ALLMOTION

EZStepper® *Model EZ4AXIS*

**Intelligent 4-axis Controller/Driver with Dual Encoder Feedback**

General Specifications

Supply Input.......................... 9–30V 4A *Examples*: Digikey part 102-1337-ND or 62-1047-ND (enclosed)

Dimensions........................... 2.25" X 2.25" (57mm X 57mm) square, .6" (15mm) thick

Step Resolution/speed .... 1/16 microstep; 59000 microsteps/second

Operating Modes.................. PC controlled or standalone

PC Control .... Up to 16 controllers can be daisy-chained together.

Communications Protocol..... USB and RS485. Direct USB and RS485 connections built in. Provision built in for future addition of CAN protocol.

Control Protocol................... Compatible with devices that use the Cavro DT or OEM protocol. Can use EZCommander™ Windows application or serial terminal program such as HyperTerminal to issue commands. ASCII text-based commands.

Motor Compatibility.............. Typically compatible with any stepper motor that is 3" or smaller (size 23 or smaller). Outputs can regulate to any motor voltage via software commands.

Mating Connectors .... AMP MTA 100 series. Recommended tools: Digikey A9982; or (better) A1998 + A2031

Digital/Analog Interface .... Accepts 10 opto-electronic or 12 mechanical switch inputs, or 4 mechanical switch inputs. Also 12 ADC inputs. ADC inputs accurate to 7 bits; can be modified to 10 bit (contact factory

Signal Levels: <0.8V Vlow; >2V Vhigh (TTL compatible). Threshold set at 1.23V; can be changed via programming

Optical switch specifications: Transistor optical switch with IC> 1 mA @ IF=20mA. Examples: Digikey QVA11134 or H21A1; Honeywell HOA1887-012 or HOA1870-33 (prewired); OPTEK OPB830W11 (prewired).

5V Output Current .... <200mA (power available for encoders and sensors)

Encoder Interface .... Max. freq. 4 MHz, 5V signals (3.3V upon special request)

Operating Temperature......... -20 to 85° C PCB copper temperature

Relative Humidity.................. 10% to 90% non condensing (operating and storage)
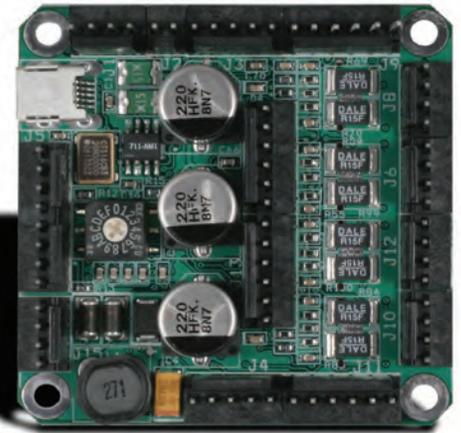
Model EZ4AXIS actual size

For rapid implementation of multi-axis stepper motor solutions in products requiring automation. Controls four fully independent stepper motors.
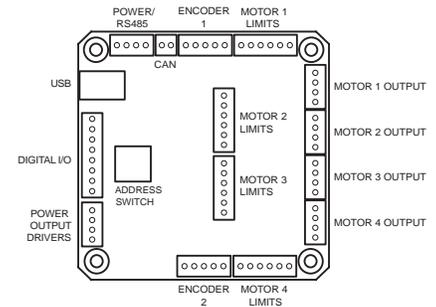
DIGITAL I/O CONNECTOR
Mating connector: AMP MTA 100 Series 8 pin, 26 GA, part 3-643815-8 Digikey part A31030-ND

Pin	Function	Notes
1	Switch input #2, A/D input #2	10k Ω pullup to 3.3V. Switch closure is to ground.
2	Switch input #1, A/D input #1	10k Ω pullup to 3.3V. Switch closure is to ground.
3	Opto sensor #2 LED	See Note 1.
4	Opto sensor #2 input, A/D input #4, switch	10k Ω pullup to 3.3V. Switch closure is to ground.
5	Opto sensor #2 ground	Common input ground
6	Opto Sensor #1 LED	See Note 1.
7	Opto Sensor #1 input, A/D Input #3, switch	10k Ω pullup to 3.3V. Switch closure is to ground.
8	Opto sensor #1 ground	Common input ground

ENCODER CONNECTORS (2)
Mating connector: AMP MTA 100 Series 5 pin, 26 GA, part 3-643815-5 Digikey part A31027-ND

Pin	Function	Notes
1	Ground	Ground for encoder
2	Index	Input from encoder. High level must be >4.5V (external pullups may be required).
3	Chan A	Input from encoder. See comment for Pin 2.
4	+5V (V+)	Power to encoder
5	Chan B	Input from encoder. See comment for Pin 2.

POWER OUTPUT DRIVERS CONNECTOR
Mating connector: AMP MTA 100 Series 4 pin, 22GA, part 3-643813-4 Digikey part A31108-ND

Pin	Function	Notes
1	ON/OFF Driver #2 (V-)	Open collector
2	ON/OFF Driver #2 (V+)	2A peak; 1A continuous
3	ON/OFF Driver #1 (V-)	Open collector
4	ON/OFF Driver #1 (V+)	2A peak; 1A continuous

Note 1: Each LED sensor input includes a series 200 Ω resistor to 5V. Resistor can be removed for sensors needing direct access to 5V. Max current draw is <200mA.

POWER AND RS485 COMMUNICATION
Mating connector: AMP MTA 100 Series 4 pin, 22 GA, part 3-643813-4 Digikey part A31108-ND

Pin	Function
1	V+ (external supply) +9–30V
2	GROUND
3	RS485 B
4	RS485 A

MOTOR OUTPUT CONNECTORS (4)
Mating connector: AMP MTA 100 Series 4 pin, 22 GA, part 3-643813-4 Digikey part A31108-ND

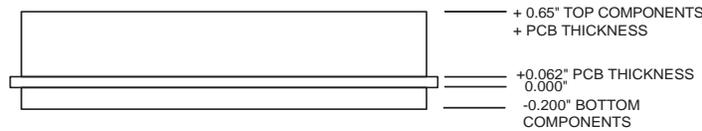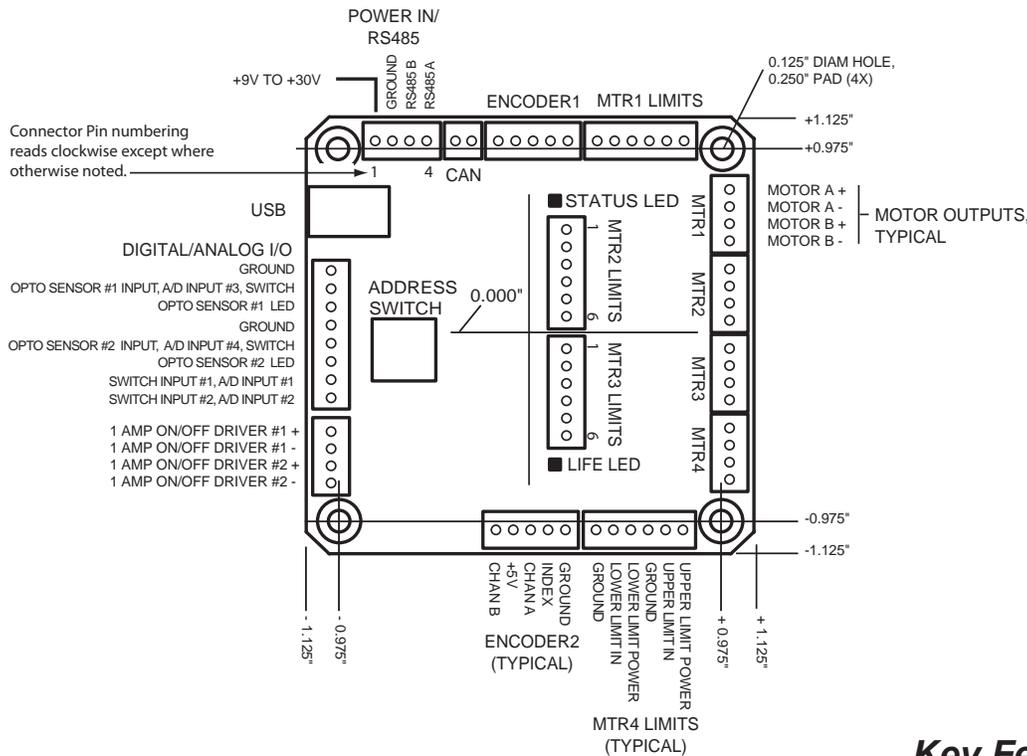| Pin	Function
1	Motor A+
2	Motor A-
3	Motor B+
4	Motor B-

MOTOR LIMIT CONNECTORS (4)
Mating connector: AMP MTA 100 Series 4 pin, 22 GA, part 3-643813-4 Digikey part A31108-ND

Pin	Function	Notes
1	Upper Limit Power	Typically optical sensor LED. See Note 1.
2	Upper Limit In	Optical sensor/switch to ground
3	GROUND	Ground
4	Lower Limit Power	Typically optical sensor LED. See Note 1.
5	Lower Limit In	Optical sensor/switch to ground
6	GROUND	Ground

Mechanical Specifications

POWER IN/ RS485

+9V TO +30V

GROUND
RS485 B
RS485 A

0.125" DIAM HOLE, 0.250" PAD (4X)

ENCODER1   MTR1 LIMITS

+1.125"
+0.975"

Connector Pin numbering reads clockwise except where otherwise noted.

1   4   CAN

USB

STATUS LED

MOTOR A +
MOTOR A -
MOTOR B +
MOTOR B -

MOTOR OUTPUTS, TYPICAL

MTR1

DIGITAL/ANALOG I/O
GROUND
OPTO SENSOR #1 INPUT, A/D INPUT #3, SWITCH
OPTO SENSOR #1 LED
GROUND
OPTO SENSOR #2 INPUT, A/D INPUT #4, SWITCH
OPTO SENSOR #2 LED
SWITCH INPUT #1, A/D INPUT #1
SWITCH INPUT #2, A/D INPUT #2

1 AMP ON/OFF DRIVER #1 +
1 AMP ON/OFF DRIVER #1 -
1 AMP ON/OFF DRIVER #2 +
1 AMP ON/OFF DRIVER #2 -

ADDRESS SWITCH

0.000"

MTR2 LIMITS

MTR3 LIMITS

LIFE LED

MTR2

MTR3

MTR4

-0.975"
-1.125"

- 1.125"
- 0.975"

CHAN B
+5V
CHAN A
INDEX
GROUND

ENCODER2 (TYPICAL)

GROUND
LOWER LIMIT IN
LOWER LIMIT POWER
UPPER LIMIT IN
UPPER LIMIT POWER

+ 0.975"
+ 1.125"

MTR4 LIMITS (TYPICAL)

+ 0.65" TOP COMPONENTS
+ PCB THICKNESS

+0.062" PCB THICKNESS
0.000"

-0.200" BOTTOM COMPONENTS

Key Features

- Full-featured 4-axis position controller with power drivers
- Accepts dual encoders
- Four independent 1A chopper (PWM) drives
- 9V to 30V 4A operation
- 1/16th microstep resolution
- Up to 59000 microsteps/second
- Pre-wired for opto-switch and Limit inputs
- 12 ADC inputs. Halt/branch on ADC value
- RS232, RS485, or USB-based communications
- Direct USB and RS485 connection built in
- Industry standard communications protocol
- Single 4-wire bus links up to 16 AllMotion products.
- Standalone operation with no connection to a PC
- 12 digital in and two 1A power on/off drivers
- Switch-selectable device address
- Software-selectable max. currents
- On-board EEPROM for user program storage
- Hold current automatically selected upon move completion
- Homes to opto or switch closure with one command
- Independent parameters for all axes (acceleration, velocity, currents, etc.)
- Fully programmable acceleration ramps and speeds

Ordering Information

Name	Order Number
EZ4AXIS Stepper Controller/Driver	EZ4AXIS
RS232 to RS485 Converter (option)	RS485

RoHs-compliant available on special order

See EZ4AXIS wiring diagram (on website) for application details.

MOTOR1 LIMITS

POWER INPUT AND RS485 COMMUNICATION

+10V TO +40V
GROUND
RS485 B
RS485 A

ENCODER1

GROUND
INDEX
CHAN A
+5V
CHAN B

MOTOR1 UPPER LIMIT POWER
MOTOR1 UPPER LIMIT IN
MOTOR1 LOWER LIMIT POWER
MOTOR1 LOWER LIMIT IN
GROUND

USB CONNECTION

USB

☐ **STATUS LED**

DIGITAL I/O CONNECTOR

OPTO SENSOR #1 GROUND / SW CLOSURE GND
OPTO SENSOR #1 PHOTO TRANSISTOR
OPTO SENSOR #1 LED
OPTO SENSOR #2 GROUND / SW CLOSURE GND
OPTO SENSOR #2 PHOTO TRANSISTOR
OPTO SENSOR #2 LED
☐ SWITCH CLOSURE TO GROUND INPUT
☐ SWITCH CLOSURE TO GROUND INPUT

POWER OUTPUT DRIVERS

1 AMP ON/OFF DRIVER #1 +
1 AMP ON/OFF DRIVER #1 -
1 AMP ON/OFF DRIVER #2 +
1 AMP ON/OFF DRIVER #2 -

ADDRESS SWITCH

MOTOR2 UPR LIM PWR
MOTOR2 UPPER LIM IN
GROUND
MOTOR2 LWR LIM PWR
MOTOR2 LOWER LIM IN
GROUND

MOTOR2 LIMITS

MOTOR3 UPR LIM PWR
MOTOR3 UPPER LIM IN
GROUND
MOTOR3 LWR LIM PWR
MOTOR3 LOWER LIM IN
GROUND

MOTOR3 LIMITS

☐ **LIFE LED**

MOTOR1 A+
MOTOR1 A-
MOTOR1 B+
MOTOR1 B+   **MOTOR 1**

MOTOR2 A+
MOTOR2 A-
MOTOR2 B+
MOTOR2 B+   **MOTOR 2**

MOTOR3 A+
MOTOR3 A-
MOTOR3 B+
MOTOR3 B+   **MOTOR 3**

MOTOR4 A+
MOTOR4 A-
MOTOR4 B+
MOTOR4 B+   **MOTOR 4**

DO NOT UNPLUG LOADS WHILE POWER IS ON

DO NOT UNPLUG LOADS WHILE POWER IS ON

CHAN B
+5V
CHAN A
INDEX
GROUND

ENCODER1

GROUND
MOTOR4 LOWER LIMIT IN
MOTOR4 LOWER LIMIT POWER
GROUND
MOTOR4 UPPER LIMIT IN
MOTOR4 UPPER LIMIT POWER

⬇ **PAGE DOWN** ⬇

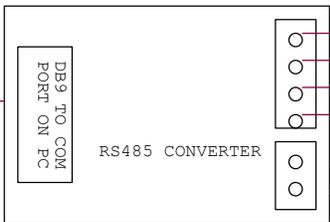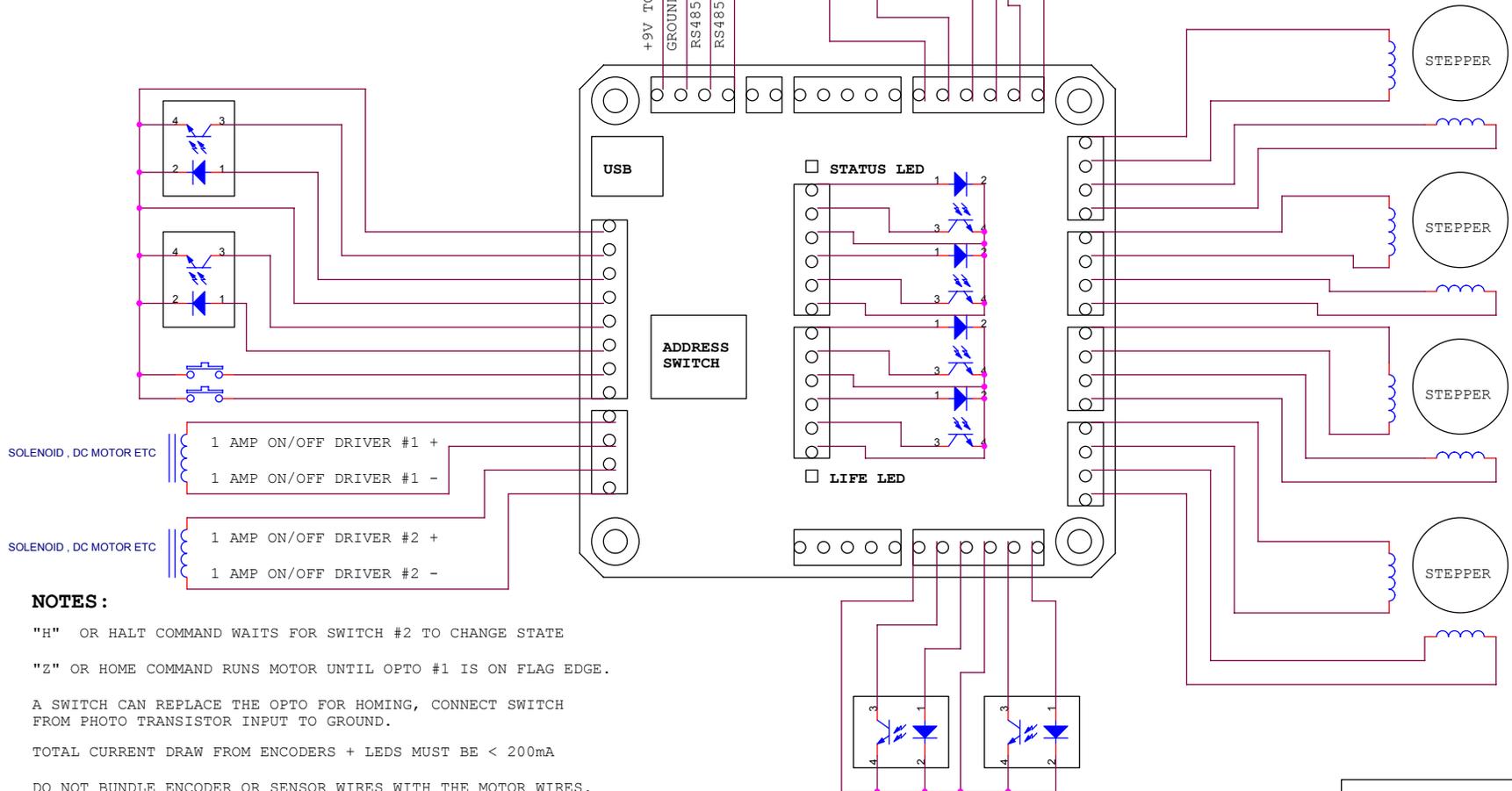**MOTOR4 LIMITS**

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EZ 4AXIS DRIVER CONTROLLER

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TO PC COM PORT

USE 9600 BAUD
8BIT, NO PARITY,
1 STOP, NO FLOW
CTRL.

DB9 TO COM PORT ON PC

RS485 CONVERTER

+9V TO +30V

GROUND

TO OTHER
EZ STEPPERS

+9V TO +30V
GROUND
RS485 B
RS485 A

STEPPER

STEPPER

STEPPER

STEPPER

USB

ADDRESS SWITCH

☐ STATUS LED

☐ LIFE LED

SOLENOID , DC MOTOR ETC

1 AMP ON/OFF DRIVER #1 +

1 AMP ON/OFF DRIVER #1 -

SOLENOID , DC MOTOR ETC

1 AMP ON/OFF DRIVER #2 +

1 AMP ON/OFF DRIVER #2 -

NOTES:

"H" OR HALT COMMAND WAITS FOR SWITCH #2 TO CHANGE STATE

"Z" OR HOME COMMAND RUNS MOTOR UNTIL OPTO #1 IS ON FLAG EDGE.

A SWITCH CAN REPLACE THE OPTO FOR HOMING, CONNECT SWITCH
FROM PHOTO TRANSISTOR INPUT TO GROUND.

TOTAL CURRENT DRAW FROM ENCODERS + LEDS MUST BE < 200mA

DO NOT BUNDLE ENCODER OR SENSOR WIRES WITH THE MOTOR WIRES.

SHIELD MOTOR WIRES WITH A GROUNDED BRAID TO REDUCE EMI

4 AXIS STEPPER DRIVER CONTROLLER WITH DUAL ENCODERS

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EZ 4 AXIS DRIVER CONTROLLER ACESSORIES AND OTHER ELECTRICAL NOTES

MATING CONNECTORS:

AMP MTA 100 SERIES

4PIN 22 GA DIGIKEY P/N A31108 (INPUT / MOTOR / OUTPUT CONNECTOR)

8PIN 26 GA DIGIKEY P/N A31030 (FOR OPTOS)

6PIN 26 GA DIGIKEY P/N A31028 (FOR OPTOS)

5PIN 26 GA DIGIKEY P/N A31027 (FOR ENCODER)

T HANDLE CRIMP TOOL DIGIKEY P/N A9982

PISTOL GRIP TOOL DIGIKEY P/N A1998 + A2031

MOTORS:

1) THE EZ STEPPER WILL DRIVE MOST STEPPER MOTORS

2) FOR BEST PERFORMANCE SELECT A MOTOR THAT IS RATED AT ABOUT 1/4 OF THE SUPPLY VOLTAGE. (Eg USE A 6V MOTOR WITH A 24V SUPPLY).

3) FOR (UNIPOLAR) STEPPER MOTORS WITH CENTER TAPPED WINDINGS , TYPICALLY LEAVE THE CENTER TAP UNCONNECTED, OR WIRE PER MANUFACTURERS RECOMMENDATIONS.

SUITABLE POWER SUPPLIES:

1) FOR FIRST TIME USERS, TO GUARD AGAINST A POSSIBLE MISWIRE, A CURRENT LIMITED LAB SUPPLY SET TO 12V AND 0.5A IS RECOMMENDED.

2) A SUPPLY OF 24V AND 2A CAPABILITY IS GOOD FOR MOST PURPOSES. POSSIBLE CHOICES ARE:
   DIGIKEY P/N 237-1296-ND
   DIGIKEY P/N 237-1395-ND (ENCLOSED)

3) INPUT CURRENT IS MUCH LESS THAN MOTOR CURRENT DUE TO THE SWITCHING (PWM). IT CAN BE CALULATED BY CONSIDERING CONSERVATION OF POWER. HOWEVER IT IS IMPORTANT TO MAKE SURE THAT THE SUPPLY WILL NOT FOLD BACK AS IT IS COMING UP SINCE THE EZ STEPPER WILL DRAW MORE CURRENT AT LOWER VOLTAGES.

OPTO HOME SWITCH:

1) "Z" OR HOME COMMAND RUNS MOTOR UNTIL OPTO #1 IS ON FLAG EDGE.

2) AN OPTO SWITCH PROVIDED WITH EACH STARTER KIT

3) USE TRANSISTOR OPTO THAT HAS Ic > 1mA @ IF = 20mA.

4) EXAMPLES OF ACCEPTABLE OPTOS ARE:
   DIGIKEY P/N QVA11134
   DIGIKEY P/N H21A1
   HONEYWELL HOA1887-012 (IS PREWIRED)
   HONEYWELL HOA1870-33 (IS PREWIRED)
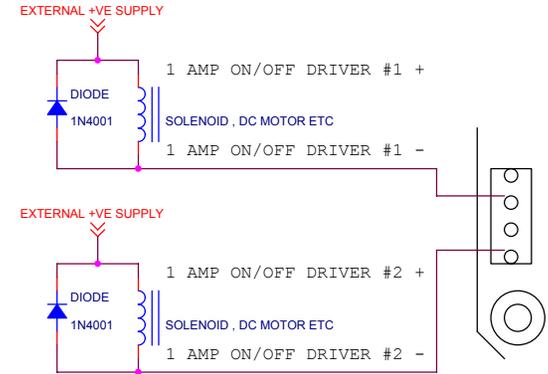   OPTEK OPB830W11 (IS PREWIRED)

5) THE OPTO COUPLER LED PIN HAS 150 OHM TO 5V IN SERIES ON THE BOARD. THE 150 OHM CAN BE REMOVED IF DESIRED FOR RUNNING SENSORS THAT REQUIRE DIRECT ACESS TO 5V. THE COLLECTOR OF THE TRANSISTOR HAS A 10K PULLUP TO 5V.

6) ALL INPUTS WORK ON TTL LEVEL SIGNALS

ON/OFF DRIVERS ALTERNATE WIRING DIAGRAM

1) ON/OFF DRIVERS RATED AT 2 AMPS PEAK, 1 AMP CONTINUOUS.

2) THE NEGATIVE PIN OF THESE DRIVERS IS ACTUALLY AN OPEN COLLECTOR TYPE OUTPUT THAT PULLS DOWN TO GROUND. IT IS POSSIBLE TO DRIVE LOADS THAT ARE OF A DIFFERENT VOLTAGE THAN THE SUPPLY VOLTAGE, BY CONNECTING THE POSITIVE SIDE OF THE LOAD TO AN EXTERNAL SUPPLY, AND THE NEGATIVE SIDE TO THE -VE OUTPUT PIN. HOWEVER, IN CASE THIS IS DONE IT IS NECESSARY TO PLACE AN EXTERNAL "FREE WHEELING" DIODE ACROSS ANY INDUCTIVE LOADS. EXTERNAL SUPPLY VOLTAGE MUST BE LESS THAN SUPPLY VOLTAGE TO EZ STEPPER

3) EXTERNAL DIODE IS NOT NECESSARY IF BOTH SIDES OF LOAD ARE WIRED BACK TO THE EZ STEPPER.

ON/OFF DRIVERS ALTERNATE WIRING DIAGRAM

EXTERNAL +VE SUPPLY

DIODE
1N4001   SOLENOID , DC MOTOR ETC

1 AMP ON/OFF DRIVER #1 +

1 AMP ON/OFF DRIVER #1 -

EXTERNAL +VE SUPPLY

DIODE
1N4001   SOLENOID , DC MOTOR ETC

1 AMP ON/OFF DRIVER #2 +

1 AMP ON/OFF DRIVER #2 -

EXTERNAL SUPPLY VOLTAGE MUST BE LESS THAN SUPPLY TO EZ STEPPER

PAGE DOWN FOR MORE INFO   **COPYRIGHT ALLMOTION.COM**

| Title		
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SIMPLE CIRCUIT,
7 BIT ACCURACY

FEEDBACK POT1 GROUND
FEEDBACK POT1 WIPER
FEEDBACK POT1 POWER

500 OHM POT

POSITION COMMAND POT2 GROUND
POSITION COMMAND POT2 WIPER
POSITION COMMAND POT2 POWER

500 OHM POT

SWITCH #1 CLOSURE TO GROUND INPUT
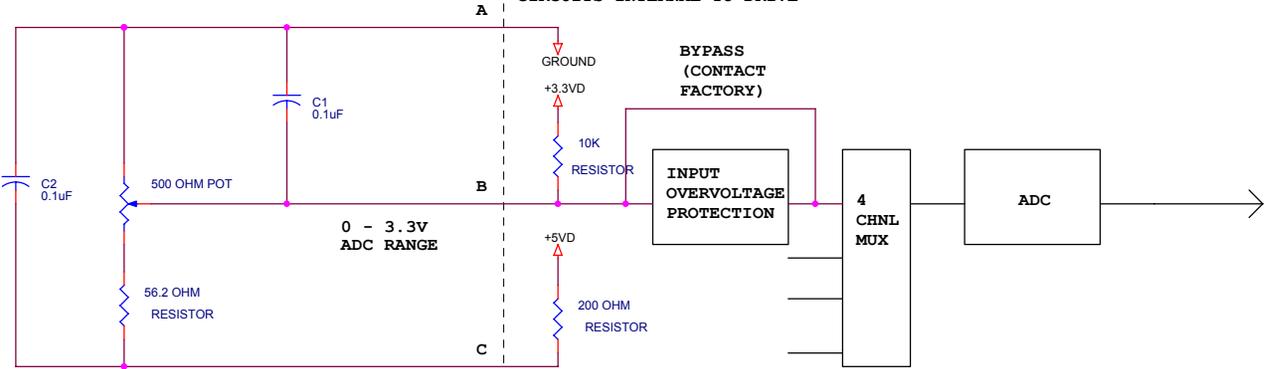SWITCH #2 CLOSURE TO GROUND INPUT

A
B
C

ADDRESS
SWITCH

STEPPER

500 OHM POT
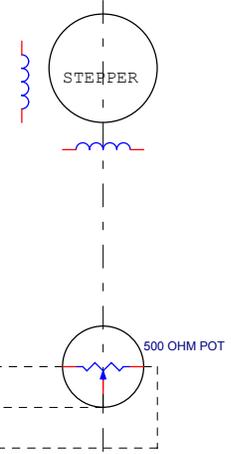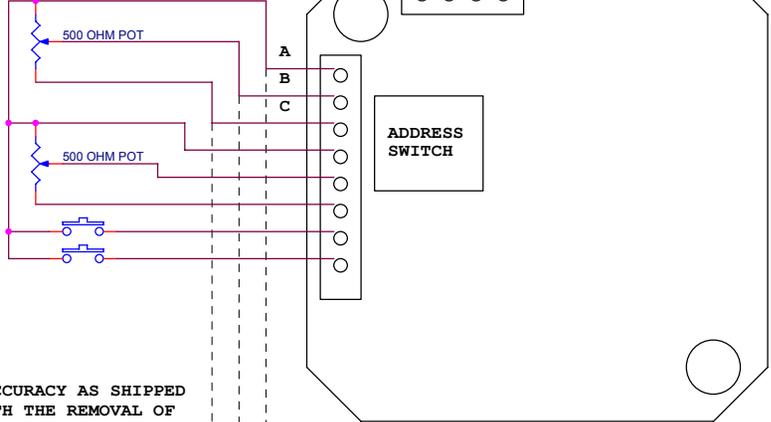
NOTES:

1) ALL 4 INPUTS ARE ANALOG INPUTS

2) ADC's VALUES RANGE FROM 0-16368. THE ACCURACY AS SHIPPED
IS 7 BIT BUT CAN BE IMPROVED TO >10BIT WITH THE REMOVAL OF
THE INPUT PROTECTION CIRCUITRY, CONTACT FACTORY FOR DETAILS

3) POTS IN THE RANGE OF 500 OHM - 10K ARE SUGGESTED,
LOWER VALUES ARE LESS AFFECTED BY INTERNAL 10K
PULLUP. 500 OHM RECOMMENDED.

4) IF USING POT FOR POSITION FEED BACK WITH /1N3R MODE, IF
 MOTOR EXHIBITS POSITIVE FEEDBACK, SWITCH ENDS OF POT

5) 10K INTERNAL PULLUP WILL INTERFERE WITH LINEARITY OF POT
VOLTAGE, AND MAY NEED TO BE REMOVED - CONTACT FACTORY.

6) INPUT OVERVOLTAGE PROTECTION CIRCUITRY MAY NEED TO BE
REMOVED FOR >7BIT ACCURACY - CONTACT FACTORY.

CIRCUITS INTERNAL TO DRIVE

A

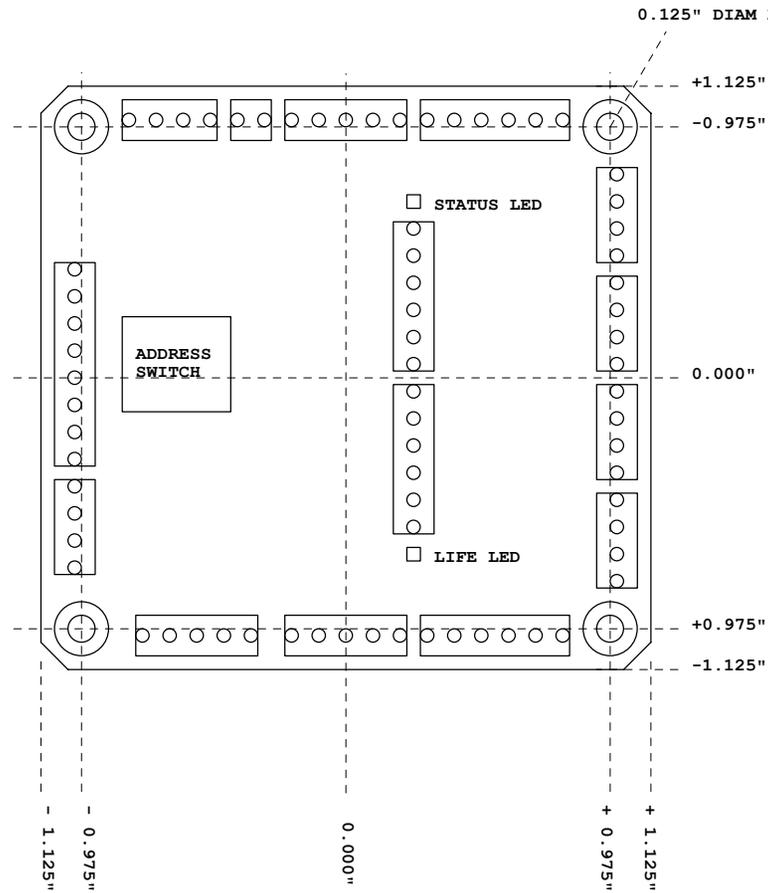GROUND

+3.3VD

BYPASS
(CONTACT
FACTORY)

C1
0.1uF

10K
RESISTOR

C2
0.1uF

500 OHM POT

B

INPUT
OVERVOLTAGE
PROTECTION

4
CHNL
MUX

ADC

0 - 3.3V
ADC RANGE

+5VD

56.2 OHM
RESISTOR

200 OHM
RESISTOR

C

ENHANCED EXTERNAL CIRCUIT FOR > 10BIT ACCURACY

WIRING DIAGRAM ANALOG INPUT OR
POTENTIOMETER FEEDBACK

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0.125" DIAM HOLE, 0.250" DIAM PAD. (4X)

+1.125"

−0.975"

STATUS LED

ADDRESS
SWITCH

0.000"

LIFE LED

+0.975"

−1.125"

− 1.125"

− 0.975"

0.000"

+ 0.975"

+ 1.125"

+ 0.762" TOP COMPONENTS + PCB THICKNESS

+0.062" PCB THICKNESS
0.000"

−0.200" BOTTOM COMPONENTS

4 AXIS CONTROLLER DRIVER DIMENSIONAL INFORMATION   COPYRIGHT ALLMOTION.COM

User Guide

Programming instructions for Models EZHR17EN, EZHR23ENHC, and EZ4AXIS

EZStepper™

Command Set document A49

Manual revision 1.0

Important Notices

Life and Safety Policy

AllMotion, Inc. products are not authorized for use as critical components in life support systems for surgical implant into the body, or other applications intended to support or sustain life or any other applications whereby a failure of the AllMotion, Inc. product could create a situation where personal injury, death or damage to persons, systems, data or business may occur.

Table of Contents

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 14.)

Table 1. Command Set

Command (case sensitive)	Operand	Description
POSITIONING COMMANDS (Note that negative positions are allowed in firmware versions 6.7 and above, e.g. /1A-1000R)		
A	0-(2^31)	**Move motor to absolute position .** (microsteps or quadrature encoder ticks - 32 Bit Positioning). E.g. */1A10000R*
P	0-(2^31)	**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. */1P10000R*
D	0-(2^31)	**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. */1D10000R* NOTE: Ending position must be > 0
HOMING COMMANDS		
Z	0-(2^31) (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. */1Z300000R* See Appendix 2 for further details.
z	0-(2^31)	**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*

ALLMOTION

Command (case sensitive)	Operand	Description
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. */1F1R*
SET VELOCITY COMMANDS		
V	1-2^24 (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. */1V100000R* If the encoder ratio (*aE* 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 */1L1R* 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 *n1* command.
LOOPING AND BRANCHING COMMANDS		
g		**Beginning of a repeat loop marker.** See examples below on how to set up a loop. E.g. */1gP10000M1000G10R*
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. */1gP10000M1000G10R*
H	01-14	**Halt current command string and wait until condition specified:** *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 */1R*. Also see *S* 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. H01H11 is a rising edge detect. E.g. */1gH02P10000G20R* - 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	**Skip next instruction depending on status of switch.** *01* Skip next instruction if low on input 1 (Switch 1) *11* Skip next instruction if high on input 1 (Switch 1) *02* Skip next instruction if low on input 2 (Switch 2) *12* Skip next instruction if high on input 2 (Switch 2) *03* Skip next instruction if low on input 3 (Opto 1) *13* Skip next instruction if high on input 3 (Opto 1) *04* Skip next instruction if low on input 4 (Opto 2) *14* Skip next instruction if high on input 4 (Opto 2) Program branching to a complex subroutine can be implemented by making the next instruction a stored string execution. (See examples). Loops can be escaped by branching to a stored string with no commands. E.g. */1gS02A10000A0G20R* - skips on switch 2 Also see *H* command for I/O dependant program execution.
PROGRAM STORAGE AND RECALL	
s	0-15	**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. */1s1A10000A0R* NOTE: This command takes approx 1 second to write to the EEPROM.
e	0-15	**Executes stored program 0-15.** E.g. */1e1R*
	PROGRAM EXECUTION	
R		**Run the command string that is currently in the execution buffer.** E.g. */1R*
X		**Repeat Run the current command string.**
	SET MAX MOVE CURRENT / HOLD CURRENT	
m	0-100 (25)	**For Steppers " Move" Current on a scale of 0 to 100% of max current.** 100% = 2A for EZHR17EN. E.g. */1m40R*
h	0-50 (10)	**Sets "Hold" current on a scale of 0 to 50% of max current.** 100% = 2A for EZHR17EN E.g. */1h15R*
aw	-	Reserved
ax	-	Reserved
ay	-	Reserved
	MISC	
p	0-65000	**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. */1gA1000p3333A0G0R* 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.

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Command (case sensitive)	Operand	Description
		SET MICROSTEP RESOLUTION / ENCODER
j	**1, 2, 4, 8, 16, 32, 64, 128, 256** **(256)**	**Adjusts the resolution in micro-steps per step.** It is recommended that step resolution be left at 256 microsteps (default). (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.) For best microstep results, a motor must be selected that is capable of microstep operation.
N	**1-5** **(1)**	**Special Modes** *1* = Encoder With No Index (Default). Homes to Opto. *2* = Encoder With Index. Homes to Index. *3* = Uses Potentiometer 1 as an encoder. See Appendix 9. *4* = First Home to Opto Then home to Index (future Release) *5* = CANBUS slave mode. In this mode the unit is a slave to position messages received via the CANBUS EZLink Connector. (future release)

2. Command Set

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

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Command (case sensitive)	Operand	Description
		MISCELLANEOUS
b	9600 19200 38400 to 230400 (9600)	**Adjustable baud rate** E.g. */1b19200R* 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**
ar	5073	**Processor reset** (Available in V6.7+) This command will initiate a Processor Reset the same as that which happens on power up. 5073 is chosen to avoid inadvertent resets. E.g. */1ar5073R<CR>*
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. */aP1000R<CR>* 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.
		STEPPER DRIVE DAUGHTER CARD COMMANDS
aM	1 - 2	**Selects drive.** */1aM1R* Selects first drive. From then on all commands are sent to drive 1. */1aM2R* selects drive2. See Appendix 11. The Second drive homes to opto #2 or Switch#1.
		BIDIRECTIONAL DRIVE DAUGHTER CARD
l	0-100	*/1l80R* **sets current to 80% (Lower case L).**
O	1	*/1O1R* sets the current flow one way.
I	1	*/1I1R* sets the current flow in the other direction.

2. Command Set

Command (case sensitive)	Operand	Description
		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. */1?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. */1at106144R* 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. */1?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. */1ao1000R<CR>*
am	0-20000 (256)	**The Potentiometer value is multiplied by this value and divided by 256 to get the position command.** E.g. */1am512R<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. */1ad100R<CR>*
		Hardware protocol: The EZStepper® communicates over the RS485 bus at 9600 baud, 1 Stop bit, No Parity, No flow control.

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Command (case sensitive)	Operand	Description
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.	
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
?	**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.**
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. */?A* returns current position, */1?V* returns velocity, and */1?m* 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)

/1A12345R<CR>

Command breakdown:

/	Start character. It lets the EZSteppers® know that a command is coming in.
1	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)

/1gA10000M500A0M500G10R<CR>

Command breakdown:

/	Start character. Tells the EZSteppers® that a command is coming in.
1	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 */1T*.

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Example #3 (Program storage and recall)

This example stores a command string for later execution:

/1s2gA10000M500A0M500G10R<CR>

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

/1e2R<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., */1s0R*

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)

/1s0m75h10gJ3M500J0M500G10H02A1000A0Z10000R<CR>

Command breakdown:

/1s0	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.

3. Single-Axis Programming Examples

Example #5 (Nested loop example)

/1gA1000A10000gA1000A10000G10G100R<CR>

Command breakdown:

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

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

Example #6 (Skip/Branch instruction)

Examples:

/1s0gA0A10000S13e1G0R<CR> (stored string 0)

/1s1gA0A1000S03e0G0R<CR> (stored string 1)

This stores two programs in string0 and string1, 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:

/1	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:

/1	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.

3. Single-Axis Programming Examples

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

/1s0gS11e1S12e2S13e3S14e4G0R<CR>

/1s1A1000e0R<CR>

/1s2A2000e0R<CR>

/1s3A3000e0R<CR>

/1s4A4000e0R<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 */1T*.

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)

/1gH02H12P1000G0R

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 */1T*.

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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)

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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:

/_A10000R<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.

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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 ¼ 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

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. */1P100R,* 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 */1f1R* to reverse the polarity that is expected of the home flag.

Issue the command */1Z100000R* or */1f1Z100000R* 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 */1n2R*. (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. */1f1R* 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.

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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 */1gZ10000GR*.

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. */1s1z0R* (Store set current position to zero program 1.)
2. */1z100000gD1S04e1GR* (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. */1z0R* (lower case "z") zeros the position counter and encoder for the motor that is currently selected. */1z333R* sets the position to 333 etc. So */1aM1z0R* zeros the counters for motor 1 and */1aM2z0R* zeros the position counters for motor 2.

Homing to the index

The main axis will home to the encoder index in /1N2R mode. The index must be at least 100µS in width.

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 */1?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 */1?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 */1?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.

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[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

/1A12345R<CR> in DT protocol is equivalent to

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

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

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

OEM Protocol Example 2

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

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

Sequence Character:

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

When the repeat bit is set consecutive commands received by the drive must have a different sequence number in order to get executed. (Only the sequence number is looked at—not the command itself)

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 from 0-15:

Bit	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)

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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.

Appendix 7. Device Response Packet

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.

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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= ((200x256)/(400x4)) x1000=32000

Issue the command */1aE32000R* 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 */1n0R* to clear any special modes.

4. Issue */1z0R*, which will zero both the encoder and step position.

5. Issue */1A100000R* and ensure that the move completes at a velocity that does not stall.

6. Issue */1?0*, which reads back the current position. This should be 100000.

7. Issue */1?8*, which reads back the encoder position.

8. Issue */1aE0R* which auto divides these two numbers.

9. Issue */1?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 */1aE32000R*, 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. /1aC50R (default is 50)

3. (Optional) Set the Overload Timeout Value.

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

   E.g. */1au10000R* (default is 100)

4. Enable the feedback mode.

1. Zero positions just prior to enabling feedback mode by issuing */1z0R*. (Or issue */1z10000R* etc. if you need to at this time.)

2. Enable position correction mode by issuing */1n8R*.

   Example (V6.7+):

   /1z0aC50h40m40au100aE32000V1000n8R starts the position correction mode.

Fine position correction (V6.99+)

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

- The COARSE ALGHORITHM, 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. */1x10R* 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.

Appendix 8. Position Correction Mode and Overload Report Mode

Other Notes

- When position correction mode is enabled (*/1n8R*) 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, */1T* 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 */1n0R* 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 */1n16R*, and requires the encoder ratio to be entered correctly via the "*aE*" command. Issue */1zR* to zero both the encoder and position counter just prior to issuing */1n16R*.

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 querried. 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 */1s13p1202n520R.* This sets error recovery script to send "1202" on every recovery.

   /1s12p1201R sets final script to send "1201."
2. */1aM1m5h5z0aC50au5u3aE12800L100n520R* sets h= 5 and m=5 so that we can stall the motor easily.
3. Setup encoder ratio as appropriate: */1aE32000R* etc.
4. Zero Encoder and Position Counter */1z0R*
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	1-65000 (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.
ac	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.**

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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., */1?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: */1at309999R<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 */1?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. */1at308000gS03P1000G0R*.

- A potentiometer can be placed as shown in the wiring diagram, and its position read back via the */1?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 */1A12345R*-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 */1aM1ao100ad100am1000n8192R<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. */1ao1228R<CR>* sets *ao* offset to 1228. Default is 0.

E.g. */1am256R<CR>* sets *am* multiplier to 256. Default is 256.

E.g. */1ad100<CR>* sets the deadband in microsteps to 100. Default is 50).

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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 */1n65536R* to enter velocity mode.

   Once in this mode, */1z0R* will set zero velocity to the current position on the potentiometer.

2. Issue */1P0* to start an endless move based on the velocity as read from the potentiometer.

   — */1zxxxR,* 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:

   velocity in microsteps/sec or encoder ticks/sec = [(potentiometer value(0to16368) – (potentiometer zero value from "z" command) - ("*ad*" deadband value/2)] x (*am*/256)

So,

/1ad100am1000n65536z0P0R starts the mode.

to terminate, type

/1n0<CR>

/1T<CR>

The actual velocity can be read back by */1?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.

/1ad100am1000n65664z0P0R 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).

/1ad100aC400am128n65552aE12800z0P0R

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 */1an16384R*.

Example: */1ad100am1000an16384n65538z0P0R* switches limits to the alternate inputs, and enables limits (65536 +2 = 65538).

Appendix 9. Analog Inputs and Analog Feedback

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 */1N3R* 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 */1?aa* command.
3. Turn the potentiometer all the way to zero by issuing a *D* command, e.g. */1D1000R*.
4. Issue */1z0R* to zero the motor position.
5. Issue */1N3R* to enable the potentiometer as encoder .
6. Move motor by issuing *P* commands until it is about ¾ of potentiometer range.
7. Issue */1aE0R* to automatically work out the "encoder ratio" for the potentiometer.
8. Issue */1n8R* 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 0.1µF capacitance between the wiper terminal and ground.

NOTE: To start feedback at a non-zero potentiometer position, read the current potentiometer value (position) with */1?aa* , say it's 2345, then issue */1z2345N3n8R*.

Example: (V6.7+) :

/1aM1z0aC50h40m40au100aE32000V1000N3n8R

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

/1aM1z0aC50ac10x10h40m40au100aE32000L100N3n8R

NOTE: See Appendix 8 for parameter explanations.

To exit this mode, type */1n0R* followed by */1T*.

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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 three daughter cards:

- Dual Axis Stepper Daughter Card (Requires firmware V6.79 or later)
- Bidirectional Drive Daughter Card (Requires firmware V3.85 or later)
- Logic Output Daughter Card

Dual Axis Stepper Daughter Card (requires 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. */1aM2V10L1A1000A0R*

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 */1aM2z0R*

The */1?0* and */1?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.

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/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.)
- */1gD1S04e1GR* (Go backwards in an endless loop until input 4 goes high.)

Bidirectional Drive Daughter Card For I/O Function

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

/1l80R sets the current in this drive to 80% for example. (lower case L)

/1O1R sets the current flow one way.

/1l1R 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.

Appendix 11. Daughter Card s

Logic Output Daughter Card

There are four logic signals that come into 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 1µS 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.

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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.*"

- */1A10000000R<CR>* will start the move.
- */1V10000<CR>* will change the velocity while moving.
- */1A0<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		**Allows up to 48 drives to be addressed by adding 16 or 32 to the value of the address switch.** CAUTION: Use this command <u>ONLY</u> if you have more than 16 motors on the bus. Else <u>DO NOT</u> use it.
	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		NOTE: Use this command ONLY if you have more than 16 motors on the bus. Otherwise DO NOT use. **Sets the address of a device to any binary number between 0 and 127 decimal. *XXX* will be the number in decimal.** For example */1aB496065R* 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 */A&*. Typically, this command would be stored in the EEPROM, for example */1s0aB496065R*.
	_aB49520R	**Globally sets all addresses to bank zero. Issue if address is lost.** NOTE: The underscore "_" global character (decimal 095) is not allowed with the *aB496XXX* command.

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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 */1?8* reads the primary encoder on the 5-pin connector, and */1?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 */1n32R* mode is enabled.

Additionally, *1aM1R* and */1aM2R* switch back and forth between the primary and secondary motors; and */1?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 */1n32R* etc.

2. Turn on "Motor Slave to Encoder2" by issuing */1n64R*.

Examples: */1n96R* (96=32+64) enables step and direction mode and slaves the motor to it. */1n64R* enables the encoder mode and slaves the motor to it.

The input step count (readable by */1?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 */1n4R*. 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 */1?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 */1n2R* command.

The default expects optos which are low when away from the limit. This polarity can be changed by issuing */1f1R*, 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 */1an16384R*.

Note that limit switches can be used to kill moves, e.g. */1n2gA100000A0GR* 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. 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
/1?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 */1am3Z100000R*.

On-the-Fly parameter change

The velocities accelerations and target positions can be changed "on the fly."

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

E.g., */1V2000R* (no *R* required if in motion) will change the velocity of the currently moving axis.

/1V1000,2000,3000,4000R will change the velocities of all four axes while in motion.

The Status of the Home inputs can be read:

/1?aa1

/1?aa2

/1?aa3

/1?aa4

Coordinate mode and Semi-Independent mode

/1an16R . 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.

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

•   The 4-axis drive is always in 1/16th step mode.