



User Guide

Programming instructions for Models EZHR17EN,
EZHR23ENHC, and EZ4AXIS



Version 1.3
October 30, 2015

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Important Notices	2
1. Introduction	7
Overview	7
Command Syntax	7
2. Command Set.....	8
3. Single-Axis Programming Examples	17
Example #1 (A move to absolute position)	17
Example #2 (Move loop with waits)	17
Example #3 (Program storage and recall).....	18
Example #4 (Set current, wait for Switch 2 closure, home to opto).....	18
Example #5 (Nested loop example).....	19
Example #6 (Skip/Branch instruction).....	20
Example #7 (Monitor four switches and execute four different programs depending on which switch input is pushed)	21
Example #8 (Move 1000 steps forward on rising edge of Switch2)	21
4. Multiple-Axis Coordinated Motion Programming Examples	22
Introduction	22
Addressing Individual Motors	22
Addressing Banks of Motors.....	22
Addressing All Motors At Once.....	23
Addressing More Than 16 Motors	23
Example #9 (Coordinated motion with axes performing same motion).....	23
Example #10 (Coordinated motion with axes performing different motions).....	23
Appendix 1. Stepper Motor Electrical Specification	24
Appendix 2. Homing Algorithm Detail	26
Overview	26
Main Axis Homing Details.....	27
Second Axis Homing Details	27
Manual homing	28
Homing to a hard stop	28
Homing to the index.....	28
Other Notes on Homing.....	28
Appendix 3. Microstepping Primer	29
Appendix 4. Heat Dissipation.....	30
Appendix 5. Step Loss Detection Using Opto.....	31
Appendix 6. OEM Protocol With Checksum	32
Introduction	32

OEM Protocol Example 1	32
OEM Protocol Example 2	33
Appendix 7. Device Response Packet.....	34
Introduction	34
Response Packet Structure.....	34
Example Initialization Error Response	35
Example Invalid Command Response	35
Example Operand Out Of Range Response	35
Example Overload Error Response.....	35
Example Response To Command “/1?4”	36
Appendix 8. Position Correction Mode and Overload Report Mode.....	37
Position Correction Mode (V6.7+)	37
Setting Up Encoder Feedback.....	37
Fine position correction (V6.99+)	38
Notes On Feedback Mode.....	39
Other Notes	40
Dual Axis Position Correction Mode	40
Arbitrary Measurement Units.....	40
Overload Report Mode	40
Auto Recovery in Feedback Mode	41
Appendix 9. Analog Inputs and Analog Feedback.....	43
Analog Inputs.....	43
Potentiometer Position Command.....	44
Potentiometer Velocity Mode (joystick mode)	45
Potentiometer Position Feedback	46
Appendix 10. Sinusoidal Scan	48
Appendix 11. Daughter Cards.....	49
Dual Axis Stepper Daughter Card (firmware V6.79 or later)	49
Bidirectional Current Mode Drive Daughter Card For I/O Function.....	50
Bidirectional Drive Daughter Card For DC Servo.....	50
Bidirectional Voltage Mode Drive Daughter Card For I/O Function (-PW).....	51
Logic Output Daughter Card.....	51
Input Current Consideration When Using Daughter Cards	51
Appendix 12. On-the-fly Parameter Change.....	52
Appendix 13. Addressing More Than 16 Motors On Same Bus.....	53
Appendix 14. Encoders and Step/DIR Pulse Input	54
Read-Only Mode	54
Encoder/Step and Direction Following Mode	54
Main Axis Encoder Feedback Mode.....	54

Dual Axis Feedback Mode..... 55

Electrical 55

Appendix 15. Jog Modes and Limit Switches 56

 Jog 56

 Limit Modes 56

 Noise Considerations 56

Appendix 16. S Curve 57

Appendix 17. Inputs and Outputs..... 58

Appendix 18. EZ4AXIS Special Commands..... 59

 To move one motor at a time..... 59

 To move all motors simultaneously 59

 On-the-Fly parameter change 60

 Home inputs status..... 60

 Coordinate mode and Semi-Independent mode 60

 Exceptions to main command set 61

 Halt and Skip on status of limit switches 61

 Reading back encoder inputs as I/O 61

 Home Flags 61

 Programmable Threshold on Axis Inputs 62

 Current and voltage ratings and motor selection..... 63

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1. Introduction

Overview

This document describes the operation and command set for the EZStepper® models EZHR17EN, EZHR23ENHC, and EZ4AXIS controllers/drivers.

Command Syntax

Commands for the EZStepper® are single alpha characters normally followed by a numeric value. The alpha character represents “what to do” and the numeric value represents “how much to do it”.

You can set values for desired velocities, accelerations, and positions. Commands can be issued one at a time or sent in a group. This allows the setting of all move parameters in one command. You can also create loops in the strings and cause the EZStepper® to become a stand-alone device that responds to switch inputs. Finally, storing such strings in the onboard EEPROM allows the EZStepper® to power up into a mode of your choice, so that it can act with no computer attached.

The commands are simply typed into a terminal program such as “Hyperterminal”; no special software is required. The EZStepper® can even be commanded from a serial enabled PDA (personal digital assistant).

2. Command Set

(Also see examples beginning on page 17.)

Table 1. Command Set

Command (case sensitive)	Operand	Description
POSITIONING COMMANDS		
NOTE: In firmware versions 6.7 and above, negative positions are allowed (e.g. /1A-1000R).		
A	0-(2³¹)	Move motor to absolute position . (microsteps or quadrature encoder ticks - 32 Bit Positioning). E.g. /1A1000R
P	0-(2³¹)	Move Motor relative in positive direction. (microsteps or quadrature encoder ticks) A value of zero will cause an endless forwards move at speed V. (i.e., enter into Velocity Mode) The velocity can then be changed on the fly by using the V command. An endless move can be terminated by issuing a T command or by a falling edge on the Switch2 Input. E.g. /1P1000R
D	0-(2³¹)	Move Motor relative in negative direction. (microsteps or quadrature encoder ticks) (NOTE: for a finite move, the ending Absolute position must be greater than zero). 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. An endless move can be terminated by issuing a T command or by a falling edge on the Switch2 Input. E.g. /1D1000R NOTE: Ending position must be > 0
HOMING COMMANDS		
Z	0-(2³¹) (400)	Home/Initialize Motor. Motor will turn toward 0 until the home opto sensor (opto #1) is interrupted. If already interrupted it will back out of the opto and come back in until re-interrupted. Current motor position is set to zero. E.g. /1Z30000R See Appendix 2 for further details.
z	0-(2³¹)	Change current position without moving. Sets current position to be position specified without moving motor. New microstep position (preferably) should have the same remainder as old position, when divided by 1024, else the motor may physically move/lose up to 2 steps when this command is issued. E.g. /1z65536R NOTE: This command must be issued after at least one A command, because the first A command initializes all registers to zero.
f	0 or 1 (0)	Home Flag polarity. Sets polarity of home sensor, default value is 0. (See Appendix 2) E.g. /1f1R

Command (case sensitive)	Operand	Description
ap	0 to 15	Invert inputs. (requires firmware V7.05F+) Inverts each of the 4 main inputs depending on whether the binary interpretation of the 4-bit number has the bit set or zero. This command is useful for toggling the polarity of the home flags and limits. E.g. <i>/1ap7R</i> will invert inputs 0,1 & 2 (binary of 7 is 0111)
F	0 or 1 (0)	Change direction of rotation considered positive. This should only be done once on power up. Do not use if in Encoder Feedback mode. E.g. <i>/1F1R</i>
SET VELOCITY COMMANDS		
V	1-2²⁴ (305064)	In Position Mode Set Max/Slew Speed of motor. Sets microsteps per second. It is recommended that this drive be left in 256 micro-step mode, since very high microsteps/sec numbers can be issued. E.g. <i>/1V10000R</i> If the encoder ratio (<i>aE</i> command) is set, the units of velocity change to encoder counts/second.
SET ACCELERATION COMMANDS		
L	0-65000 (1000)	In EZHR17EN, set acceleration factor. Accel in microsteps / sec ² = (L Value) x (400,000,000/65536) . E.g.. using $t=V/a$ <i>/1L1R</i> takes 16.384 seconds to get to a speed of $V=100000$ microsteps/second NOTE: Acceleration does not scale with encoder ratio.
B	0-65000	Bump jog distance. See <i>n1</i> command.
LOOPING AND BRANCHING COMMANDS		
g		Beginning of a repeat loop marker. See examples below on how to set up a loop. E.g. <i>/1gP1000M1000G10R</i>
G	0-30000	End of a repeat loop marker. Loops can be nested up to 4 levels. A value of 0 causes the loop to be infinite. (Requires T command to Terminate). If no value is specified 0 is assumed. E.g. <i>/1gP1000M1000G10R</i>
H	01-14	Halt current command string and wait until condition specified: <ul style="list-style-type: none"> 01 Wait for low on input 1 (Switch 1) 11 Wait for high on input 1 (Switch 1) 02 Wait for low on input 2 (Switch 2) 12 Wait for high on input 2 (Switch 2) 03 Wait for low on input 3 (Opto 1) 13 Wait for high on input 3 (Opto 1) 04 Wait for low on input 4 (Opto 2) 14 Wait for high on input 4 (Opto 2) If Halted operation can also be resumed by typing <i>/1R</i> . Also see <i>S</i> command for I/O dependant program execution. If an edge detect is desired, a look for Low and a look for High can be placed adjacent to each other E.g. <i>H01H11</i> is a rising edge detect. E.g. <i>/1gH02P10000G20R</i> - waits for switch 2 H command with no number after it waits for Switch 2 Closure (low).

2. Command Set

Command (case sensitive)	Operand	Description
S	01-14	<p>Skip next instruction depending on status of switch.</p> <p>01 Skip next instruction if low on input 1 (Switch 1) 11 Skip next instruction if high on input 1 (Switch 1) 02 Skip next instruction if low on input 2 (Switch 2) 12 Skip next instruction if high on input 2 (Switch 2) 03 Skip next instruction if low on input 3 (Opto 1) 13 Skip next instruction if high on input 3 (Opto 1) 04 Skip next instruction if low on input 4 (Opto 2) 14 Skip next instruction if high on input 4 (Opto 2)</p> <p>Program branching to a complex subroutine can be implemented by making the next instruction a stored string execution. (See examples). Loops can be escaped by branching to a stored string with no commands. E.g. <i>/1gS02A10000A0G20R</i> - skips on switch 2 Also see <i>H</i> command for I/O dependant program execution.</p>
PROGRAM STORAGE AND RECALL		
s	0-15	<p>Stores a program 0-3 or 0-15 depending on model, Program 0 is executed on power up. (25 full commands max per string) E.g. <i>/1s1A10000A0R</i> NOTE: This command takes approx 1 second to write to the EEPROM.</p>
e	0-15	<p>Executes stored program 0-15. E.g. <i>/1e1R</i></p>
PROGRAM EXECUTION		
R		<p>Run the command string that is currently in the execution buffer. E.g. <i>/1R</i></p>
X		<p>Repeat Run the current command string.</p>
SET MAX MOVE CURRENT / HOLD CURRENT		
m	0-100 (25)	<p>For Steppers “ Move” Current on a scale of 0 to 100% of max current. 100% = 2A for EZHR17EN. E.g. <i>/1m40R</i></p>
h	0-50 (10)	<p>Sets “Hold” current on a scale of 0 to 50% of max current. 100% = 2A for EZHR17EN E.g. <i>/1h15R</i></p>
aw	-	Reserved
ax	-	Reserved
ay	-	Reserved
MISC		
p	0-65000	<p>Ping Command (lower case “p”) This command will send a numeric message back to the host, when that point in the string is reached. E.g. <i>/1gA1000p3333A0G0R</i> Will send the number 3333 every time through the loop. NOTE: Care must be taken when using this command because it can tie up the 485 bus.</p>

Command (case sensitive)	Operand	Description
SET MICROSTEP RESOLUTION / ENCODER		
j	1, 2, 4, 8, 16, 32, 64, 128, 256 (256)	<p>Adjusts the resolution in micro-steps per step.</p> <p>It is recommended that step resolution be left at 256 microsteps (default).</p> <p>(It is recommended that this drive be left in 256 micro-step mode. Only use reduced resolution if step and direction mode (n96) is selected and high frequency step pulses cannot be generated.)</p> <p>For best microstep results, a motor must be selected that is capable of microstep operation.</p>
N	1-5 (1)	<p>Special Modes</p> <p>1 = Encoder With No Index (Default). Homes to Opto.</p> <p>2 = Encoder With Index. Homes to Index.</p> <p>3 = Uses Potentiometer 1 as an encoder. See Appendix 9.</p> <p>4 = First Home to Opto, then home to Index (future release)</p> <p>5 = CANBUS slave mode. In this mode the unit is a slave to position messages received via the CANBUS EZLink Connector. (future release)</p> <p>6 = Home to Index Exactly, even if the index is on a microstep (available with beta firmware V7.15).</p>

2. Command Set

Command (case sensitive)	Operand	Description
n	0-128000 (0)	<p>Sets Modes – Interpret as combination of binary bits.</p> <p>Bit0 (LSB) - <i>/1n1R</i> Enable Pulse Jog mode. Jog distance is given by “B” command. Velocity is given by <i>V</i> command . The Switch Inputs become the Jog Inputs.</p> <p>Bit1 - <i>/1n2R</i> Enable Limits. (The two optos become limits switches). The polarity of the limits is set by the <i>f</i> command</p> <p>Bit2 - <i>/1n4R</i> Enable Continuous Jog mode. Continuous run of motor while switch is depressed. Velocity is given by <i>V</i> command.</p> <p>Bit3 - <i>/1n8R</i> Enables Position Correction mode. See Appendix 8.</p> <p>Bit4 - <i>/1n16R</i> Enabled Overload Report Mode. See Appendix 8.</p> <p>Bit5 - <i>/1n32R</i> Enable Step And Direction Mode if (1) or enable Dual Encoder Mode if (0) E.g. <i>/1n96R<CR></i> (96=32+64) Enables step and dir mode and slaves the motor to it. (<i>/1?10</i> reads the count) See Appendix 14.</p> <p>Bit6 - <i>/1n64R</i> Enable Motor slave to encoder/step-dir.</p> <p>Bit7 - <i>/1n128R</i> Used for Joystick mode. See Appendix 9.</p> <p>Bit8 - <i>/1n256R</i> When set, this bit will disable the response from the drive. (future release)</p> <p>Bit9 and Bit10 - When set, these bits will execute one of the stored programs 13, 14 or 15 whenever the feedback shuts down the drive due to an overload or an error. (“au” retries are exhausted. See Appendix 8.</p> <p><i>/1n512R</i> will execute program 13. <i>/1n1024R</i> will execute program 14. <i>/1n1536R</i> will execute program 15. See Appendix 8 for an example..</p> <p>Bit11 - <i>/1n2048R</i> Reserved. Bit12 - <i>/1n4096R</i> Reserved. Bit13 - <i>/1n8192R</i> Uses potentiometer 2 to command the motion of the motor. See Appendix 9.</p> <p>Bit14 - <i>/1n16384R</i> When Set, this bit will kill any move if switch 1 is pushed. See also “d” command.</p> <p>Bit15 - <i>/1n32768R</i> When Set, this bit will kill any move if switch 2 is pushed. . See also “d” command.</p> <p>Bit16 - <i>/1n65536R</i> When Set, potentiometer on Opto 2 input will set velocity. (Joystick Mode) See Appendix 9.</p>
an	16384	<p><i>/1an16384</i> switches the limits from the main axis from the two opto inputs (inputs 3,4) to the two switch inputs (inputs 1,2) .</p> <p>Example <i>/1an16384R</i> . The second axis limits remain unchanged at 1,2. (Firmware version 6.998+)</p>
POSITION CORRECTION / FEEDBACK MODE		
		<p>See Appendix 8 for position correction commands. See Appendix 16 for s curve modes.</p>

Command (case sensitive)	Operand	Description
MISCELLANEOUS		
b	9600 19200 38400 to 230400 (9600)	Adjustable baud rate E.g. <code>/1b19200R</code> This command will usually be stored as program zero and execute on power up. Default baud rate is 9600. NOTE: correct termination and strict daisy chaining required for reliable operation at higher baud rates.
o	0-3000 (1500)	Allows the user to correct any unevenness in microstep size. It is best to adjust this with a current probe, but adjusting for lowest audible noise is a good approximation. This command can be executed while the motor is running. Try values very near 1500, such as 1470.
M	0-29999	Wait M number of milliseconds.
B	0-65000	Set jog distance when in n1 mode
aP	0-30000 (5)	Response delay (Available in V6.79+) This command allows the delay from the controller receiving the command to the response being sent out to be programmed. E.g. <code>/aP1000R<CR></code> sets the delay to 1000mS (measured in milliseconds)
d	0-65000 (10)	Switch debounce value Applies to kill move command only, The switch one or two must be depressed for a period of this number x 50µS prior to a Kill Move being called.
K	0-65000 (0)	Backlash compensation 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.
SINUSOIDAL SCAN (Available in V5.1 +)		
aA	0-2^31	Sets amplitude of scan. See Appendix 10.
aW	0-2^31	Sets frequency of scan. See Appendix 10.
ON/OFF POWER DRIVER		
J	0-3 (0)	On/Off Driver – Interpret as 2 bit Binary Value. 3=11= Both Drivers On, 2=10=Driver2 on Driver 1 Off etc. NOTE: If total current input to the board exceeds 2A, it will be necessary to change the input fuse to up to 4A.
STEPPER DRIVE DAUGHTER CARD COMMANDS		
aM	1 – 2	Selects drive. <code>/1aM1R</code> selects first drive. From then on all commands are sent to drive 1. <code>/1aM2R</code> selects drive 2. See Appendix 11. The second drive homes to opto #2 or switch #1.
BIDIRECTIONAL DRIVE DAUGHTER CARD		
<i>NOTE: When using the Logic Output daughter card, all the daughter card control signals become available as TTL digital outputs, including PWM. See Appendix 11.</i>		
I	0-500	<code>/1I400R</code> (lower-case L) sets current to 80%. (NOTE: the range was changed from 0-100 to 0-500 in firmware version V7.05A)
O	1	<code>/1O1R</code> sets the current flow one way.

2. Command Set

Command (case sensitive)	Operand	Description
I	1	/I1R sets the current flow in the other direction.
DEVICE RESPONSE PACKET		
		See Appendix 7 for detailed description of device response to commands. Some commands are new and present only in later models. (AllMotion, Inc. reserves the right to enhance the specifications at any time)
ANALOG-TO-DIGITAL CONVERTER COMMANDS		
		All four Inputs are ADC inputs, and can be read and acted upon by the program. Please see Appendix 9.
?aa		Reads back all 4 Input ADC values. E.g. /I?aa<CR> The readback order is channels 4:3:2:1
at	100000 to 116368 200000 to 216368 300000 to 316368 400000 to 416368 (6144)	Sets the threshold, upon which a “one” or “zero” is called for each of the 4 channels. The Number represents the channel number followed by a 5 digit number from 00000-16368 which represents the threshold on a scale from a 0-3.3V. The default values are 6144 for all 4 channels which represents 1.24V. Changing the threshold allows the H and S commands to work on a variable analog input value which essentially allows the program to act upon an analog level. This can be used for example to regulate pressure to a given level, by turning a motor on/off at a given voltage. E.g. /Iat106144R sets the threshold of channel 1 to 6144. Note that leading zeros are required for the threshold value, which is always 5 digits plus the channel number.
?at		Reads back the thresholds for all 4 channels. The readback order is channels 4:3:2:1 E.g. /I?at<CR>
POTENTIOMETER POSITION COMMAND		
		The motion of the Stepper can be slaved to value read from Potentiometer2. Please see Appendix 9.
ao	0-20000 (0)	After multiplication by the am value, this offset is added to obtain the position command. E.g. /Iao1000R<CR>
am	0-20000 (256)	The Potentiometer value is multiplied by this value and divided by 256 to get the position command. E.g. /Iam512R<CR>
ad	0-20000 (50)	Sets a deadband (in microsteps) around the potentiometer value used for the last move, which must be exceeded before a new move command is issued. The deadband is measured in microsteps and will need to be increased as the gain is increased. E.g. /Iad100R<CR>
Hardware protocol:		
The EZStepper® communicates over the RS485 bus at 9600 baud, 1 stop bit, no parity, no flow control.		
IMMEDIATE QUERY COMMANDS		
The following commands are “Immediate” commands, and cannot be cascaded in strings or stored. These commands execute while others commands are running. These commands do not require an “R” at the end.		

Command (case sensitive)	Operand	Description
T		Terminate current command or loop. E.g. /1T
?	0	Returns the current commanded motor position. E.g. /1?0
?	1	Reserved
?	2	Returns the current Slew/Max speed for Position mode.
?	3	Reserved
?	4	Returns the status of all four inputs, 0-15 representing a 4-bit binary pattern. Bit 0 = Switch1 Bit 1 = Switch2 Bit 2 = Opto 1 Bit 3 = Opto 2
?	a4	Returns the status of all four inputs, plus the value of the primary encoder inputs, read as digital I/O bits 0-127, representing a 7-bit binary pattern. /1?a4 Bit 0 = Switch1 Bit 1 = Switch2 Bit 2 = Opto 1 Bit 3 = Opto 2 Bit 4 = Encoder CHA Bit 5 = Encoder CHB Bit 7 = Encoder Index
?	5	Returns the current velocity mode Speed. (Stepper Only).
?	6	Returns the current step size microsteps /step (HR Version Only). Selected using J command.
?	7	Returns the current 'o' value. (HR version only)
?	8	Returns Encoder Position. (can be zeroed by zi command)
?	9	Erases all stored commands in EEPROM.
?	10	Returns the second encoder (n=0) / or step and dir input (n=32) count. NOTE: It is possible to just count pulses on switch inputs with this mode. (future release)
&		Returns the current firmware revision and date.
Q		Query current status of EZStepper®/EZServo®. Returns 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 EZStepper/EZServo is ready to accept commands. It is cleared when the EZStepper/EZServo is busy. The least significant four bits of the Status byte contain the completion code. The list of the codes is: 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 7.
n		The n mode works in both immediate mode and in strings.
\$		/1\$<CR> Returns the currently executing command string.

2. Command Set

Command (case sensitive)	Operand	Description
Other Query		In firmware version 7.02 and above it is possible to query parameters by using the same letter that set the parameter. E.g. <i>/?A</i> returns current position, <i>/1?V</i> returns velocity, and <i>/1?m</i> returns move current setting.

3. Single-Axis Programming Examples

The following examples are command strings in DT protocol.

Example #1 (A move to absolute position)

```
/I12345R<CR>
```

Command breakdown:

/ Start character. It lets the EZSteppers® know that a command is coming in.

I Device address, (set on address switch on device).

A12345 Turn to absolute position 12345

R Run the command.

<CR> Carriage return. Tells the EZStepper® that command string is complete and should be parsed.

NOTE: Hyperterminal issues each character as you type it in. Therefore it is not possible to cut and paste in Hyperterminal. Backspace is allowed only up to the address character. If backspace is used, all characters “backspaced” must be retyped in. If a typing error is made, typically hit enter and type it all in again – what was typed in will be overwritten as long as the *R* command at the end was not present.

Example #2 (Move loop with waits)

```
/IgA10000M500A0M500G10R<CR>
```

Command breakdown:

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

I Device address, (set on address switch on device).

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.

<CR> Carriage return. Tells EZStepper® that command string is complete and should be parsed.

To terminate the above loop while in progress, type */IT*.

3. Single-Axis Programming Examples

Example #3 (Program storage and recall)

This example stores a command string for later execution:

```
/!s2gA10000M500A0M500G10R<CR>
```

This stores the program in the preceding example as program 2.

```
/!e2R<CR>
```

Will execute the stored program #2.

NOTE: Program 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.

To erase a program, store the program without any commands.

e.g., /!s0R

NOTE: The first-ever A command will reset some motion parameters to default; hence it is recommended that programs stored in s0 have A0 as the first command.

Example #4 (Set current, wait for Switch 2 closure, home to opto)

```
/!s0m75h10gJ3M500J0M500G10H02A1000A0Z10000R<CR>
```

Command breakdown:

/!s0	Stores the program that follows in motor number 1 stored string 0 (string 0 is executed on power-up).
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.
M500	Wait 500 mS.
J0	Turn off both on off drivers.
M500	Wait 500 mS.
G10	Repeat loop above 10 times.
H02	Wait for a switch2 input to go low.
A1000	Move to position 1000.
A0	Move to position 0.
Z10000	Home the stepper to opto #1. Max steps allowed to find opto = 10000.
R	Run.

Example #5 (Nested loop example)

```
/lgA1000A10000gA1000A10000G10G100R<CR>
```

Command breakdown:

<i>/1</i>	Talk to drive number 1.
<i>g</i>	Start outer loop.
<i>A1000</i>	Go to Absolute position 1000.
<i>A10000</i>	Go to Absolute position 10000.
<i>g</i>	Start inner loop.
<i>A1000</i>	Go to Absolute position 1000.
<i>A10000</i>	Go to Absolute position 10000.
<i>G10</i>	Do inner loop 10 times. (end of Inner loop).
<i>G100</i>	Do outer loop 100 times. (end of outer loop).
<i>R</i>	Run.

NOTE: To terminate the above loop while in progress, type */IT*.

3. Single-Axis Programming Examples

Example #6 (Skip/Branch instruction)

Examples:

```
/Is0gA0A10000S13e1G0R<CR> (stored string 0)
```

```
/Is1gA0A1000S03e0G0R<CR> (stored string 1)
```

This stores two programs in string 0 and string 1, and the code switches from one program to the other depending on the state of input 3. In the example above, the code will cycle the motor between position A0 and A10000 if input 3 is high, and between A0 and A1000 if input 3 is low.

Stored string 0:

```
/I      Talk to motor 1.  
s0      Store following in string0 (executed on power-up).  
g       Start loop.  
A0      Go to absolute position 0.  
A10000  Go to absolute position 10000.  
S13     Skip next instruction if 1 (high) on input 3.  
e1      Jump to string 1.  
G0      End of loop (infinite loop).  
R       Run.
```

Stored string 1:

```
/I      Talk to motor 1.  
s0      Store what follows in string0 (executed on power up).  
g       Start loop.  
A0      Go to absolute position 0.  
A1000   Go to absolute position 1000.  
S03     Skip next instruction if 0 (low) on input 3.  
e0      Jump to string0.  
G0      End of loop (infinite loop).  
R       Run.
```

Example #7 (Monitor four switches and execute four different programs depending on which switch input is pushed)

```
/s0gS11e1S12e2S13e3S14e4G0R<CR>  
/s1A1000e0R<CR>  
/s2A2000e0R<CR>  
/s3A3000e0R<CR>  
/s4A4000e0R<CR>
```

This stores five program strings for an endless loop.

- At power-up String 0 automatically executes and loops around sampling the switches one by one, and skipping around the subsequent instruction if it is not depressed.
- Then for example when Switch1 is depressed stored String 1 is executed, which moves the stepper to position 1000.
- Execution then returns to Stored String 0, due to the e0 command at the end of the other stored strings.
- If the switch is still depressed it will jump back to String 1 again, but since it is already at that position there will be no visible motion.

To terminate the above endless loop, type */IT*.

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

Example #8 (Move 1000 steps forward on rising edge of Switch2)

```
/lgH02H12P1000G0R
```

The endless loop first waits for a 0 level on switch1, then waits for a “1” level on Input2.

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

To terminate the above endless loop, type */IT*.

4. Multiple-Axis Coordinated Motion Programming Examples

Introduction

Up to 16 motors can be addressed individually or in banks of 2, 4, or “All”, increasing versatility and ease of programming. Synchronized motion is possible by issuing commands addressed to individual EZSteppers® without the “R” (Run) command, which sets up the command without executing it. At the proper time, the “R” command is sent to a bank of motors to start several actions in concert.

Addressing Individual Motors

Addressing motors 1-9:

Use /1, /2, etc.

Addressing motors 10-16:

Use the ASCII characters that are above 1 through 9:

10 /: (colon)

11 /; (semi colon)

12 /< (less than)

13 /= (equals)

14 /> (greater than)

15 /? (question mark)

16 /@ (“at” sign) – use setting zero on the address switch for this.)

For example, /=A1000R moves stepper #13 to absolute position 1000.

Addressing Banks of Motors

Addressing banks of two motors:

Motors 1 and 2 /A

Motors 3 and 4 /C

Motors 5 and 6 /E

Motors 7 and 8 /G

Motors 9 and 10 /I

Motors 11 and 12 /K

Motors 13 and 14 /M

Motors 15 and 16 /O

Addressing banks of four motors:

Motors 1,2,3, and 4 : /Q

Motors 5,6,7, and 8 : /U

Motors 9,10,11, and 12: /Y

Motors 13,14,15 and 16 : /] (close square bracket)

Addressing All Motors At Once

Use the global address `/_` (underscore).

Addressing More Than 16 Motors

It is possible to have add an offset of 16 or 32 to the number on the address switch. Please see the *aB* command in Appendix 13 for explanation.

Example #9 (Coordinated motion with axes performing same motion)

Command:

```
/_A1000R<CR>
```

Breakdown:

`/_` (Slash then underscore) Address all 15 motors.

`A1000` Go to absolute position 1000.

`R` Run. All motors go to absolute position 1000.

Example #10 (Coordinated motion with axes performing different motions)

Command:

```
/1A10000<CR>
```

```
/2A200<CR>
```

```
/AR<CR>
```

Breakdown:

`/1A10000<CR>` Set up motor 1 command buffer to go to absolute position 10000.

`/2A2000<CR>` Set up motor 2 command buffer to go to absolute position 2000.

`/AR` Execute current commands in buffer for bank address "A" which is motors 1 and 2. (The "A" here is an address of a bank of motors 1 and 2 because it comes after the slash, and should not be confused with the "A" that means absolute position.) Both moves will start at the same time, and complete at a time determined by the velocity set for each axis.

Appendix 1. Stepper Motor Electrical Specification

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

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

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

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

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

$$I = (V/R) (1 - \exp(-tR/L))$$

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

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

1. Reduce the inductance of the motor.
2. Increase the forcing function voltage V .

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

For (2) the trick is to use a motor which is rated at about $\frac{1}{4}$ of the supply voltage (V). This means that it takes less time to ramp the current to a given value. (Once the current reaches the desired value the “chopper” type drive used in the EZSteppers® will “chop” the input voltage in order to maintain the current—so the current never actually gets to the final value of V/R , but the advantage of “heading towards” a higher current with the same time constant is that the current gets to any given value faster.) The lower voltage motor also has less back EMF, and does not subtract as much from the applied voltage.

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

Appendix 2. Homing Algorithm Detail

Overview

The Z command is used to initialize the motor to a known position. When issued, the motor will turn toward 0 until the home opto sensor is interrupted. If already interrupted, it will back out of the opto and come back in until re-interrupted. Current motor position is set to zero. The homing is done at the current speed V. The maximum number of steps allowed to go toward home is defined by the Z command operand + 400. The maximum number of steps away from home (while sensor is cut) is 10000.

To set up the home flags:

First ensure that a positive move, e.g. */IP100R*, moves away from home and the home flag. If motor does not move away from home, flip the connections to only one of the windings of the stepper.

The default condition expects the output of the home flag to be low when away from home (as is the case in an opto). If home flag is high when away from home (as in the case of the “normally open” switch), issue the command */If1R* to reverse the polarity that is expected of the home flag.

Issue the command */IZ100000R* or */IfIZ100000R* as necessary.

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

Opto and flag should be set up to be unambiguous. For example, when the motor is at one end of travel, the flag should cut the opto; and when at other end of travel, the flag should not cut the opto. There should be only one black-to-white transition possible in the whole range of travel. Home can be done to an opto (N1 mode) or index pulse (N2 mode).

The main axis homes to opto1 (input 3). This opto is also the lower limit.

The main axis uses opto 2 (input 4) as its upper limit.

The second axis on the daughter card uses the two switch inputs as home and limits:

- Switch 1 (input 1) is home and lower limit.
- Switch 2 (input 2) is the upper limit.

Note that limits are engaged by */In2R*. (lower case “n”). The default (n0) mode does not check the limits when moving.

Default “f” mode (*f0*) expects the inputs to be low when the axis is away from the limits/home. */If1R* reverses this, “f1” can be chosen per axis, e.g., */1aM1f1aM2f0R* selects different polarities for the home flags of the two different axes.

Furthermore, the threshold for the inputs’ high/low transition level can be programmed via the “at” (@) command. Thus, if for example the home sensor does not fully pull to a TTL low level, as in the case of a

reflective sensor, the intermediate level can be accommodated by the EZStepper® circuits without external signal conditioning.

NOTE: The optos and switches are interchangeable. If four optos are desired, power for the extra optos can be drawn from the 5V supply on the encoder connector. These extra optos may require an external resistor in series with the LED. When connecting switches, connect between any input and ground.

Main Axis Homing Details

There are four full steps in a single electrical cycle that moves the stepper motor (A+, B+, A-, B-). For repeatability in homing, the home position is set to first step in that cycle which occurs after the flag edge has been seen. (This means that the home position is defined some ways beyond the middle of the flag).

However, there is a small but definite chance that an ambiguity in home position may occur in the rare case that the exact point of switching into A+ occurs at the same point at which the flag gets cut. In this case, a four-step ambiguity in home position may exist, because sometimes the flag may cut just before and sometimes just after. The procedure below describes a method by which the ambiguity can be removed. However, this procedure need not be followed if a four-step inaccuracy in Home position is acceptable.

To eliminate the home position ambiguity:

Issue the Z command, and allow the motor to home.

Move 2 full steps (in any direction),

Mechanically move the flag edge (or sensor) such that it trips in the middle of the sensor by adjusting it while watching the status LED on the board which shows the status of the home sensor. This will ensure that the flag trips at A- and thus the motor will home to a unique position of A+.

Another way to do this, if it is not hazardous:

Put the motor in an endless homing loop via `/!gZ10000GR`.

Move the flag/opto around while the motor is homing. It will be noticed that the motor will home to two distinct positions that are four steps apart. Make sure the high-to-low transition point of the opto is NOT near these positions (the exact position does not matter as long as it is not near the place where it homes to).

Second Axis Homing Details

The second axis will home to the exact transition of the home flag, and does not seek a Phase A zero. The second axis uses the switch inputs for homing and limits.

Manual homing

Motors can be manually homed to any input by the use of a polling loop such as:

1. */IsIz0R* (Store set current position to zero program 1.)
2. */Iz100000gDIS04e1GR* (Go backward in an endless loop until input 4 goes high.)

Homing to a hard stop

It is possible to send the motor against a hard stop and then force the position counter to zero or some other value as necessary. */Iz0R* (lower case “z”) zeros the position counter and encoder for the motor that is currently selected. */Iz333R* sets the position to 333 etc. So */IaM1z0R* zeros the counters for motor 1 and */IaM2z0R* zeros the position counters for motor 2.

Homing to the index

N2 Mode: The main axis will home to the encoder index in */IN2R* mode. The index must be at least 100µS in width. The axis will home to the next phase A zero after passing the Index. In this mode it is necessary to ensure that the Index is not on a Phase A zero, or else a four-step ambiguity in home position will exist. This is explained in Main Axis Homing Details, above. Note that the index is sampled at a 20kHz rate, and may be missed if the speed of motion is too high.

N6 Mode (available in beta firmware V7.15): In this mode, the motor will home to the index position exactly, even if the index is on a micro-step position. This mode employs a high-speed input capture to ensure that the index will be detected even at high speed. The motor will decelerate to rest slowly after the index has passed, and will have a negative position after homing. In order to view the exact home position, issue an *A0* after the *Z* command.

Example:

/In0m30h30P100V1000aE25600N5ZI10000A0n8ac1R

Other Notes on Homing

For accuracy, it is important to home at a slow speed. If high-speed homing is desired, then home at high speed first and then at low speed.

e.g. */IV100000ZI100000V1000ZI100000R*

If homing to a slotted wheel, ensure that the slot is at least 16 full steps wide. Note that the exact width of the slot does not matter since it homes to an edge.

Note that it is possible to plug an opto sensor or switch into the encoder connector and use the home to index function.

Appendix 3. Microstepping Primer

First consider a full stepping driver.

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

When full stepping, a typical sequence is:

A+ (Only winding A current applied in +ve Direction)

B+ (Only winding B current applied in +ve Direction)

A- (Only winding A current applied in -ve Direction)

B- (Only winding B current applied in -ve Direction)

(A full electrical cycle consists of four steps.)

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

Now consider microstepping:

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

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

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

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

Appendix 4. Heat Dissipation

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

When the drive generates heat, the heat first warms the circuit board and heat fin (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.

The electronics for EZSteppers® are fully capable of running at the rated voltage and current. However, due to the small size of the boards, which limits the steady state heat transfer to the ambient, care must be taken when the drive is used in high duty cycle and/or high current applications. For conservative operation, it is recommended that the duty cycle be reduced linearly, from 100% duty at 50% of rated current, to 25% duty at 100% of rated current. (Duty cycle means the percentage of the time that the drive is moving the load – average 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.

In case the EZStepper® is required to run 100% of the time at 100% current, forced air cooling or bolting against an aluminum heat fin with heat-conductive foam is recommended. Use a compliant foam pad such as Bergquist BER224, available from Digikey.

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

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

Appendix 5. Step Loss Detection Using Opto

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

Step loss is easily detected by following the algorithm below:

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

If the opto was not at the state expected, steps may have been lost.

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

¹ See homing algorithm detail in Appendix 2.

Appendix 6. 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

/IA12345R<CR> in DT protocol is equivalent to *(CtrlB)11A12345R(Ctrl C)#* in OEM protocol.

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

/lgA1000M500A0M500G10R<CR> in DT protocol is equivalent to *(CtrlB)1lgA1000M500A0M500G10R(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)

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 7. Device Response Packet

Introduction

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

Response Packet Structure

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

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

Bits 3 thru 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.”

A program that receives these responses must continuously parse for /0 and take the response from the bytes that follow /0. The first character that comes back may be corrupted due to line turnaround transients, and should not be used as a “timing mark.”

Example Initialization Error Response

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

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

Example Invalid Command Response

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

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

Example Operand Out Of Range Response

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

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

Example Overload Error Response

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

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

Example Response To Command “/1?4”

- FFh: RS485 line turn around character. It's transmitted at the beginning of a message.
- 2Fh: ASCII “/” Start character. The DT protocol uses the ‘/’ for this.
- 30h: ASCII “0” This is the address of the recipient for the message. In this case ASCII zero (30h) represents the master controller.
- 60h: This is the status character (as explained above).
- 31h: These two bytes are the actual answer in ASCII. This is an eleven which represents the status of the four inputs. The inputs form a four-bit value. The weighting of the bits is:
- Bit 0 = Switch 1
 - Bit 1 = Switch 2
 - Bit 2 = Opto 1
 - Bit 3 = Opto 2
- 03h: This is the ETX, or end-of-text character. It is located at the end of the answer string.
- 0Dh: This is the carriage return.
- 0Ah: This is the line feed.

Appendix 8. Position Correction Mode and Overload Report Mode

Position Correction Mode (V6.7+)

Position correction mode, when enabled, will move until the encoder reads the correct number. Once enabled, positions are given in quadrature encoder counts of the encoder (not in microsteps). If the motor stalls during a move, the mode will re-attempt the move until the encoder reads the correct number. These algorithms run while the stepper is in motion and will detect a stalled motor during a move.

There are two main types of feedback arrangements: the first method is to place the encoder on the motor shaft. The second method is to place the encoder on the component that is finally positioned, and may be only be loosely coupled to the motor due to backlash etc. The EZStepper® will work with either type of feedback.

Setting Up Encoder Feedback

1. Set the encoder ratio.

NOTE: the encoder ratio should preferably be changed when at the zero position.

Encoder Ratio = (microsteps/rev divided by quadrature encoder ticks/rev) x 1000.

The encoder ratio must preferably be a whole number after the multiply by 1000. (If this is not a whole number, see discussion further down).

The motor must be left in 256th microstep mode for correct operation of feedback mode.

For example, a 1.8-degree stepper (running in 1/256th step mode), which has 200x256 microsteps /rev, is hooked up to a 400-line encoder that has 1600 quadrature encoder counts.

$$aE = ((200 \times 256) / (400 \times 4)) \times 1000 = 32000$$

Issue the command `/aE32000R` to set this encoder ratio.

NOTE: If the encoder ratio is unknown, do the following:

1. Leave the encoder ratio at its power-up default of 1000.
2. Ensure that the encoder increases its count when the motor moves in the positive direction. If not, switch either the AB lines on the encoder, which will reverse the count direction; or switch the wires to one of the windings on the stepper motor, which will reverse the direction of rotation (do not use the *F* command).
3. Issue `/In0R` to clear any special modes.
4. Issue `/Iz0R`, which will zero both the encoder and step position.

5. Issue `/IA100000R` and ensure that the move completes at a velocity that does not stall.
6. Issue `/I?0`, which reads back the current position. This should be 100000.
7. Issue `/I?8`, which reads back the encoder position.
8. Issue `/IaEOR` which auto divides these two numbers.
9. Issue `/I?aE`, which reads back the encoder ratio computed.

This value read-back is only a rough guide, and will be out by a few counts due to inaccuracies in the motor position and run-out in the encoder.

NOTE: The value read-back MUST be overwritten by the EXACT value that represents ratio.

10. Issue `/IaE32000R`, or whichever exact number represents the encoder ratio.

2. (Optional) Set the error in quadrature encoder ticks allowed before a correction is issued.

E.g. `/IaC50R` (default is 50)

3. (Optional) Set the Overload Timeout Value.

This is the number of retries allowed under a stall condition.

E.g. `/Iau10000R` (default is 100)

4. Enable the feedback mode.

1. Zero positions just prior to enabling feedback mode by issuing `/Iz0R`. (Or issue `/Iz10000R` etc. if you need to at this time.)
2. Enable position correction mode by issuing `/In8R`.

Example (V6.7+):

`/Iz0aC50h40m40au100aE32000V1000n8R` starts the position correction mode.

Fine position correction (V6.99+)

When in `n8` mode, there are two position correction algorithms:

- The COARSE ALGORITHM, as described above, operates to bring the motors to within the value given by “`aC`” (upper case C). This algorithm runs all the time (while the stepper is in motion) and will detect a motor that is stalled or lagging by more than “`aC`” during a move. When a problem is detected the axis will stop and reissue a move starting from zero velocity so as to slowly spin up motor that may have stalled at high speed.

In firmware version 6.99+, a fine position correction integrator algorithm (FINE ALGORITHM) is engaged once the major move is completed to zero out any small residual position error. The speed of this correction is affected by the “`x`” integration period value. `/Ix10R` is default. Smaller values of `x` correct faster but may lead to

oscillations, e.g., $/1x3R$. The fine position correction deadband is set by “ac” (lower case c) E.g.: $/1ac10R$, the default ac is 20 encoder counts. This can be adjusted down to zero, if desired but it may take time to settle depending on stiction and backlash, especially if the encoder is decoupled from the motor. The integration algorithm runs on hold current, and this may need to be adjusted to a reasonably high number, depending on the load. It is also best to run hold current equal to move current so that the motor does not relax and detent at the end of the move.

Move complete (non busy) will be asserted when the move completes to within “ac” for the first time. Subsequent disturbances greater than “ac” but less than “aC” will be corrected by the fine correction algorithm and will not be reported as “busy”. Only disturbances greater than “aC” will result in the coarse correction algorithm being engaged and busy being asserted.

Example: (V6.99+)

$/1aM1z0aC50ac10x10h40m40au100aE32000L100n8R$

Notes On Feedback Mode

- If motor consistently stops during a move:

If a very fine line count encoder is used such that for example the encoder ratio is around 2000, or if the encoder is decoupled from the motor shaft, or if the encoder ratio has some fractional component and is non integer, increase the error (aC) allowed for the coarse algorithm, for example set aC to 2000. This way a move that is in progress will not be halted and restarted, because the coarse algorithm detects that the following error is too large. Instead, the move will complete with some error, and the fine algorithm integrator will null out the error to within the lower case “ac” value at the end of the move.

- Busy/Non Busy Status:

The status will read busy until any move is reached to within the “ac” value; however, once a move is complete any subsequent disturbance is handled by the fine integrator as long as it is less than “aC” (upper-case C). These subsequent corrections by the fine algorithm will not read busy; however, if the error becomes greater than “aC” the dead reckoning algorithm is turned on, and a formal correction move is initiated. This move changes the drive status to busy, and no external commands will then be accepted. It is important to set the coarse dead reckoning deadband (aC value) to a reasonable number (for example, 50) else the drive will always be attempting to correct.

Other Notes

- When position correction mode is enabled (*/In8R*) the drive will keep retrying any stalled moves until “*au*” retries are exhausted, and will NOT halt any strings or loops upon detection of a stall.
- During position correction mode, */IT* will halt any move, but there is a possibility that the drive may instantly reissue itself a position correction command, especially if it is fighting a constant disturbance. It may be necessary to issue a */In0R* to positively halt a move in progress.
- If the encoder ratio is changed from its default of 1000, the allowed max position will be decreased from $+2^{31}$ by the same ratio. The count will rollover from positive to negative range when this limit is exceeded.
- Do not use the upper case “*F*” (reverse direction) command when using encoder feedback mode. Instead, switch the encoder AB lines or the wires to one phase of the motor.
- Jog mode will not work with encoder feedback on.

Dual Axis Position Correction Mode

In firmware V6.78 and later, it is possible to put both axes into correction mode.

Examples:

- */1aM1z0aC50au5u3aE12800L100n8R* sets up encoder feedback mode for axis 1.
- */1aM2z0j16aC500ac10au10000aE1000n8R* sets up encoder feedback mode for axis 2.

The second encoder is wired to the 8-pin I/O connector as shown in the wiring diagram.

Arbitrary Measurement Units

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

Overload Report Mode

In *n8* feedback mode, the drive will automatically correct any stalled moves up to the limit given by “*au*.” Only then will it report Error 9 of an overload.

However, it may be desirable to detect a stall but not correct it. The *n16* mode does just this. The encoder value is continuously compared against the commanded position and Error 9 is set when these do not match to within the error band specified by “*aC*”. When this error occurs, the

drive will exit from any loops or multiple command strings it may be executing.

Overload report mode is enabled by */InI6R*, and requires the encoder ratio to be entered correctly via the “*aE*” command. Issue */IzR* to zero both the encoder and position counter just prior to issuing */InI6R*.

When an overload occurs, the drive can be set to execute stored strings 13, 14, or 15. See auto recovery scripts below.

Auto Recovery in Feedback Mode

Auto Recovery is available in firmware V6.997+.

Auto Recovery Scripts (Available in V6.997+)

In n8 mode, the EZStepper® determines a stalled or overload condition by checking to see if the encoder is tracking the commanded trajectory. If the encoder is not following the commanded trajectory within the error specified by “*ac*”, a number of retries given by the “*au*” command are executed.

When an overload condition is detected (retry counter has exceeded the “*au*” value), it will be reported back as an upper or lower case “*I*” (Error 9) when the status is queried. 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. For this purpose, we have the “n” mode bits n512 and n1024.

It is necessary to combine these bits with n8 so, for example, n512+n8 = n520.

Depending on which of these bits is set, the servo will execute stored program 13, 14 or 15 when an overload is detected. Program 12 is also executed as a last resort if programs 13,14, or 15 cannot auto recover after retrying the number of times given by the “*au*” command. NOTE: an overload error on any motor, if enabled, will execute error recovery.

Example:

1. Enter */IsI3pI202n520R*. This sets error recovery script to send “1202” on every recovery.
/IsI2pI201R sets final script to send “1201.”
2. */IaMIm5h5z0aC50au5u3aE12800L100n520R* sets h= 5 and m=5 so that we can stall the motor easily.
3. Setup encoder ratio as appropriate: */IaE32000R* etc.
4. Zero Encoder and Position Counter */IzOR*
5. Set *au* = 5 so that 5 retries max are allowed
6. Set *u* = 5 so that program 13 is run a maximum of 3 times.
7. Set *n* =520 = *n8* + n512 so that stored program 13 will be issued on error condition.
8. Now move the motor shaft so that the motor tries to correct 5 times and then gives up.

Appendix 8. Position Correction Mode and Overload Report Mode

9. After the 5th retry the motor will execute stored program 13 and will attempt to send a 1202 on the 485 bus. Then the feedback turns on and 5 more tries are made. If the motor is held stalled, the 1202 will be sent 32 times followed by a 1201 as the final recovery script , stored program 12, is run.

Typical reasons that the following error is too great:

- “m” value (current) set too low.
- “L” value (acceleration) set too high for torque available from motor.
- “V” value (velocity) set too high for torque available from motor.
- Physical obstruction, or excessive friction.

Table 2. Position Correction Mode Commands

Command	Operand	Description
aC	1-65000 (50)	When in position correction mode, set distance allowed to move before the motor corrects using encoder feedback. E.g. /1aC100R See Appendix 8.
aE	1000-10 ⁶ (1000)	Set Encoder ratio. This sets the ratio between the encoder ticks/rev and the microsteps/rev for the motor. E.g. /1aE12500R See Appendix 8.
au	1-64999 (10)	Set Overload Timeout. This sets the number of times the move is retried in case a move stalls. E.g. /1au10000R When the au retries are exhausted, the drive will drop out of feedback mode (n8) and report Error 9 (overload)
x	1-10000 (10)	Set Integration period (V 6.99 +) A fine position correction integrator algorithm is engaged once the major move is completed to zero out any small residual position error. The speed of this correction is affected by the “x” integration period value. /1x10R is default. Smaller values of x correct faster but may lead to oscillations E.g. /1x3R
n	0-4095 (0)	Bit3 : /1n8R enables Position Correction mode. See Appendix 8. Bit4 : /1n16R enables Overload Report mode. Bit9 and Bit10: When set, these bit will execute one of the stored programs 13, 14, or 15 whenever the feedback shuts down the drive due to an overload or an error. (The “au” retries are exhausted. See Appendix 8. /1n512R executes program 13. /1n1024R executes program 14. /1n1536R executes program 15.
zsac	1-65000 (50)	Sets the final error allowed by the fine position correction algorithm.
u	1-65000 (0)	In Version 6.99 and greater, sets the number of times error recovery scripts 13, 14, or 15 are run prior to calling upon final recovery script 12.

Appendix 9. Analog Inputs and Analog Feedback

Analog Inputs

The four inputs of the EZStepper® are all ADC inputs.

- The ADC values can be read via RS485, E.g., `/I?aa<CR>`. These values are on a scale of 0-16368 as the input varies from 0-3.3V. The inputs as shipped are good to about 7 bits, but can be made to be better than 10 bits with the removal of the input overvoltage protection circuitry (call factory for details).
- The threshold upon which a digital “one” or “zero” is called can be varied with the “*at*” command and affect the Halt H command or Skip S command.

Example: `/Iat309999R<CR>`. This sets the threshold on input 3 to 09999. Note that it is necessary to insert leading zeros after the input number (3), since the threshold value must always be entered as five digits (00000-16368).

- The thresholds for all four inputs can be read back with the `/I?at<CR>` command. The units have a default threshold value of 6144 (1.24V).
- It is possible, for example, 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. E.g. `/Iat308000gS03P1000G0R`.
- A potentiometer can be placed as shown in the wiring diagram, and its position read back via the `/I?aa<CR>` command. Note that the supply provided (which normally drives an LED) has 200 ohms in series with 5V, so the use of a 500-ohm potentiometer will give a range of almost 0-3.3V range on the inputs.

Potentiometer Position Command

Potentiometer 2 (see wiring diagram) can be used to command the position of the main axis only (Motor 1). The value read back on potentiometer 2, from 0-16368, is multiplied by the multiplier “*am*” and then divided by 256. Then an offset given by “*ao*” is added. The motor will use this number just as if it had been commanded by a */IA12345R*-type command. Further, there is a “deadband” command, “*ad*”, which sets a dead band on the 0-16368 potentiometer value read back such that a value outside this deadband must be seen before a command is issued to cause a move.

The command */IaM1ao100ad100am1000n8192R<CR>* enables potentiometer command mode.

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

Use 500-ohm potentiometer. (see wiring diagram)

Supply pin of potentiometer already has 200 ohms in series on the board to 5V

Value from potentiometer = 0 to 16368 for 0-3.3V on wiper.

E.g. */Iao1228R<CR>* sets *ao* offset to 1228. Default is 0.

E.g. */Iam256R<CR>* sets *am* multiplier to 256. Default is 256.

E.g. */Iad100<CR>* sets the deadband in microsteps to 100. Default is 50).

Potentiometer Velocity Mode (joystick mode)

This is available in firmware version 6.7+

Potentiometer 2 (see product wiring diagram) can be used to command the velocity of the main axis only (motor1). The value read back on potentiometer 2, from 0-16368, is multiplied by the multiplier “am” and then divided by 256. The motor uses this number just as if it had been commanded by a V command.

1. Use */In65536R* to enter velocity mode.

Once in this mode, */IzOR* will set zero velocity to the current position on the potentiometer.

2. Issue */IP0* to start an endless move based on the velocity as read from the potentiometer.

— */IzxxxR*, where *xxx* is non zero, will set zero to that value of the potentiometer.

— *ad* sets the dead band on the potentiometer about mid scale.

— *am* sets the multiplier where:

$$\text{velocity in microsteps/sec or encoder ticks/sec} = [(\text{potentiometer value}(0\text{to}16368) - (\text{potentiometer zero value from “z” command}) - (“ad” deadband value}/2))] \times (am/256)$$

So,

/Iad100am1000n65536zOPOR starts the mode.

to terminate, type

/In0<CR>

/IT<CR>

The actual velocity can be read back by */I?V<CR>*.

It is also possible to use the potentiometer to set the magnitude of the velocity and Switch1 input to be the direction of the velocity. Bit 7 Enables this.

/Iad100am1000n65664zOPOR starts the mode. (65664=65536+128)

(Please request V6.998 or later firmware for this feature.)

Further, it is possible to know if the shaft is following the commanded velocity, by using a shaft encoder for feedback and setting the encoder ratio (*aE*) and the following error (*aC*), and setting n16 mode to report overloads 65552 = (65536 + 16).

/Iad100aC400am128n65552aE12800zOPOR

If the potentiometer velocity mode is to be used with limits, the limits can be switched to the two switch inputs, so as not to interfere with the potentiometer. The command to do this is */Ian16384R*.

Example: */Iad100am1000an16384n65538zOPOR* switches limits to the alternate inputs, and enables limits (65536 +2 = 65538).

Beginning in firmware version 7.05C, in the mode where the direction of motion is set by switch 1: if this mode is enabled with the limits also enabled, Input 3 opto 1 becomes the direction line. So Switch 1 and 2 can then be made limits with the *an16384* command. The result is joystick mode with limits enabled and TTL direction input.

```
/1ad100am1000an16384n65666z0P0R
```

(65666=65536+128 +2)

note that the *fl* command can reverse the polarity of the limits if needed.

```
/1f1ad100am1000an16384n65666z0P0R
```

Potentiometer Position Feedback

This is available in Firmware V6.7+.

Potentiometer 1 can be used as an encoder for the main axis only (Motor 1). The value read back is from 0-16368.

NOTE: Please read Appendix 8 on encoder feedback mode first. Operation in potentiometer position feedback mode is identical to encoder feedback mode except that the potentiometer acts as an encoder which generates positions between 0 and 16386.

The command */IN3R* designates Potentiometer 1 as the encoder (in place of the quadrature encoder).

To use this mode:

1. Wire a 500-ohm linear taper potentiometer to the Potentiometer 1 position.
2. Connect the motor shaft to the shaft of the potentiometer, such that a move in the positive direction for the motor increases the value read from the potentiometer using the */I?aa* command.
3. Turn the potentiometer all the way to zero by issuing a *D* command, e.g. */ID1000R*.
4. Issue */Iz0R* to zero the motor position.
5. Issue */IN3R* to enable the potentiometer as encoder .
6. Move motor by issuing *P* commands until it is about $\frac{3}{4}$ of potentiometer range.
7. Issue */IaE0R* to automatically work out the “encoder ratio” for the potentiometer.
8. Issue */In8R* to enable feedback mode.

Note that if the motor shaft is forced, a correction will be issued to return the motor to its original position.

If shaft oscillates at some positions, this may be because of a nonlinearity in the potentiometer. Try increasing the dead band set by the *aC* command. Or it could be because the zero position was not set correctly. Another cause of oscillations is a “scratchy” potentiometer. Try adding a 0.1 μ F capacitance between the wiper terminal and ground.

NOTE: To start feedback at a non-zero potentiometer position, read the current potentiometer value (position) with */I?aa* , say it's 2345, then issue */Iz2345N3n8R*.

Example: (V6.7+) :

/1aM1z0aC50h40m40au100aE32000V1000N3n8R

Example (V6.99+ ,with fine position correction):

/1aM1z0aC50ac10x10h40m40au100aE32000L100N3n8R

NOTE: See Appendix 8 for parameter explanations.

To exit this mode, type */In0R* followed by */IT*.

Appendix 10. Sinusoidal Scan

Sinusoidal scan requires firmware V6.7+.

The EZHRXXEN models can be commanded to automatically scan in a sinusoidal profile.

- The amplitude of the scan motion is set by the “*aA*” command.

Example: */1aA51200R* sets a peak-to-peak amplitude of 51200 microsteps (one revolution on a 1.8-degree stepper). Any change in amplitude will be made as the sinusoid goes through the zero crossing.

- The frequency of the scan is set by the “*aW*” command.

Example: */1aW1000R* sets frequency to be $f = (X) * 20000 / (1024 * 65536)$, where *X* is 1000 in this example.

To exit from this mode, issue a zero amplitude */1aA0R*.

Appendix 11. Daughter Cards

The EZHR17EN model can accept one of four daughter cards:

- Dual Axis Stepper Daughter Card (Requires firmware V6.79 or later)
- Bidirectional PWM Current Mode Drive Daughter Card
- Bidirectional PWM Voltage Mode Drive Daughter Card
- Logic Output Daughter Card

Dual Axis Stepper Daughter Card (firmware V6.79 or later)

The Dual Stepper Daughter card is a 1 Amp 1/16th-step capable daughter card.

NOTE: this card only works from a 10V-30V supply.

To issue commands to the daughter card first issue the command */1aM2R* (*Motor 2*). All subsequent commands go to the daughter card motor. */1aM1R* returns to the primary axis. E.g. */1aM2V10L1A1000AOR*

The second axis can run full, half, quarter, and 1/16th step only (*/1aM2j16R* etc).

The default resolution is half step.

The second axis daughter card is rated at One Amp.

The second axis homes to Switch 1, and uses Switch 1 and 2 as its limits (*/1n2R* mode).

It is possible to home to the index on the channel 2 encoder by issuing the command */1aM2N2R*. Then the second axis will home to Opto2, where the second axis encoder index is connected.

NOTE: Beta versions of firmware before V6.74 always homed to Opto2.

The second axis and the second encoder can be zeroed by issuing */1aM2zOR*

The */I?0* and */I?8* position queries report the position of the current axis and encoder selected by the last */1aM2R* or */1aM1R* command

Simultaneous motion: Beginning with firmware V6.78, it is possible to run both axes simultaneously in full encoder feedback mode. It is possible to issue *A*, *P*, and *D* commands simultaneously to both axes, (only these three commands (*A*, *P*, and *D*) work with the following examples. Commands are separated by commas.)

/1A1000,-1000R will move axis one to 1000 and axis two to -1000.

/1P-1000,1000R will move axis one backwards by 1000 and axis 2 forward by 1000.

Dual axis encoder feedback mode example:

Both axes can simultaneously feed back from encoders or even potentiometers.

/1aM1j256au10000aE32000n8R sets up the encoder feedback mode for axis 1.

/1aM2j16au10000aE4000n8R sets up the encoder feedback mode for axis 2.

Note that, when feedback is used, the encoder inputs use up the limit switches for the second axis. In case the drive needs to be “homed” when in feedback mode, one of the other inputs will need to be used, and a manual home routine written.

Manual homing can be done by sampling one of the inputs.

E.g., use stored program zero as an escape from an endless loop:

- */1s1R* (Store nothing in program 1.)
- */1gDIS04e1GR* (Go backwards in an endless loop until input 4 goes high.)

Bidirectional Current Mode Drive Daughter Card For I/O Function

The bidirectional current mode drive daughter card can drive a bipolar current, for example to operate a bidirectional latching relay.

/1I80R sets the current in this drive to 80% for example. (lower case “L”)

/1O1R sets the current flow one way.

/1I1R sets the current flow in the other direction .

It is not necessary to issue dual axis commands such as *aM2* when using this daughter card.

Bidirectional Drive Daughter Card For DC Servo

Requires firmware version 7.06+.

The bidirectional daughter card can drive a bipolar current, and hence can be used to control a DC motor with full feedback servo function.

A DC motor with its encoder connected to the secondary encoder input (as shown in the product wiring diagram) will allow Axis 2 to be a DC servo.

1. Issue */1N8R* to enable this mode.
2. Connect as shown in the wiring diagram and issue the command */1N8aM2 A10000A0R*.

The motor should rotate back and forth. If the motor spins out of control, reverse the motor leads (or reverse the encoder AB leads) and try again.

PID values can also be changed with the *w x* and *y* commands,
w x y = P I D.

Bidirectional Voltage Mode Drive Daughter Card For I/O Function (-PW)

The Bidirectional Voltage Mode Drive Daughter Card produces a bipolar PWM voltage, for driving resistive loads or a DC motor with open-loop voltage. Commands are the same as described above for the bidirectional current mode daughter card.

Logic Output Daughter Card

There are four logic (TTL) signals that come out of the daughter card via the miniature DSUB on the main board. These have been put through 24mA-capable drive chips and made available on a connector by this daughter card. The signals respond to commands designed for the other daughter cards, and thus can, for example, be used to drive an external drive.

The four logic signals are:

- Step – step pulses that are approx 1 μ S wide are present when Axis 2 moves.
- Direction – High/low level on this pin sets the direction of motion on axis 2. This can also be modified by the *O/I* command.
- Current PWM – 20KHz PWM whose duty cycle responds to commands that set current E.g. “*m*”, “*h*” for axis 2 , and “*l*” for the bi-directional daughter.
- Step resolution – activated by the *j2 /j16* command.

Input Current Consideration When Using Daughter Cards

Note that the input fuse on the EZHR17EN is set to 2A, depending on the daughter card and the ratio of input voltage to the load. The fuse may be increased to up to 4A. Call factory for details.

Measure the input current under full load to see if it is necessary to do this. Typically the input current is much less than the motor current by the ratio of the motor voltage to the supply voltage (conservation of power), the drive essentially acting as a switching supply.

Appendix 12. On-the-fly Parameter Change

The EZHR17EN firmware version 6.9981 and later allows on-the-fly position, velocity, and acceleration change. This allows virtually any trajectory to be generated.

Once moving, commands can be issued ONE AT A TIME without the “R.”

- */IA1000000R<CR>* will start the move.
- */IV10000<CR>* will change the velocity while moving.
- */IA0<CR>* will make the drive automatically decelerate and then head back to zero.

For example: a *P200* command, if issued while moving, will cause the motor to go 200 steps from the current position (not final target).

A, P, D, L, and *V* can be changed on the fly.

Appendix 13. Addressing More Than 16 Motors On Same Bus

Table 3. Address Bank Selection (V6.7+)

Basic Command (case sensitive)	Subset	Description
aB		<p>Allows up to 48 drives to be addressed by adding 16 or 32 to the value of the address switch.</p> <p>CAUTION: Use this command <u>ONLY</u> if you have more than 16 motors on the bus. Else <u>DO NOT</u> use it.</p>
	aB49520	Sets address bank to 0-15 (normal default mode).
	aB49521	Sets address bank to 16-32 (uses ascii 61-70 for addressing).
	aB49522	Sets address bank to 33-47 (uses ascii 71-7f for addressing).
	/_aB49520	Globally sets all addresses to bank zero. Issue if bank is unknown.

Table 4. Binary Address Selection (V7.02+)

Basic Command (case sensitive)	Subset	Description
aB		<p>NOTE: Use this command <u>ONLY</u> if you have more than 16 motors on the bus. Otherwise <u>DO NOT</u> use.</p> <p>Sets the address of a device to any binary number between 0 and 127 decimal. XXX will be the number in decimal.</p> <p>For example <i>/1aB496065R</i> sets the address of the device to 65, which is "A" in ascii. After sending this command, further communication with the device is by using "A" as the address. The device now responds to <i>/A&</i>.</p> <p>Typically, this command would be stored in the EEPROM, for example <i>/1s0aB496065R</i>.</p>
	aB49520R	<p>Globally sets all addresses to bank zero. Issue if address is lost.</p> <p>NOTE: The underscore "" global character (decimal 095) is not allowed with the <i>aB496XXX</i> command.</p>

Appendix 14. Encoders and Step/DIR Pulse Input

The EZHR17EN model has dual encoder inputs. Any quadrature encoder with AB and (optional) index input is acceptable. In addition, step and direction style position counting is also supported on the secondary encoder.

Read-Only Mode

In this, the simplest mode, the encoders are simply read back.

The command */I?8* reads the primary encoder on the 5-pin connector, and */I?10* reads back the secondary encoder on the 8-pin connector. The primary encoder is always in quadrature encoder mode and expects quadrature pulses on the AB lines. The secondary encoder can be placed in quadrature encoder or in step and direction counting mod, depending on whether or not */In32R* mode is enabled.

Additionally, *1aM1R* and */1aM2R* switch back and forth between the primary and secondary motors; and */I?8* reads back the primary encoder when in *aM1* mode, and the secondary encoder when in *aM2* mode.

Encoder/Step and Direction Following Mode

In this mode, the motor takes the count from the secondary encoder and uses this count as a commanded position. The count can come in from another AB quadrature style encoder, or from step and direction pulses.

1. Select AB or step and direction using */In32R* etc.
2. Turn on “Motor Slave to Encoder2” by issuing */In64R*.

Examples: */In96R* (96=32+64) enables step and direction mode and slaves the motor to it. */In64R* enables the encoder mode and slaves the motor to it.

The input step count (readable by */I?10*) is related to the motor position by the following relationship: stepper position = (“am” multiplier / 256) x (step and direction count or encoder count).

Counts are in microsteps set by the *j* command.

Main Axis Encoder Feedback Mode

The main axis can use the primary encoder for feedback and the secondary encoder for “command.” Please see the section on encoder feedback.

Dual Axis Feedback Mode

The main axis can use the primary encoder for feedback and the second axis can use the second encoder for feedback. Please see the section on Dual Axis.

Electrical

Please see the appropriate product wiring diagram for wiring details.

The encoder(s) must draw a total current of <100mA from the 5V pin.

Encoders must have 0.2V Low to 4V High swing at the input of the connector.

Appendix 15. Jog Modes and Limit Switches

Jog

The EZHR17EN can be placed in a mode that will allow the two switch inputs to “Jog” the motor backwards and forwards. The command for this is */In4R*. Once issued, the motor can be moved by pressing switch 1 or 2. Internally these inputs are “pulled up” with 10K ohms to 3.3V. A closure to ground is all that is required.

Note that these are inputs 1 and 2, and that the status of the switches can be read via firmware by */I?4*. This command returns a binary number between 0-15, which represents the status of the four inputs.

Limit Modes

The EZHR17EN uses the two opto inputs as limits. These are inputs 3 and 4. It should be noted that these inputs are general-purpose inputs and can be driven by switch closures, etc., or any device that produces a voltage change. The inputs are actually ADC inputs, and the One/Zero threshold can be set by the “*at*” command.

Input 3 is the lower limit and also the home switch. Input 4 is the upper limit. Both limits are simultaneously turned on by the */In2R* command.

The default expects optos which are low when away from the limit. This polarity can be changed by issuing */IfIR*, for example when normally open switches are used for limits. (NOTE: normally closed switches are better for limits, since any disconnect of the wires will shut down the motion). When n2 mode is engaged, the motor will not move in the direction in which a limit is active, but will back out of the limit.

In V 6.998 and later firmware, the limits can be moved to the switch inputs 1, 2 if desired by issuing the command */Ian16384R*.

Note that limit switches can be used to kill moves, e.g. */In2gA100000A0GR* will loop between *A100000* and *A0*, but if say the positive limit is cut during the *A100000* then that command is terminated and the *A0* command is run.

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 may slow the response.

Appendix 16. S Curve

NOTE: S-curve acceleration is available beginning with special beta release firmware version 7.21.

This acceleration is useful for moving fluids, for example where the fluids will not “slosh” at the end of the move.

The S curve mode is turned on by issuing a non zero “jerk” value. This is done by issuing the *aj* command.

Example: */1aj1V51200P10000R*

For smoother motion in S curve mode, the second axis computation can be turned off and the first axis computation run twice as often if the command */1N32R* is issued. This will give better S curve performance at high speed.

Setting the *aj* value to 0 will turn this mode off. This mode only works for finite A, P and D moves. On-the-fly parameter change is not allowed, since the entire profile is pre-computed in the S-curve mode.

Appendix 17. Inputs and Outputs

Table 5. Input and Output Commands

Command (case sensitive)	Operand	Description
NOTE: The EZHR17EN, in addition to driving the motor and reading two encoders, has a total of seven inputs and five outputs.		
ANALOG INPUTS		
All four Inputs are ADC, and can be read and acted upon by the program. Please see Appendix 9.		
?aa		<p>Reads back all four Input ADC values. E.g. /1?aa<CR> The readback order is channels 4:3:2:1</p> <p>In the EZ4AXIS, additional /1?aa1 or /1?aa2 or /1?aa3 or /?aa4 reads back the analog values on the home flag connectors for the respective axis.</p>
at	<p>100000 to 116368 200000 to 216368 300000 to 316368 400000 to 416368 (6144)</p>	<p>Sets the threshold upon which a “one” or “zero” is called for each of the four channels. The first numeral represents the channel number. The following 5-digit number, which can range from 00000-16368, represents the threshold on a scale from 0-3.3V. The default value for all four channels is 6144, which represents 1.24V.</p> <p>Changing the threshold allows the H and S commands to work on a variable analog input level. This can be used, for example to regulate pressure to a specified level by turning a motor on/off at a given input voltage.</p> <p>Example: /1at106144R sets the threshold of channel 1 to 6144. Note that leading zeros after the channel number are required for the threshold value to maintain five digits plus the channel number.</p>
?at		<p>Reads back the thresholds for all four channels. The readback order is channels 4:3:2:1 E.g. /1?at<CR> to read back channel 1.</p>
DIGITAL INPUTS		
?	4	<p>Returns the status of all four inputs, 0-15 representing a 4-bit binary pattern. /1?4 Bit 0 = Switch1 Bit 1 = Switch2 Bit 2 = Opto 1 Bit 3 = Opto 2</p>
?	a4	<p>Returns the status of all four inputs, plus the value of the primary encoder inputs, read as digital I/O bits 0-127, representing a 7-bit binary pattern. /1?a4 Bit 0 = Switch1 Bit 1 = Switch2 Bit 2 = Opto 1 Bit 3 = Opto 2 Bit 4 = Encoder CHA Bit 5 = Encoder CHB Bit 7 = Encoder Index</p>
DIGITAL OUTPUTS		
J	0-3 (0)	<p>On/Off Power Driver – Interpret as 2-bit binary value. 3=11= Both Drivers On, 2=10=Driver 2 on, Driver 1 Off etc.</p>

Appendix 18. EZ4AXIS Special Commands

The EZ4AXIS Four-Axis Controller/Driver follows the general architecture described in this document.

The following commands have been implemented. These commands are as described earlier in this manual: A,b,B, aB,c,D,e,f,g,G,H,J,p,P,K,L,aM,M,n,N,an,s,at,v,V,h,m,z,Z

Some commands can be issued to the currently selected motor, or to all four motors simultaneously.

To move one motor at a time

/1aM1A1000A0R

/1aM2A1000A0R

/1aM3A1000A0R

/1aM4A1000A0R

Once an axis is selected, all subsequent single-axis commands and queries will correspond to that axis:

/1aM4R Selects Axis 4

/1A1000R Moves Axis 4 to position 1000

/I?0 Retrieves Axis 4 position

/1L10R Sets Axis 4 Acceleration

To move all motors simultaneously

/1A1000,1000,1000,1000A0,0,0,0R

Note that motors will wait until all have completed their motion.

To only move certain axes, omit the number in the non-moving axes (firmware V7.04).

Example: */1A1000,,1000,A0,,0,R* will only move axes 1 and 3.

The following commands can only be issued to all four axes simultaneously:

/1L100,100,100,100R Set Accn.

/1V1000,1000,1000,1000R Set Velocity.

/1h10,10,10,10R Set hold currents.

/1m30,30,30,30R Set move (m) currents.

/1P1000,-1000,1000,-1000R Relative forwards move (note negative numbers allowed)

/1D1000,1000,1000,1000R Relative backwards move

Note that all other commands (e.g., Z command) require individually selecting the motor and issuing the command */1am3ZI00000R*.

On-the-Fly parameter change

The velocities accelerations and target positions can be changed “on the fly.” This requires V7.05G firmware.

This can be done for one motor (currently selected axis) or for all 4 motors.

Examples:

/IV2000R (no *R* required if in motion) will change the velocity of the currently moving axis.

/IV1000,2000,3000,4000 will change the velocities of all four axes while in motion.

/IA1000,2000,3000,4000 will change the targets of all four axes while in motion.

/IA1000,,1000, will change the target position for axes 1 and 3 while running.

NOTE: The on-the-fly mode allows truly independent control of the motors, as opposed to a stored program mode where drives will wait for each other to reach a coordinate.

Home inputs status

The status of the Home inputs can be read:

/I?aa1

/I?aa2

/I?aa3

/I?aa4

Coordinate mode and Semi-Independent mode

/Ian16R . If bit 4 of the “an” command is zero (default), the device acts in coordinate mode, where all axes will wait for the others to get to the coordinate before executing the next command. If bit 4 is set to one, the next command is allowed to start before all motors finish the current command. However, the command following the next command will not execute until the first command is exited by all motors. This applies to commands stored in a program only, commands sent by the computer will be accepted at any time as an on the fly parameter change.

NOTE: any multi-axis command will reset the default motor to Motor 1.

Exceptions to main command set

- The EZ4AXIS drive is always in 1/16th step mode.
- The EZ4AXIS has a max V of 59900
- The EZ4AXIS equation for *accn* (acceleration) is:

$$\text{Acceleration in microsteps / sec}^2 = (L \text{ value}) \times (100,000,000/65536)$$
For example, if $V=10000$ and $L=1$, it will require 6.5536 seconds to reach final velocity.
- */I?aA* reads back positions of all four motors (requires V7.50 or higher firmware).
- */Ian65536* puts axes 1 and 2 into linear interpolation mode, where the speed of the faster axis is slowed such that both axes arrive at the destination at the same time. (Note: this mode is active only with the ‘A’ command.)

Issue commands such as */Ian65536A1000,2000R*. Omit axes 3 and 4 (requires V7.50 or higher firmware)
- */I?aV* reads back velocities of all four motors (requires V7.50 or higher firmware).

Halt and Skip on status of limit switches

The EZ4AXIS drive, in addition to Halt and Skip on the 4 primary inputs, can also Halt and Skip in response to the status of the limit switches. The normal 2-digit *HXX* command or *SXX* command is extended to 3 digits, with the most significant digit being the I/O block / axis number. The commands are:

/IH101P100R – Halt for a zero on block 1 input 2.

/IH211P100R – Halt for a one on block 1 input 1.

Etc. (16 possibilities for Halt and 16 possibilities for Skip)

Reading back encoder inputs as I/O

In addition to the */I?4* command, which reads back the binary value of the four main inputs as a number from 0-15 for bits 3,2,1,0, an additional command (*/I?a4*) has been implemented. This adds bits 7,6,5 to yield a number from 0-127. The additional bits are bit 6 (64), the index input, Bit 5 (32), the middle pin on the encoder connector labeled CHAN A, and Bit 4 (16), the end pin on the encoder connector labeled CHAN B.

Home Flags

Each motor has its own set of home flags; these are on the 6-pin connectors. The polarity of each flag can be changed individually, e.g., */IaM3f1R* etc

Programmable Threshold on Axis Inputs

Similarly to the “at” threshold command described elsewhere in this document, the threshold of the I/O associated with each axis can be programmed:

Simply add the axis number to the beginning of the command. For example, to set axis 4 upper limit to 10000, issue */1at4210000R* (note seven numerical digits).

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

All four axes' thresholds can be read back by issuing the */1?aat* command. The order of readback is 12, 11, 22, 21, 32, 31, 42, 41 (requires V7.50 firmware).

Current and voltage ratings and motor selection

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

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

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

Typically if using the motor at high current and high duty cycle (move time), the drive must be heat sunk against an aluminum surface with a very thin layer of a Bergquist type heat sink foam (BER225 on digikey.com), or forced-air cooled. Typically, if the drive gets too hot, the motors will start “clicking” on and off. The drive should be operated well away from this region for long life.

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

NOTE: AllMotion® provides a heat sink for this drive. Please see the stepper accessories section of the AllMotion® website.