew speed (velocity) of default or selected motor. (positioning mode)** Sets encoder counts per second. Max V is 99999999. E.g. */1aM2V10000R* sets max. velocity of Axis 2 motor.
SET ACCELERATION		
L	0-64999 (10)	**Set acceleration factor.** Acceleration factor = *L** (*TBD*). For example, if *V*=10000 and *L*=1, it will require TBD seconds to reach final velocity. E.g., */1aM21LR* (Axis 2 specified)
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).

Command (case sensitive)	Operand/ (default)	Description
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.
H	101-414	**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** **Halt and wait for status of inputs of channel1:** *101* Wait for low on input 1 of channel1 *111* Wait for high on input 1 of channel1 *102* Wait for low on input 2 of channel1 *112* Wait for high on input 2 of channel1 *103* Wait for low on input 3 of channel1 *113* Wait for high on input 3 of channel1 *104* Wait for low on input 4 of channel1 *114* Wait for high on input 4 of channel1 similarly *201* Wait for low on input 1 of channel2 *301* Wait for low on input 1 of channel3 *401* Wait for low on input 1 of channel4 Etc E.g. */1gH102P10000G20R*. Waits for low on input 2 of channel 1 (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., *H101H111* is a rising edge detect. (16 possibilities for Halt)

Command (case sensitive)	Operand/ (default)	Description
S	101-414	**Skip next instruction depending on input or limit switch status.** **Skip on status of inputs of channel1:** *101* Skip next instruction if low on input 1 *111* Skip next instruction if high on input 1 *102* Skip next instruction if low on input 2 *112* Skip next instruction if high on input 2 *103* Skip next instruction if low on input 3 *113* Skip next instruction if high on input 3 *104* Skip next instruction if low on input 4 *114* Skip next instruction if high on input 4 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. */1gS102A10000A0G20R* - skips if low on Switch 2.

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.
SET MAX MOVE / HOLD CURRENT		
h	**0-50** **(0)**	**Sets torque mode current within a scale of 0 to 50% of max current.** 100% = 5A E.g. */1aM2h15R = 15%* (Axis 2 specified). Applies to specified axis. Note: this value is non linear below 25%
m	**0-100** **(25)**	**Set max move current within a scale of 0 to 100% of max current.** 100% = 5A E.g. */1aM2m40R = 40%* (Axis 2 specified) Applies to specified axis. Note: this value is non linear below 25% Note that if currents below 25% are desired it is better to change the current sense resistor on the drive which will change the full scale range from say 0-5A to 0-2A for m=0 to100. The current sense resistor is the 2512 size resistor on the bottom side near each of the mounting holes. This is normally 0.04 Ohms . Changing this to 0.1 Ohms for example will change the max current to 2Amps (Max current is reached when 0.2V is present across this resistor)

N MODE COMMANDS		
N	1-3 (1)	**Initiates designated mode determined by operand.** **Example? specify axis?** *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.
n MODE COMMANDS		
n	0-128000 (0)	**Initiates designated mode determined by operand.** Bit0 (LSB) - */1n1R* Not used in EZQUAD SERVO. 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 EZQUAD SERVO. Bit3 - */1n8R* - Reserved Bit4 - */1n16R* Enables - Reserved Bit5 - */1n32R* Not used in EZQUAD SERVO. Bit6 - */1n64R* Enable Encoder Following mode. Axes 1 and 2 only. Bit7 - */1n128R* Not used in EZQUAD SERVO. Bit8 - */1n256R* Not used in EZQUAD SERVO. 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.) TBD Not In Beta release. */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* - Reserved Bit14 - Reserved Bit15 - Reserved Bit16 - - Reserved **NOTE: Any n mode change may require upto 20mS to propergate through the firmware. If modes are being dynamically changed a small wait command such as M20 may be required before a move command that follows it.**

an MODE COMMANDS		
an	0 or 65536	**Places axes 1 and 2 and separately axes 3 and 4 interpolation mode.** This mode draws straight lines. In this mode, the speed of the faster axis is slowed such that both axes arrive at the destination at the same time. You may issue a multi-axis command addressed to all four axes to enter linear interpolation mode. In such a case Axes 1 and 2 will move in interpolation fashion, and separately Axes 3 and 4 can move in a linear interpolated fashion. *1an65536,65536,0,0R sets* Axes 1 and 2 into linear interpolation mode for drawing straight lines. */1an0,0,65536,65536R sets* Axes 3 and4 into linear interpolation mode for drawing straight lines. */1an65536,65536,65536,65536R sets* Axes 1 and 2 into linear interpolation mode and separately sets axes 3 and 4 into interpolation mode. Type /1an0,0,0,0R to exit more

OVERLOAD COMMANDS		
u	1-24999 (10000)	**Set overload timeout.** Overload Timeout (Milliseconds) When the Servo detects an overload condition it will shut down after this number of Milliseconds. An overload condition is when the max allowed current "m" is reached due to excessive position error. Also see the auto recovery n mode commands *n512*, *n1024*, and *n1536R*.
au NOT IN BETA	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.** Also see the auto recovery n mode commands *n512*, *n1024*, and *n1536R*.
POWER DRIVER CONTROL		
J NOT IN BETA	0-15 (0)	**Turn driver On/Off** Digits following the *J* command are interpreted as 4-bit binary equivalents: 1111 binary = 15 decimal = all drivers on /1gJ15,15,15,15J0,0,0,0GR will toggle all outputs on and off /1gJ1,0,0,0J0,0,0,0GR will toggle output 1 on axis 1 on and off tection.
ak aak NOT IN BETA	250-511	**Changes driver outputs to PWM and sets PWM duty cycle.** *Not implemented*
POTENTIOMETER POSITION COMMANDS		
These commands apply to the Potentiometer Positioning mode (*n8192*).		
ad NOT IN BETA	0-65535 (50)	**Sets a deadband (in encoder counts) 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 0–65535 which represents 0–3.3V. E.g. */1aM2ad100R* (Axis 2 specified)
am NOT IN BETA	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).
ao NOT IN BETA	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)

MISCELLANEOUS COMMANDS		
aP NOT IN BETA	0-30000 (5)	**Response delay** (not implemented) 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 NOT IN BETA	0-15	**Inverts polarity of inputs on 8-pin connector as seen by *?4*, *S*, and *H* commands.** (not implemented) 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. NOTE: correct termination and strict daisy chaining required for reliable operation at higher baud rates.
K NOT IN BETA	0-64999 (0)	**Set backlash compensation.** Units are number of encoder counts. (not implemented) 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.
M	0-29999	**Wait for specified period.** Units are milliseconds.
p (lower case) NOT IN BETA	0-64999	**Ping Command** (not implemented) 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.
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 do not require an "R" at the end. • In later versions of firmware it will be 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. • Other commands may be executed as immediate commands.		
/1$		**Reports the command string currently executing, or most recently executed on drive.** E.g., */1$R* 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.

`/1&`		**Reports the current firmware revision number and date.** E.g., */1&* Example response: *EZQuad Servo Allmotion V1.25 7-7-17 No Error*
`/1?0` `(?zero)`		**Reports the current commanded position for last commanded axis.** E.g. */1aM2?0* (e.g., for Axis 2) Example response: *10000 No Error*
`/1?A` `/1?aA`		**Reports positions of all four** E.g., */1?A or /1/aA* Example response (Axes 1 through 4 in order): *102000,35000,35000,5000 No Error*
`/1?aV`		**Reports max programmed velocities of all four motors.** E.g., */1?aV* Example response: *568,568,568,568 No Error*
`/1?1`		**Reports start speed for default or selected motor.** E.g., */1aM2?1* (Axis 2 specified)
`/1?2`		**Reports the current Slew/Max speed for default or selected motor.** E.g., */1aM2?2* (Axis 2 specified)

`/1?41`
`/1?42`
`/1?43`
`/1?44`
		Digital Input Query. Reports the high/low status of all four Digital/Analog IO inputs
		E.g., */1?4*
		0-15 represents a 4-bit binary pattern:
		Bit 0 = Switch1 (input 1) (Thresholded Analog Input 1)
		Bit 1 = Switch 2 (Input 2) (Thresholded Analog Input 2)
		Bit 2 = Opto 1 (input 3) (Home / LoweLimit Input)
		Bit 3 = Opto 2 (Input 4) (Upper Limit Input)
		Example: 11 = all high except input 3 (bit 2)

`?8`		**Reports encoder position for currently selected motor.** *E.g., /1aM1R <enter> then* */1?8* (Motor/encoder 1 specified) */1aM2R <enter> then* */1?8* (Motor/encoder 2 specified) Example response: *1000*
`?a8`		**Reports encoder position all axes.** *E.g., /1?a8* Example response: *1000,300,2990,4567*

`/1?aa1`
`/1?aa2`
`/1?aa3`
`/1?aa4`
		Reports analog values on all 2 Analog Inputs and 2 Analog Drive parameters per axis
		E.g. */1?aa1*
		Example response: *64300,15, 64300, 64300 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 00000-65535

`/1?aat`		**Reports thresholds for all four axes on Limit/Home connections.** Read thresholds of all ADCs on the four 10 pin I/O connectors on the drive. The order of readback (in terms of the axis/input identifiers explained above) is *LEFT END* is1ADC2, Axis1ADC1, Axis2ADC2, Axis2ADC1, Axi3ADC2, Axis3ADC1, Axis4ADC2, Axis4ADC1. *RIGHT END* Example readback: *6144,6144,6144,6144,9999,6144,6144,6144 No Error*
`/1?L` `/1?aL`		**Reports acceleration for default or selected axis.** e.g., */1aM2R then /1?L* (Axis 2 specified)
`?V` `/1?aV`		**Reports programmed velocity (slew rate) for default or selected axis.** e.g., */1aMR2R then /1?V* (Axis 2 specified)
`/1?G`		**Reports end of loop/repeat value set with *G* command for a loop in progress on a drive.** This applies to a loop in progress. It enables a user to determine how many repetitions of the loop remain at the time of inquiry. e.g., */1?G – not implemented in beta* Note: not for use in nested loop. Will give answer depending on which loop is running when query is issued, and will not identify the loop.

/1Q		**Reports current status of EZQUAD SERVO 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. 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 88. Response breaks down by axis Reply is xx,yy,zz,rr...xx axis 1 yy axis 2 etc. breakdown is first digit is the overload error status. 9=overload from PWM timeout on servo. second digit is initialization status. 1 = flag did not reach intended state.
General Immediate Query Syntax		In firmware version 7.02 and above it is possible to query parameters by using the same letter that set the parameter. E.g. */1?A* reports current position; */1?V* reports velocity, and */1?m* reports move current setting.
/1T		**Terminate current command or loop for an axis.** */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.
Other Immediate Commands		The following other commands may be issued as immediate (on-the-fly) . The drive will adapt to the new target while running: A, P, D, V, L

ANALOG INPUT (ADC) COMMANDS		
The Analog/Digital IO and Limit/Home inputs are all ADC.		
/1**at**	**X100000 to X165535** **X200000 to X265535** **Where X =1-4 depending on axis**	**Sets thresholds for "one" and "zero" on each IO connector** The number consists of the input number followed by a 5-digit number ranging from 00000-65535, which represents the threshold on a scale from 0-3.3V. The default value is 24200 (1.22V) for all four inputs. Note: threshold value= (threshold voltage/3.3) x 65535 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. IO connector thresholds can be read back with the *?at* command. See the *?at* command for details. **Setting Limit/Home Connector thresholds** 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 */1at4210000R* (note seven numerical digits). The numeral 4 specifies Axis 4, and the numeral 2 specifies the upper limit. Note that on the 10 pin Limit/Home connectors, Input 1 is the lower limit/home input, and Input 2 is the upper limit. ADc input thresholds can be read back with the *?aat* command. See the *?aat* command for details.
RESPONSE PACKET **See Appendix 4, Device Response Packet**		

Appendix 3. This Page Intentionally Blank

Appendix 4. Device Response Packet

Introduction

EZSteppers® and EZServos® respond to commands by sending text 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?41"

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.

If writing your own firmware:

DO NOT FORGET TO ADD THE CARRIAGE RETURN AND LINE FEED CHARACTERS AFTER THE "R"

Eg /1A1000A0R<CR><LF>

The CR and LF are what happens when the "Enter" key is pressed on a keyboard.

Appendix 5. This Page Intentionally Blank

Appendix 6. BLDC Motor Wiring

The procedure below describes how to figure out the phasing of the encoder and the hall sensors. However, please note that AllMotion can perform this process for no extra charge. Just ship us a motor and we will ship it back fully wired with a board.

First it is necessary to set the phasing of the Hall Sensors:
The phasing of the hall sensors is unrelated to the encoder connection, and no encoder connection is necessary at this time.

1)The procedure is to wire the BLDC motor nominally, as shown in the wiring diagram, and then try all 6 combinations of the 3 hall sensor wires until one combination works. Set the current limit low using /1m10R. (Use of current limited supply set to about quarter of the motor rated current is also recommended). With the encoder unplugged issue the command h25 and the motor should spin smoothly in one direction

2) While the motor spins hold the shaft of the motor (Only if no danger of injury) and ensure that there are no "Dead Spots" in the torque. Four of the six combinations of the 3 hall sensor wires will have obvious dead spots. Of the remaining two, one will have subtle dead spots and the other will be perfect. The Combinations are: 123,132, 213,231, 312,321 Only the Hall sensor wires need to be switched – don't switch power wires. Turn Off Power when Switching Wires or Disconnecting Motor. (because the inductance of the motor will create a high voltage spark when the motor is disconnected, which will damage the driver chip)

Second it is necessary to make sure we have negative feedback from the encoder. First plug the encoder in and rotate the shaft by hand and issue /1?8 . This command retrieves the encoder count, and if the encoder is functioning this count will go up and down as the shaft is turned.

Plug in the encoder and issue a command /1A1000R . If the motor spins endlessly and then gives up, then try again with the encoder A, B channel wires switched.

Motor Tuning: Typically (in 99% of cases) the motor will be stable with the default constants that are loaded on power up. If the behavior is oscillatory, then increase the value if the Differential constant.Eg . /1y3000R If increasing the Differential term does not work and the motor is noisy and the encoder ticks can be "heard", then simultaneous reduction of both the Proportional and Differential constant is recommended. /1w250y500R works well especially with high (4000) line count encoders.

Motor Overload: If motor gives up half way through a move, and gives an overload error (Error 9 in Ezcommander or Upper or lower case I in Hyperterminal when queried with /1Q after error) this is due to the fact that the motor could not keep up with the commanded trajectory. Typically increase the value of the move current "m" to allow the motor to move faster, or increase the supply voltage to the motor, or reduce the commanded speed V. The change in "m" changes the torque and allows the motor to combat friction losses, and also keep up with the commanded acceleration. Changing the supply voltage when using a encoder feedback controlled motor, should have no effect on the speed of the motor, if it does, then there is not enough voltage to overcome the back EMF of the motor, reduce the commanded speed V or increase the supply voltage.

Motors with no encoders: In N=0 mode Motors with no encoders will work in velocity control mode in by using the hall sensor crossings as a gage of velocity. In this mode only the Integrator is active and The "x" value controls the acceleration between speeds. (L command is inactive in this mode). The velocity is set in Revs per second using the V command.

In N= 1 mode, It is also however possible to run motors with no encoders by using the Hall sensors as a position encoder, by wiring over two of the hall lines over to the encoder A and B inputs in addition to the regular Hall connection. Any 2 of the hall lines can be wired over, however as with any encoder the A and B lines must be connected to count up when the motor moves in the positive direction. This mode typically has better performance than the N0 mode in velocity control applications, and can also act as a crude position control mode.Typically in this mode very low Accelerations and Velocity values must be used since the halls act as a very low line count encoder. Try /1L1V10000R.

When Hall sensors are used for feedback, the PID gain values should be increased from the default values to compensate for the low count rate.

It is also necessary to run the hall sensors on 5V since the encoder connections are 5V. In the EZSV17 which puts out 15V hall power, it will be necessary to use the encoder power at 5V to power the hall sensors.

Appendix 7. Heat Dissipation (EZServo® products with motor drives)

Overview

Most applications require intermittent moving of the motor. In the EZServo®, the current is increased to the move current, the move is performed, and the current is then reduced at the end of the move (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 (if any).

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 EZServos® 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), forced air cooling may be necessary.

Do not place the drive in a small sealed container as it will overheat.

EZServos® 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 (circular and linear interpolation)

NOT IMPLEMENTED IN PRELIMINARY RELEASE

The EZQUAD SERVO 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:

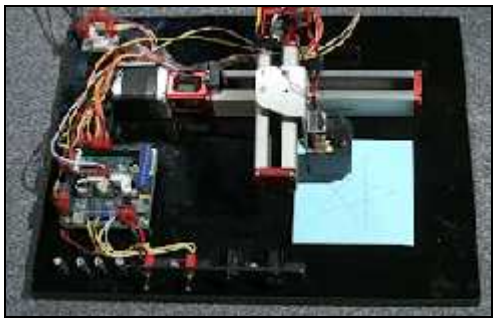


Figure 7 X-Y Mechanism for Interpolation Commands

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

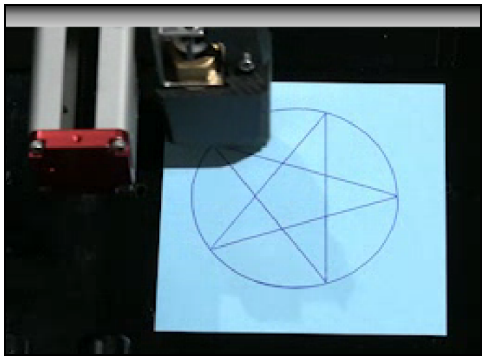


Figure 8 Circular and Linear Interpolation

Circular Interpolation NOT IMPLEMENTED IN PRELIMINARY RELEASE

There are four commands associated with circular interpolation:

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

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

aaW Sets the speed at which the circle is drawn in encoder counts/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.

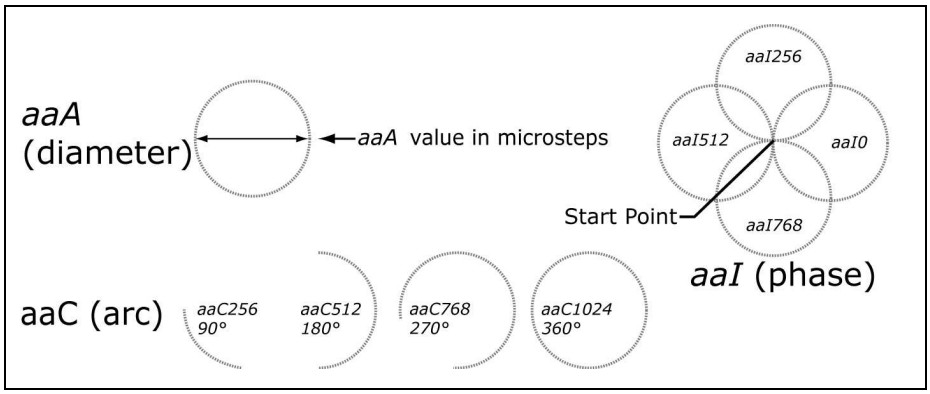


Figure 9 Circular Interpolation Command Effects

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 encoder counts/second (*aaW1000*), begins at 0° (*aaI0*), has a diameter of 14000 encoder counts (*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 NOT IMPLEMENTED IN PRELIMINARY RELEASE

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

There are two commands associated with linear interpolation:

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

an0 Exit linear interpolation mode.

You may issue a multi-axis command addressed to all four axes to enter linear interpolation mode. In such a case Axes 1 and 2 will move in interpolation fashion, and separately Axes 3 and 4 can move in a linear interpolated fashion. *1an65536,65536,0,0R sets* Axes 1 and 2 into linear interpolation mode for drawing straight lines. */1an0,0,65536,65536R sets* Axes 3 and4 into linear interpolation mode for drawing straight lines. */1an65536,65536,65536,65536R sets* Axes 1 and 2 into linear interpolation mode and separately sets axes 3 and 4 into interpolation mode

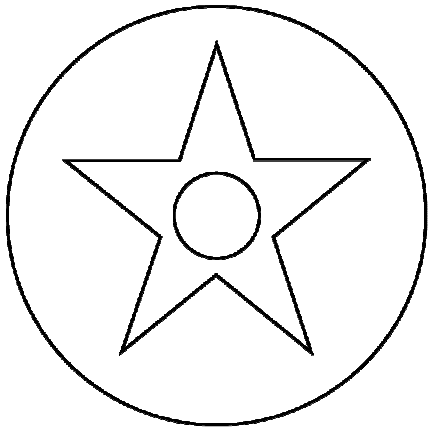
Exiting Linear Interpolation

To exit linear interpolation mode, enter the command *an0 /1an0,0,0,0R.*

Circle and Star Example

Introduction

This example describes how an EZQUAD SERVO 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:



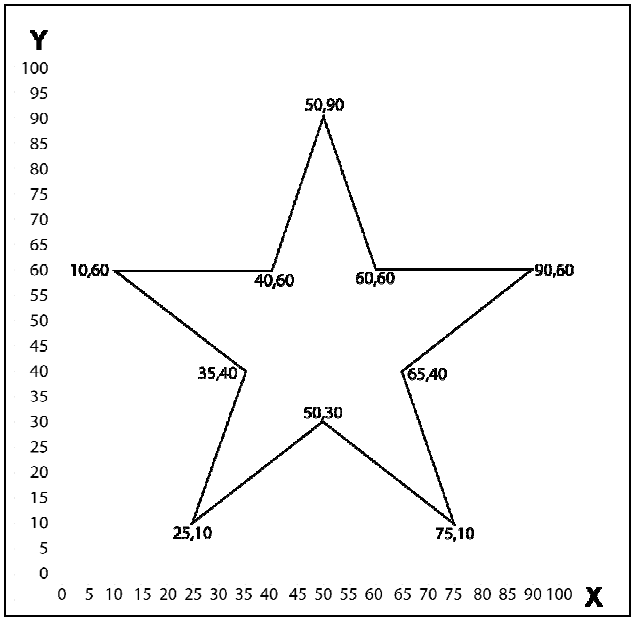
This pattern was implemented by five command strings, each stored in a different memory location in the on-board EEPROM:

- 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 encoder counts according to the desired size of the star. This star was intended to fit into a space of 64000 encoder counts, 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 encoder counts).

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) TBD Edit

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 encoder counts/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 encoder counts/second; set polarity of home flag to normally open (*f1*); and go home (*Z*), allowing 200000 encoder counts 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 encoder counts, 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 encoder counts/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 encoder counts/second.

aaI256 Set beginning phase of circle to 90 degrees.

aaA14000 Set diameter of circle to 14000 encoder counts.

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 encoder counts/second; set polarity of home flag to normally open (*f1*); and go home (*Z*), allowing 200000 encoder counts 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 encoder counts/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 encoder counts/second.

aaI0 Set beginning phase of circle to 0 degrees.

aaA64000 Set diameter of circle to 64000 encoder counts.

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 encoder counts/second; set polarity of home flag to normally open (*f1*); and go home (*Z*), allowing 200000 encoder counts 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 (5A).
L10	Set acceleration factor to 10.
V5000	Set velocity (*V*) to 5000 encoder counts/second.
f1	Set polarity of home flag to normally open (*f1*).
Z200000	Go home (*Z*), allowing 200,000 encoder counts 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 8. JoystickMode

Overview

Available on Version

EZQUAD XR AllMotion V1.25 6-25-17

1. This sets up Joystick mode on all four axes and makes the current A/D value = to velocity "zero"

/1n65536,65536,65536,65536z0,0,0,0P0,0,0,0R

2. Tests of different A/D multipliers for each axis

/1am100,200,400,800R

3. Tests different A/D deadband settings for each axis.

/1ad1000,2000,3000,4000R

4. To read back each channels 4 analog inputs, use

/1?aa1 for channel 1

/1?aa2 for channel 2 etc.

The last value shown in the string is the A/D value that sets the A/D velocity.

To get out of joy stick mode, send "/1T" then send /1n0,0,0,0R

Also, to set the parameter for only one axis, do not put values between the commas. For instance, to set only axis 4 to joys stick mode, send

/1n,,,65536z,,,0P,,,0R

You must have the commas in the string for the parser to know to ignore the value for that axis.