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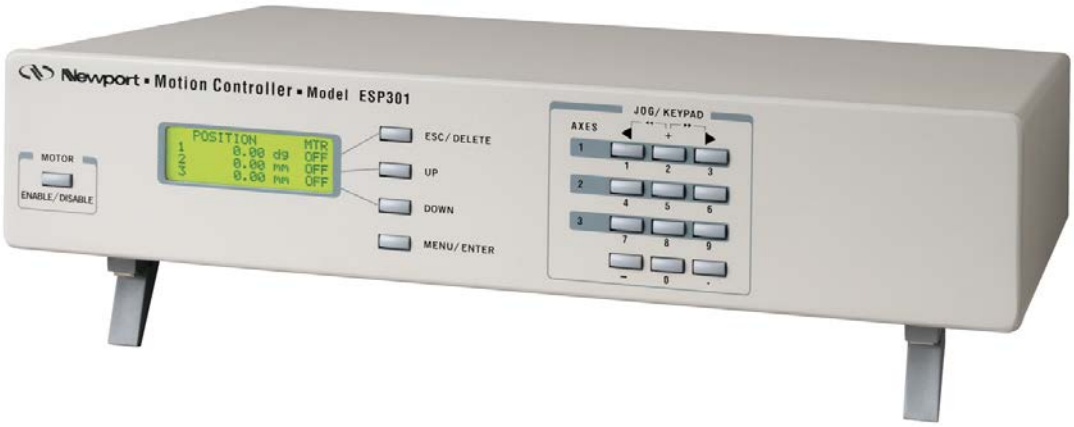
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ESP301

Integrated 3-Axis Motion Controller/Driver



ESP COMPATIBLE

RoHS Compliant

User's Manual

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EU Declaration of Conformity

ESP301

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Year CE mark affixed: 2015

EU Declaration of Conformity

The manufacturer:

MICRO-CONTROLE Spectra-Physics,
9, rue du bois sauvage
F-91055 Evry FRANCE

Hereby declares that the product:

Description: "ESP301"
Function: Motion Controller/Driver
Type of equipment: Electrical equipment for measurement, control and laboratory use
Models: ESP301-xN / ESP301xG / ESP300-J

– complies with all the relevant provisions of the Directive 2014/30/EU relating to electro-magnetic compatibility (EMC).
– complies with all the relevant provisions of the Directive 2014/35/EU relating to electrical equipment designed for use within certain voltage limits (Low Voltage)

– was designed and built in accordance with the following harmonised standards:
NF EN 61326-1:2013 « Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 1: General requirements »
NF EN 55011:2010/A1:2011 Class A
CEI 61010-1:2010 « Safety requirements for electrical equipment for measurement, control and laboratory use – Part 1: General requirements »

– was designed and built in accordance with the following other standards:
NF EN 61000-4-2
NF EN 61000-4-3
NF EN 61000-4-4
NF EN 61000-4-5
NF EN 61000-4-6
NF EN 61000-4-11

Date : 26/06/2015

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F-45340 Beaune La Rolande, France

DC2-EN rev:A

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Service Information

The user should not attempt any maintenance or service of the ESP301 Controller/Driver system beyond the procedures outlined in this manual. Any problem that cannot be resolved should be referred to Newport Corporation. When calling Newport regarding a problem, please provide the Tech Support representative with the following information:

- Your contact information.
- Unit's serial number or original order number.
- Description of problem, faults or messages.
- Environment in which the system is used.
- State of the system before the problem.
- Frequency and repeatability of problem.
- Can the product continue to operate with this problem?
- Can you identify anything that may have caused the problem?

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Newport Corporation RMA Procedures

Any ESP301 Controller/Driver being returned to Newport must have an assigned RMA number issued by Newport. Assignment of the RMA requires the unit's serial number.

Packaging

ESP301 Controller/Driver being returned under an RMA must be securely packaged for shipment. If possible, re-use the original factory packaging. For insurance purposes, it is recommended to take a digital photograph of the unit in its packaging prior to shipping.

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Section 1 - Introduction

1.1 Scope

This manual provides descriptions and operating procedures for the integrated 3 axis ESP301 Controller/Driver (ESP = Enhanced System Performance).

Safety considerations, conventions and definitions, and a system overview are provided in Section 1, Introduction.

Procedures for unpacking the equipment, hardware and software requirements, descriptions of controls and indicators, and setup procedures are provided in Section 1, Introduction.

Instructions for configuring and powering up the ESP301 and stage motors, for home and jog motions, and for system shut-down are provided in Section 1, Introduction.

Overview of operating modes (LOCAL and REMOTE) and Menu Options in LOCAL Mode are provided in Section 2, Modes of Operation.

Motion commands, language-specific information, and error-handling procedures are provided in Section 3, Remote Mode.

An overview of groups, including contours, slaving, closed loop stepping and synchronization is provided in Section 4, Advanced Capabilities.

An overview of motion parameters and equipment is provided in Section 5, Motion Control Tutorial.

Servo tuning principles and procedures are given in Section 6, Servo Tuning.

The following information is provided in the Appendices:

- Error messages
- Trouble-shooting and maintenance
- Connector pin assignments
- Decimal/ASCII/binary conversion table
- System upgrades for software and firmware
- Factory service

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1.2 Safety Considerations

The following general safety precautions must be observed during all phases of operations of this equipment. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the equipment.

Disconnect or do not plug in the power cord in the following circumstances:

- If the power cord or any other attached cables are frayed or damaged.
- If the power plug or receptacle is damaged.
- If the unit is exposed to rain or excessive moisture, or liquids are spilled on it.
- If the unit has been dropped or the case is damaged.
- If you suspect service or repair is required.
- When you clean the case.

To protect the equipment from damage and avoid hazardous situations, follow these recommendations:

- Do not make modifications or parts substitutions.
- Return equipment to Newport Corporation for service and repair.
- Do not touch, directly or with other objects, live circuits inside the unit.
- Keep air vents free of dirt and dust.
- Do not block air vents.
- Keep liquids away from unit.
- Do not expose equipment to excessive moisture (>85% humidity).

WARNING



All attachment plug receptacles in the vicinity of this unit are to be of the grounding type and properly polarized. Contact an electrician to check faulty or questionable receptacles.

WARNING



This product is equipped with a 3-wire grounding type plug. Any interruption of the grounding connection can create an electric shock hazard. If you are unable to insert the plug into your wall plug receptacle, contact an electrician to perform the necessary alterations to ensure that the green (green-yellow) wire is attached to earth ground.
System earthing must be of type earthed neutral (TN-) as defined by CEI60364.

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WARNING

This product operates with voltages that can be lethal. Pushing objects of any kind into cabinet slots or holes, or spilling any liquid on the product, may touch hazardous voltage points or short out parts.



WARNING

When opening or removing covers observe the following precautions:

- **Turn power OFF and unplug the unit from its power source**
- **Remove jewelry from hands and wrists**
- **Use insulated hand tools only**
- **Maintain grounding by wearing a wrist strap attached to instrument chassis.**

1.3 Conventions and Definitions

The following terms and symbols are used in this documentation and also appear on the ESP301 Controller/Driver where safety-related issues occur.

1.3.1 Definitions and Symbols

The following are definitions of safety and general symbols used on equipment or in this manual.



WARNING

Calls attention to a procedure, practice or condition which, if not correctly performed or adhered to, could result in injury or death.



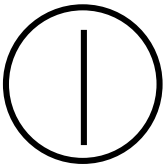
CAUTION

Calls attention to a procedure, practice, or condition which, if not correctly performed or adhered to, could result in damage to equipment

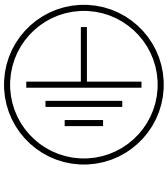
NOTE

Calls attention to a procedure, practice, or condition that is considered important to remember in the context.

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This symbol indicates the principal On/Off push-push switch is in the ON position when pressed in, and in the OFF position when de-pressed.



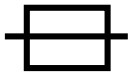
Protective conductor terminal



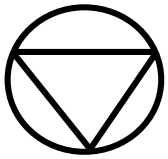
Caution, risk of electric



Caution (refer to accompanying documents)



Fuse



Stop (of action or operation)

1.3.2 Terminology

The following is a brief description of the terms specific to motion control and the ESP301 Motion Controller/Driver.

Axis – a logical name for a stage/positioner/ motion device

Encoder – a displacement measuring device, term usually used for both linear and rotary models

ESP – Enhanced System Performance motion system is synonymous with a plug-and-play motion system.

ESP – compatible – refers to Newport Corporation stage with its own firmware-based configuration parameters. Newport stages or other stages without this feature are referred to as being non ESP-compatible and must be uniquely configured by the user.

Home (position) – the unique point in space that can be accurately found by an axis, also called origin

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Jog – a motion of undetermined-length, initiated manually

Motion device – electro-mechanical equipment. Used interchangeably with stage and positioner.

Move – a motion to a destination

Origin – used interchangeably with home

PID – a closed loop algorithm using proportional, integral, and derivative gain factors for position control

Positioner – used interchangeably with stage and motion device

Stage – used interchangeably with motion device and positioner

1.4 System Overview

The Enhanced System Performance (ESP) architecture consists of ESP-compatible controllers and stages. The ESP301, an ESP-compatible controller, is an advanced stand-alone controller with integrated motor drivers. It can control and drive up to 3 axes of motion in any stepper and DC motor configuration.

The ESP plug-and-play concept significantly increases user friendliness and improves overall motion performance.

The ESP301 is used as a stand-alone controller to drive an ESP motion device. All components are designed for optimal performance.

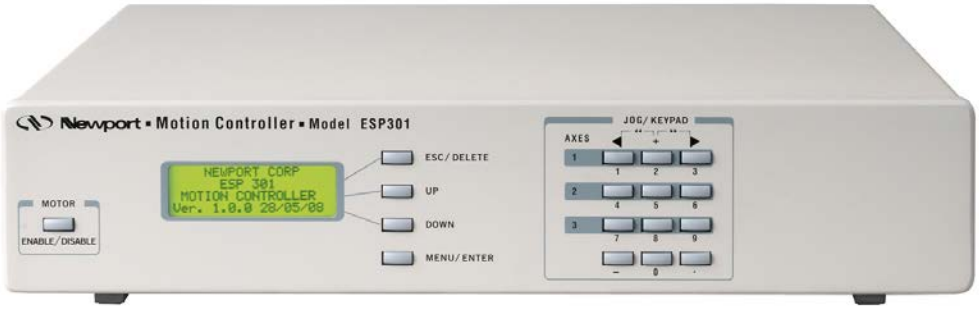


Figure 1.1: ESP301 Controller/Driver

1.4.1 Features

A number of advanced features make the ESP301 an excellent choice for many applications:

- Integrated controller and driver design is cost effective and space saving
- Compact, standard 2U height rack mountable or bench-top enclosure

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- Allows any combination of motor types (2 or 4-phase stepper and brush DC) up to 3A, 48V per axis
- 200MHz Digital Signal Processing architecture
- Real-time high speed command processing
- Powerful commands for most demanding applications
- Motion program storage (up to 99 programs) in 64kB non-volatile memory
- Advanced motion programming capabilities and complex digital I/O functions
- User selectable displacement units
- Full-featured front panel with position and status displays for each axis, push-buttons for simple motion sequences and access to an elaborate menu that allows setup of the system without use of a computer.

1.4.2 Specifications

Function:

- Integrated motion controller and driver.

Number of motion axes:

- 1 to 3, in any combination or order of 2 or 4- phase stepper and brush DC motors, up to 48VDC, 3A per axis.

Trajectory type:

- Trapezoidal velocity profile
- S-curve velocity profile.

Motion device compatibility:

- Family of motorized Newport motion devices, using either stepper or DC motors
- Custom motion devices (contact Technical Support for compatibility).

DC motor control:

- 16 bit DAC resolution
- 5 MHz maximum encoder input frequency
- Digital PIDFF servo loop, 0.4 ms update rate.

Stepper motor control:

- Up to 1000 microstep resolutions per full step.

Computer interface:

- RS232-C, 19200 baud, 8 bits, 8, N, 1
- USB, 921600 baud, 8bits, 8, N, 1
- IEEE488 (optional)

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Utility interfaces:

- 16 bit digital inputs/outputs, user definable, in blocks of 8.
- Remote motor off input (interlock).

User memory:

- 64 KB non-volatile program memory
- 512 byte command buffer

Operating modes:

- Local mode – stand-alone operation, executing motion from the front panel
- Remote mode – executing commands received over one of the computer interfaces
- Program execution mode – execution of a stored program.

Display:

- 80 character alpha-numeric LCD display
- Displays position, status, utility menus and setup screens.

Dimensions:

- 3.0" H x 16.9" W x 12. 6" D (76.2 x 429.5 x 320 mm) without feet.

Rating AC:

- 100–240 VAC
- 60/50 Hz
- 3.2 / 2.1 A

The controller should be connected to a power installation that incorporates appropriate protection devices. Refer to the installation requirements of your facility and local applicable Standards concerning the use of RCDs (residual current device).

Weight:

- 14.3 lb. max. (6. 5 Kg max.)

Operating conditions:

- Temperature: 0°C to 40°C
- Humidity: 20% to 85% RH, non-condensing

1.4.3 Description of Front Panel Version

The ESP301 is available with a front panel with LCD display and manual control buttons. A menu allows the user to change velocities, accelerations and more, without a computer interface.

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FRONT PANEL DISPLAY

A general view of the front panel is shown in **Figure 1.2.** There are two distinct areas: a display/menu section and a motion section that allows simple low and high speed manual JOG motion.

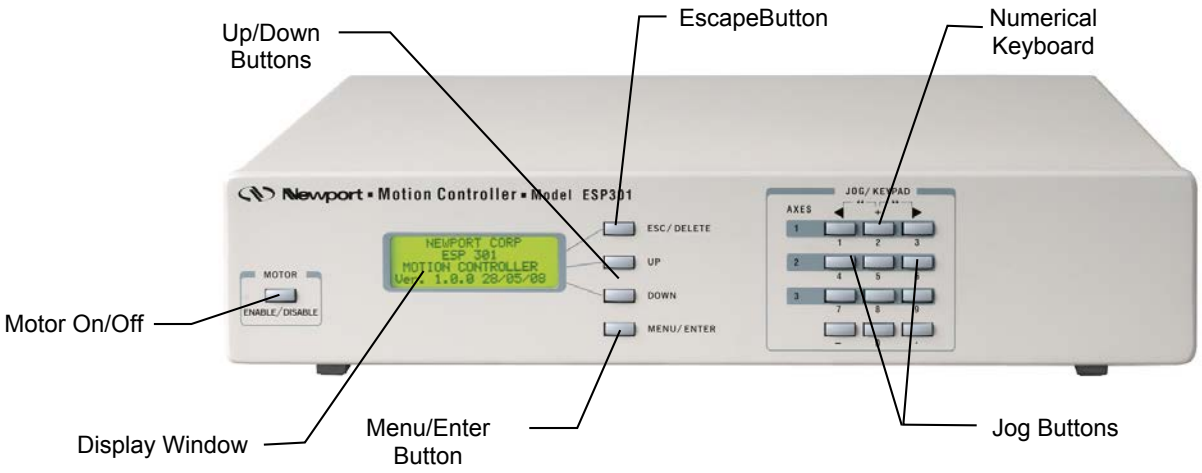


Figure 1.2: ESP301 Front Panel

Power Section

The black switch at the rear of the ESP301 controller is used to turn power On or Off.

1.4.4 Rear Panel Description

NOTE

See Appendix C for pin-outs.

AXIS CONNECTORS (AXIS 1 – AXIS 3)

There are up to three 25-pin D-Sub connectors on the rear panel, one for each axis. Unused axes have blank panels.

GPIO CONNECTOR

This is a 37-pin D-Sub connector used for general purpose, digital Input/Output signals. A variety of commands are available to control these ports. See Section 3, Remote Mode and Appendix C for Connector Pin Outs.

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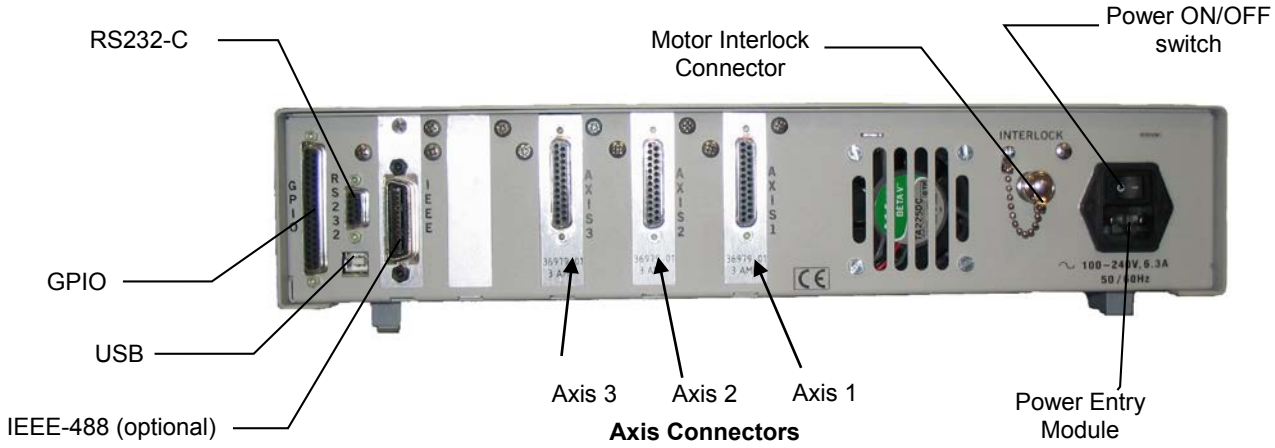


Figure 1.3: Rear Panel of the ESP301

MOTOR INTERLOCK CONNECTOR

The coaxial connector provides remote motor power interlock capability. One or more external switches can be wired to remotely inhibit the motor power in a way similar to the **Motor Off** button on the front panel.

The controller is shipped with a mating connector that provides the necessary wiring to enable proper operation without an external switch.

RS232-C CONNECTOR

The RS232-C interface to a host computer or terminal is made through this 9 pin D-Sub connector. The pin out enables the use of an off-the-shelf, pin-to-pin cable.

IEEE488 CONNECTOR

This is a standard 24 pin connector to interface with a standard IEEE488 device. (NOTE: This is an optional feature).

USB CONNECTOR

This is a standard USB B-type connector.

POWER ENTRY MODULE

The power entry section on the right side of the rear panel provides a standard IEC 320 inlet and a power ON/OFF switch.

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1.5 System Setup

This section guides the user through the proper set-up of the motion control system.

Carefully unpack and visually inspect the controller and stages for any damage. A good indicator of shipping damage is the condition of the shipping box.

Place all components on a flat and clean surface.

1.5.1 Line Voltage

NOTE

The controller can operate from 100-240VAC, ±10%, at a frequency of 50/60Hz.

1.5.2 First Power ON

Plug the AC line cord supplied with the ESP301 into the power entry module on the rear panel.

Plug the AC line cord into the AC wall-outlet.

Switch the POWER on button at the rear panel.

Shortly after the power is switched on, the ESP301 will perform a start-up sequence as described below.

- Momentarily display: "Newport ESP301" and the Firmware Version
- Momentarily show the stage type that is connected. Since there should be no stages connected at this point, the "NO STAGE" message is displayed for all axes.

NOTE

When contacting technical support, provide the firmware version which is displayed every time the controller is powered on. This is essential to troubleshoot a problem.

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1.6 Quick Start

Unpacking and Handling

It is recommended that the ESP301 Controller/Driver be unpacked in your lab or work site rather than at the receiving dock. Unpack the system carefully; small parts and cables are included with the equipment. Inspect the box carefully for loose parts before disposing of the packaging. You are urged to save the packaging material in case you need to ship your equipment.

Inspection for Damage

ESP301 Controller/Driver has been carefully packaged at the factory to minimize the possibility of damage during shipping. Inspect the box for external signs of damage or mishandling. Inspect the contents for damage. If there is visible damage to the equipment upon receipt, inform the shipping company and Newport Corporation immediately.

WARNING



Do not attempt to operate this equipment if there is evidence of shipping damage or you suspect the unit is damaged. Damaged equipment may present additional hazards to you. Contact Newport technical support for advice before attempting to plug in and operate damaged equipment.

This section serves as a quick start for ESP301.

The following paragraphs guide you through a very basic motion sequence that verifies that the ESP301 unit is working properly.

1.6.1 Connecting Motion Devices

NOTE

Never connect/disconnect stages while the ESP301 is powered on. Always verify that the power to the ESP301 is off before connecting/disconnecting stages.

If an ESP301 motion control system was purchased, all necessary hardware for set-up is included.

With ESP-compatible stages, the configuration of each axis is identified automatically by the ESP301 at power up. ESP compatible stages are visually identified with a blue "ESP Compatible" sticker, on the stage.

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Carefully connect one end of the supplied cable to the stage and the other end to the appropriate axis connector on the rear of the controller. Secure both connectors with the locking thumb-screws.

1.6.2 Motor On

After the controller and the stages are connected as described, the motors can be powered on.

Make sure that the motion devices are placed on a flat surface and their full travel is not obstructed.

CAUTION



Be prepared to quickly turn the motor power off by pressing the MOTOR ON/OFF (STOP ALL) button or power switch if any abnormal operation is observed.

After the power switch is pushed in, the controller performs the start-up sequence as described in Section 1.5.2.

The default state after start-up is motor power off.

To apply power to the motors, press the Motor ON/OFF button to the left of the display or press each button on the right of the display to enable power for each individual axis. The ON state of the motor power is indicated on the display.

1.6.3 Homing

HOME Search

The HOME Search routine is a sequence of motion segments through which the controller determines the exact location of a home (origin) switch. A detailed description of the algorithm can be found in the **Motion Control Tutorial** (Section 5).

NOTE

It is recommended that the user perform a home search routine after each controller power-on. The controller must know the exact initial position of the motion device not only to accurately repeat a motion sequence (program) but also to prevent it from hitting the travel limits (limit switches).

To perform a home search routine, at start-up, press the assigned axis key to the right of the display, then press the Menu key and select the Home menu. Then press the assigned axis key to the right of the display to home each axis.

In the position display, the home routine is indicated as in progress.

H

NOTE

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The position value is reset at the *home* position.

Only one axis can be homed at a time; i.e., even if multiple homing commands are issued, the prior axis has to finish homing before the second can start homing.

1.6.4 First Jog

If left jog key is pressed, the selected axis will move slowly in the negative direction. To move a single step at a time, press this switch once. See Section 2.2.4 for details.

If right jog key is pressed, the selected axis will move slowly in the positive direction. To move a single step at a time, press this switch once. See Section 2.2.4 for details.

If the << >> key between the jog keys is pressed **simultaneously** with one of the jog keys, the axis will jog fast in the selected direction. See Section 2 for setting of high speed rate.

At this point, you may proceed to Section 2 of this manual, to get familiar with the controller and the local motion modes.

NOTE

Remember that only motions inside the software travel limits are allowed (see 'SL' command in Section 3, Remote Mode). Any move outside these limits will be ignored.

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Section 2 – Modes of Operation

2.1 Overview of Operating Modes

The ESP301 can be operated in two basic modes:

- LOCAL mode
- REMOTE mode

2.1.1 LOCAL Mode

In LOCAL Mode the user has access to a sub-set of the ESP301 command set. In this Mode, the ESP301 is controlled by pressing the menu key and axis push-buttons on the front panel.

Using this mode, the user can adjust motion parameters like velocity and acceleration without using a computer or terminal.

NOTE: See Section 2.2 for a detailed description of the front panel.

2.1.2 REMOTE Mode

In *COMMAND Mode,* the ESP301 receives motion commands through one of its interfaces (IEEE488, RS232-C or USB) using a computer or terminal.

In this mode, the ESP301 employs a set of over 100 commands. Please refer to Section 3 (Remote Mode) for a detailed description of the ESP301 command set.

In Program Execution Mode, internally stored programs are executed (See Section 3.1).

2.2 Operation in LOCAL Mode

This section provides a detailed explanation of the LOCAL mode. Typical parameters that can be set are velocity, acceleration and the computer interface. Please remember that all menu items can also be accessed with remote commands (See Section 3, Remote Mode).

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2.2.1 Accessing the Menu

Figure 2.1 shows the menu section of the front panel. The menu listing can be accessed by pressing the *Menu* key to the bottom-right of the display.

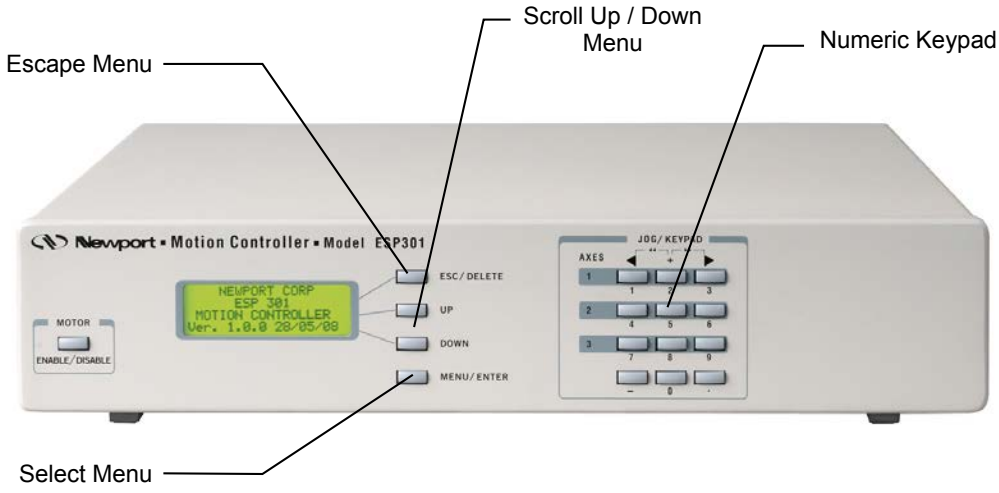


Figure 2.1: Menu Section

2.2.2 Navigating the Menu

Once in the menu listing, use four buttons to access all available menu items and change values where applicable. Keep in mind that these buttons serve multiple functions.

The *UP* and *DOWN* buttons scroll through the current Menu list. The *UP*, *DOWN* and *ESC(DEL)* buttons are assigned to the axis only in Position submenu, where each button can be used to turn on or off that specific axis.

The *MENU* button selects a menu item, the *ESC* button brings up the previous menu. The *MENU/ENT* button also executes an action for the selected axis (Home, Absolute or Relative moves).

2.2.3 Changing Values

This example is an illustration of how to change values within a menu item.

1. Press *MENU* to enter the menu listing.
2. Press the *Down* repeatedly until the cursor (diamond shaped) is aligned with the CONFIGURATION menu item.
3. Press the *MENU/ENTER* button once. Now, a sub-menu list becomes available.
4. Press the *MENU/ENTER button* to select the SET VELOCITIES menu item.
5. Press the *MENU/ENTER* button to select the SET LOW JOG VEL menu item. The screen shown below is displayed at this time.

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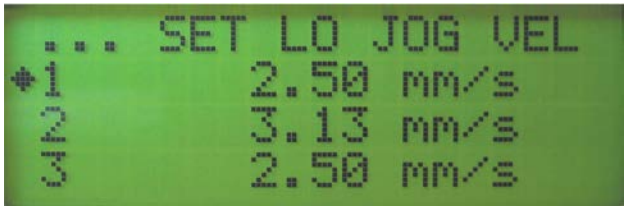


Figure 2.2: Set Low Jog Vel Menu Item

6. Use the numeric keypad on the right to enter the value desired. Use *ESC/DELETE* to delete entries.
7. Then press *MENU/ENTER* to save the new value.

2.2.4 Motion from the Front Panel

As shown in **Figure 2.3,** the right side of the front panel accommodates simple manual notion capabilities.

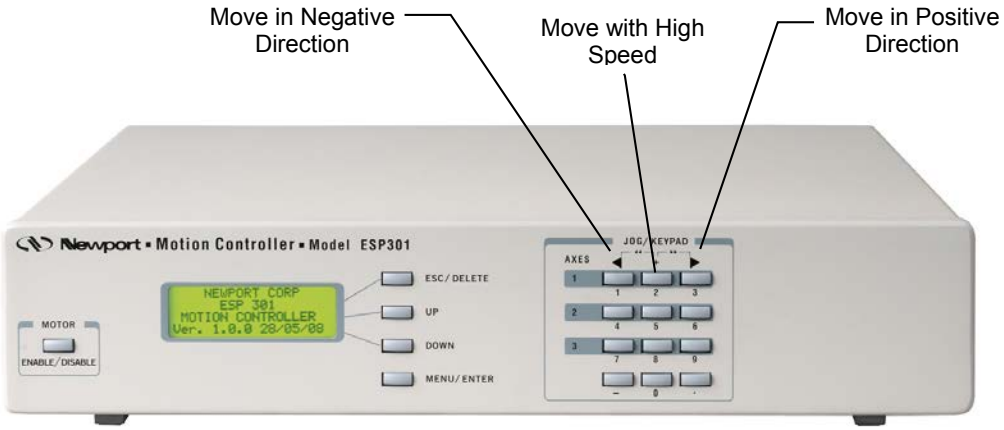


Figure 2.3: Motion from the Front Panel Displayed

Move in Negative Direction with low speed. This button can be programmed to move at low speed in the negative direction as long as it is pressed. See SET VELOCITY menu items in Section 2.2.5.

Move in Positive Direction with low speed. This button can be programmed to move at low speed in the positive direction as long as it is pressed. See SET VELOCITY menu items in Section 2.2.5.

Move with High Speed. This button is active only when pushed simultaneously with either move button above. See SET VELOCITY menu items in Section 2.2.5.

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Motor ON/OFF. During motion, when this button is pressed, all motion is stopped and the front display indicates that all motors are OFF. Pressing the button when motors are off, will turn all motors on. This button is equivalent to the Interlock connector on the rear of the unit. See **ZE** command in Section 3: Remote Mode, for further information.

This is a software function triggered by the above mention inputs.

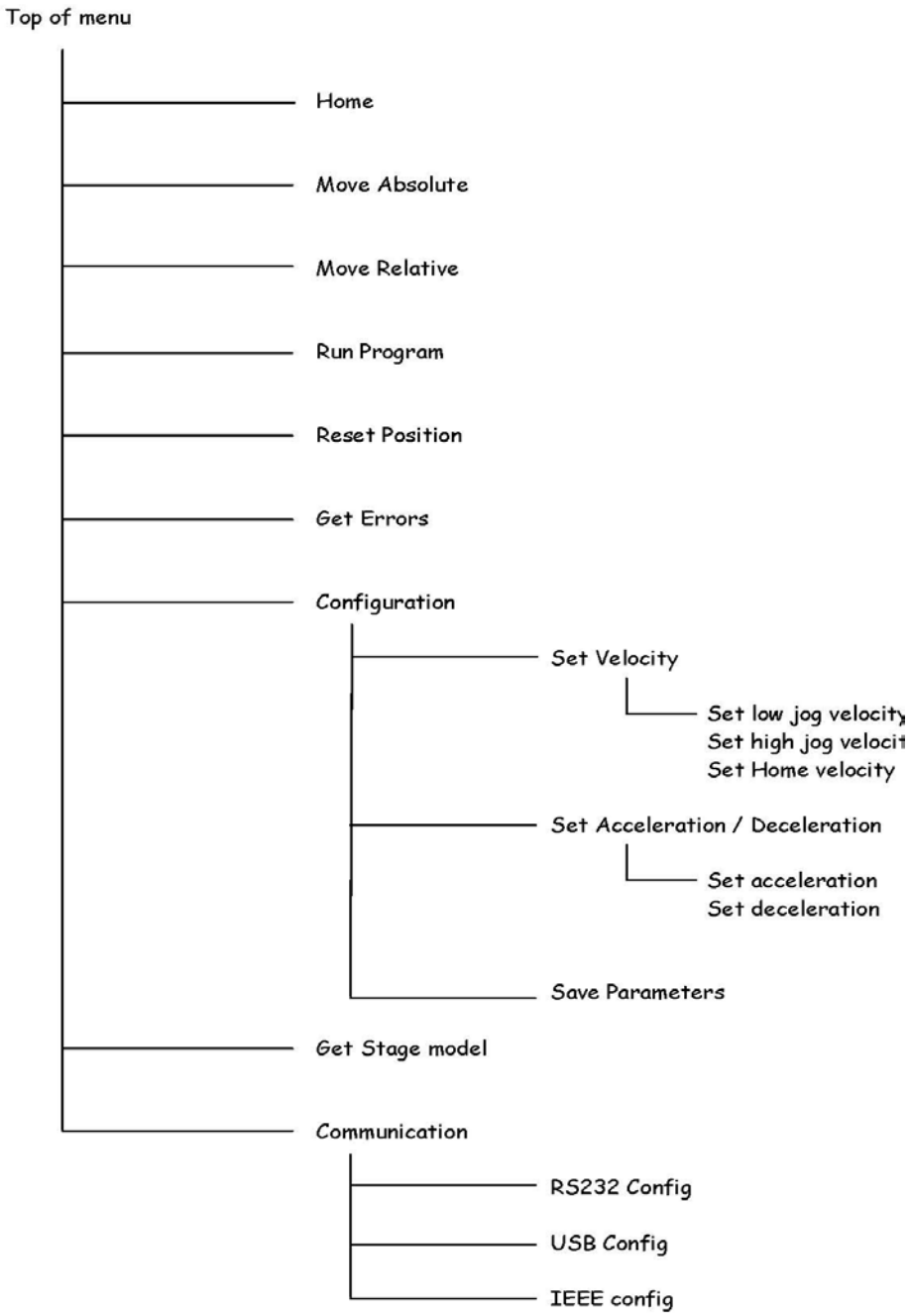


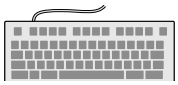
Figure 2.4: Front Panel Menu Structure

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2.2.5 Detailed Description of Menu Items

HOME

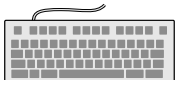
This menu item allows the user to home each stage.



OR - Search for home

MOVE ABSOLUTE

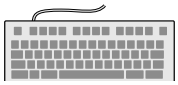
This menu item allows the user to move a stage to an absolute position.



PA - Move to an absolute position

MOVE RELATIVE

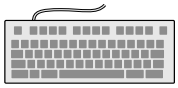
This menu item allows the user to move a stage to a relative position.



PR - Move to a relative position

RUN PROGRAM

Programs can be entered or downloaded to the ESP301 through its standard interfaces (RS232, USB or IE488). The ESP301 is capable of storing up to 99 different programs in its non-volatile program memory (64KB total). This menu allows execution of any of the stored programs.

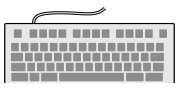


1EX - Execute program 1

RESET POSITION

This menu item allows the user to reset the current position displayed to zero.

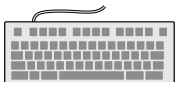
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DH - Defines the current position, HOME position

GET ERRORS

This menu item allows the user to get the errors that are stored in the error queue. The error queue can store up to 10 errors. If the number of errors exceeds ten, the oldest errors are superseded.



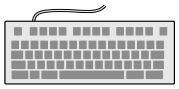
TE or **TB** - Tell error or Tell buffer

SET VELOCITY

This menu makes it possible to change velocities that are used with the jog and home search buttons. The following sub-menus are available:

SET LOW JOG VEL

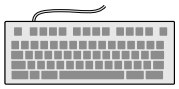
Sets the velocity of the stage when either jog button is pushed.



JL - Set low jog velocity

SET HI JOG VEL

Sets the velocity of the stage when either jog button is pushed simultaneously with the High Speed button.

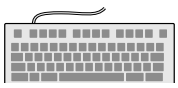


JH - Set high jog velocity

SET HOME VEL

Sets the velocity used during homing sequences. Refer to Section 1.6.3 for details on homing.

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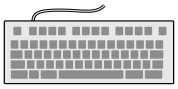
OH	-	Set home velocity

SET ACCEL/DECEL

This menu makes it possible to change acceleration and deceleration that are used with the jog and home search buttons. The following sub-menus are available:

SET ACCELERATION

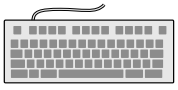
Sets the acceleration that is used to accelerate to the desired velocity when the jog buttons are used.



AC	-	Set Acceleration

SET DECELERATION

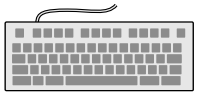
Sets the deceleration that is used to decelerate to the standstill when the jog buttons are released.



AG	-	Set Deceleration

GET STAGE MODELS

This menu allows the user to retrieve the model numbers of the stages that are connected to the respective axes.



ID	-	Get stage identifier

SAVE PARAMETERS

This menu allows the users to save all current settings (velocity, acceleration, etc.) to the ESP301 non-volatile memory.

COMMUNICATION

This menu allows the user to retrieve the current communication configuration settings.

RS232 CONFIG

This shows the current RS232 configuration settings.

USB CONFIG

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This shows the current USB configuration settings.

IEEE CONFIG

This shows the current IEEE configuration settings.

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Section 3 – Remote Mode

3.1 Programming Modes

The ESP301 is a command driven system. In general, commands are a series of two letter ASCII characters preceded by an axis number and followed by parameters specific to the command. To communicate with the ESP301 controller, a host terminal has to transfer ASCII character commands according to the respective communication protocol (See Section 3.2 for IEEE488, RS232 or USB interfaces).

As briefly mentioned in Section 2, the ESP distinguishes between two different programming modes:

COMMAND MODE

In this mode, the ESP301 controller provides a command input buffer enabling the host terminal (e.g., PC) to download a series of commands and then proceed to other tasks while the ESP301 controller processes the commands.

As command characters arrive from the host terminal, they are placed into the command buffer. When a carriage-return (ASCII 13 decimal) terminator is received, the command is interpreted. If the command is valid and its parameter is within the specified range, it will be executed. If the command contains an error, it will not be executed and a corresponding error message will be stored in the error buffer.

NOTE

The ESP301 power up state is command mode.

An example of a typical command sequence is shown below:

Example 1:

1PA + 30	*move axis 1 to absolute position 30 units*
1WS	*wait for axis 1 to stop*
2PR-10	*move axis 2 to relative position 10 units*

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Assuming that axis 1 and 2 are configured, ***Example 1*** instructs the ESP controller to move axis 1 to absolute position +30 units, wait for it to stop, and then move axis 2 motor to relative –10 units.

Note that a command prefix identifies the axis or group that should execute a command. Commands received without an axis prefix generate an error. If a command is referenced to a non-existing axis, an error is also generated. See Section 3.4 for further details on the command syntax.

Also note that it is necessary to explicitly instruct the ESP controller with the WS (Wait for Stop) command to wait for axis 1 motion to stop. This is necessary because the ESP controller executes commands continuously as long as there are commands in the buffer unless a command is fetched from the buffer that instructs the controller to wait. Executing a move does not automatically suspend command execution until the move is complete. If the WS command were not issued in ***Example 1,*** the controller would start the second move immediately after the first move begins and simultaneously move axis 1 and axis 2.

NOTE

Unless instructed otherwise, the ESP controller executes commands in the order received without waiting for completion of previous commands.

Remember that commands must be terminated with a carriage-return (ASCII 13 decimal). Until a terminator is received, characters are simply kept in contiguous buffer space without evaluation.

Example 2:
1PA+30; 1WS; 2PR-10

Example #1 and ***Example #2*** perform the same operations. In ***Example #2*** however, semicolons are used in place of carriage-returns as command delimiters, keeping the ESP301 controller from interpreting any commands on that line until the carriage-return terminator is received at the very end of the string.

PROGRAM EXECUTION MODE

The ESP301 controller also implements an internal program execution mode that enables the user to store up to 100 programs in a 64kB non-volatile memory.

Even while executing stored programs, the ESP301 controller maintains open communication channels so that the host terminal can

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continue to direct the ESP301 to report any desired status, and even execute other motion commands.

Let's illustrate program execution mode using the previous example:

Example 3:

```
EP        | invoke program entry mode
1PA+30    | enter program
1WS
2PR-10
QP        | exit program entry mode
1EX       | execute compiled program #1
```

As shown above, the sequence of commands has to be downloaded into the ESP301 controller program memory without inadvertently executing them. To facilitate this, the system provides the EP (Enter Program) command; characters received thereafter are redirected to program memory. Command syntax and parameters are not evaluated (even after the carriage-return). Instead, they are treated as a series of characters to be stored in contiguous memory.

3.2 Remote Interfaces

In this manual, *Remote Interface* refers to the three communication interfaces that the controller can use to communicate with a computer or a terminal via commands in ASCII format. It is not called a *Computer Interface* since any device capable of sending ASCII characters can be interfaced with the controller.

The remote interface should not be confused with the General Purpose Input/Output (digital I/Os, a.k.a. GPIO).

Below is a table comparing the communication speeds of the interfaces using typical commands.

Command communication and process time (in milliseconds)						
	RS232C		**USB**		**IEEE**	
Command send and read response	ESP301	ESP300	ESP301	ESP300	ESP301	ESP300
TB?	25.08	28.02	4.18	-	1.32	2.88
VE?	24.84	27.60	3.92	-	0.96	1.68

Table 3.2: Command communication and process time

Measurements have been taken from a PC using Windows XP operating system and with a 2GHz processor and 1Gb RAM.

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3.2.1 RS-232C Interface

HARDWARE CONFIGURATION

The serial (RS-232C) communication interface on the ESP controller is accessed through the 9 pin Sub-D connector located on the rear panel. The pin out is designed to interface directly with an IBM PC or compatible computer, using a straight through cable.

Appendix **C** shows the pin out of the RS-232C connector and different cable types that may be used to interface to a computer.

COMMUNICATION PROTOCOL

The RS-232C interface must be properly configured on both devices communicating. A correct setting is one that matches **all** parameters (baud rate, number of data bits, number of stop bits, parity type and handshake type) for both devices.

The ESP301's RS-232C configuration is fixed at **8 data bits, no parity, and 1 stop bit.**

To prevent buffer overflow when data is transferred to the ESP301 controller input buffer, a CTS/RTS hardware handshake protocol is implemented. The host terminal can control transmission of characters from the ESP301 by enabling the Request To Send (RTS) signal once the controller's Clear To Send (CTS) signal is ready. Before sending any further characters, the ESP will wait for a CTS from the host.

As soon as its command buffer is full, the controller de-asserts CTS. Then, as memory becomes available because the controller reads and executes commands in its buffer, it re-asserts the CTS signal to the host terminal.

3.2.2 USB Interface

HARDWARE CONFIGURATION

The USB communication interface on the ESP301 controller is accessed through the 4 pin USB Type B connector located on the rear panel. The pin out is designed to interface directly with a PC, using a straight through cable.

Appendix **C** shows the pin out of the USB connector and the cable that may be used to interface to a computer.

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COMMUNICATION PROTOCOL

The USB interface must be properly configured on both devices communicating. A correct setting is one that matches **all** parameters (baud rate, number of data bits, number of stop bits, parity type and handshake type) for both devices.

The ESP301 USB configuration is fixed at **921600 baud, 8 data bits, N parity, and 1 stop bit.**

3.2.3 IEEE-488 Interface

HARDWARE CONFIGURATION

A typical IEEE-488 setup consists of a controller (host terminal) and several devices connected to the bus. All devices are connected in parallel to the data lines, data management and synchronization lines.

As a result of this type of connection, each device on the bus must have a unique address so that the controller can selectively communicate with it.

The address can be set through the optional front panel display or with the **SA** (set address) command. (*Note that the factory default is address 1*)

COMMUNICATION PROTOCOL

The IEEE-488 interface is implemented on the motion controller somewhat differently from a typical instrument because the standard IEEE-488.2 command set and command format are inadequate for a complex motion control. Since the ESP controller has its own language and command set, the IEEE-488 interface is used only as a communication port. The extended protocol is not supported.

The ESP301 controller has an ASCII command set and also outputs system status in ASCII format. It features a command input buffer. If the buffer fills up, the ESP301 will not allow further communication until memory becomes available to accept new characters.

To send a command to the ESP301 controller, use the command specific to your IEEE-488 terminal [e.g., output (ASCII)].

If the host terminal asks the controller for a response [e.g., input (ASCII)] and no response is obtained, the controller will eventually will time-out.

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USE OF SRQ LINE

The ESP301 controller can be instructed to generate an IEEE-488 service request (SRQ) upon processing the **RQ** command. This allows the user to generate SRQs anywhere within the ESP command stream thereby facilitating efficient event synchronization capability with the host computer.

The following example illustrates the use of the **RQ** command:

1PR10; 1WS100; 2PR10; 3PR10; 3WS100; RQ
In the above example, the SRQ line is asserted only after execution of the sequence preceding the **RQ** command is finished.

SERIAL POLL

When the IEEE-488 controller senses a service request on the bus, it creates an interrupt to the application program (if configured to do so). The application program must contain a service routine for this interrupt. First, the program must determine which device on the bus generated the service request. This is usually achieved with a function called Serial Poll. The exact syntax for the serial poll command depends on the IEEE-488 controller.

Using that interrupt service routine, a serial poll command can be issued to each device. The device polled at each instance will respond with a status byte. Bit 6 of the status byte indicates whether a specific device (i.e., ESP301 controller) generated the service request or not. Bits 0 through 5 are under user control and are set with the **RQ** command. For example, command "**RQ5**" sets bits 0 and 2. This is useful in helping the application program determine which **RQ** in a program with multiple **RQ**s generated the SRQ.

3.3 Software Utilities

In order to communicate with the controller, the user must have a terminal or a computer capable of communicating through RS-232C, USB or IEEE488. One approach is to use a computer with communications software that can emulate a terminal. Windows XP provides an RS232 terminal emulation program named Hyper Terminal (HyperTrm.Exe) located in Accessories. HyperTrm allows the user to send ASCII commands to the motion controller. The user can even download text files with stored programs. Additionally, it can be used to download controller firmware for future upgrades.

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For IEEE488 communications National Instruments Inc. provides a program named IBIC with their products that allow the user to send and receive ASCII characters and download files. This could be useful in determining that the interface is working.

3.4 Command Syntax

As mentioned previously, the ESP301 controller utilizes an ASCII command set and also outputs system status in ASCII format. Commands may be either upper or lower case characters.
The diagram below illustrates the ESP301 controller command syntax. As indicated in this diagram, a valid command consists of three main fields. The first field consists of a numerical parameter “xx”, the second field consists of a two letter ASCII mnemonic, and the third field consists of numerical parameter “nn”. The command is finally terminated by a carriage return. For example, 3PA10.0 is a valid command.

If a command does not require parameter “xx” and/or parameter “nn”, that field may be skipped by leaving a blank character (space). For example, BO1, 3WS, and AB are all valid commands.

If a command requires multiple parameters in the third field, all these parameters must be comma delimited. For example, 1HN1,2 is a valid command.

In a similar fashion, multiple commands can be issued on a single command line by separating the commands by a semi-colon (;). For example, 3MO; 3PA10.0; 3WS; 3MF is a valid command line.

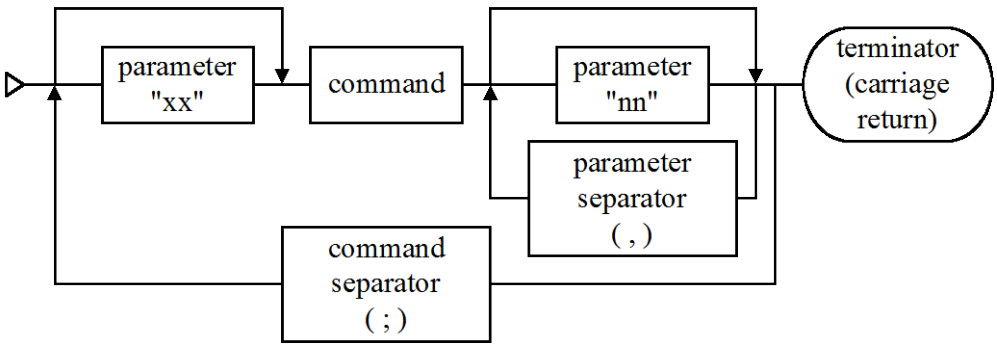


Figure 3.1: Command Syntax Diagram

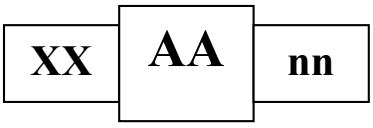
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NOTE

A controller command (or a sequence of commands) has to be terminated with a carriage return character. However, responses from the controller are always terminated by a carriage return/line feed combination. This setting may not be changed. If the IEEE interface is used, the IEEE controller has to be configured to terminate the input (read) function when it senses the line feed character.

3.4.1 Summary of Command Syntax

COMMAND FORMAT



The general format of a command is a two character mnemonic (AA). Both upper and lower case are accepted. Depending on the command, it could also have optional or required preceding (xx) and/or following (nn) parameters.

BLANK SPACES

Blank spaces are allowed and ignored between parameters and commands. For the clarity of the program and memory saving considerations, use blank spaces with restraint. The following two commands are equivalent.

2 PA 1000
2PA1000

but the first example is very confusing and uses more than twice the memory.

COMMAND LINE

Commands are executed line by line. A line can consist of one or a number of commands. The controller will interpret the commands in the order they are received and execute them sequentially. This means that commands issued on the same line are executed significantly closer to each other than if they would be issued on separate lines. The maximum number of characters allowed on a command line is 80.

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SEPARATOR

Commands issued on the same line must be separated by semicolons (**;**).

Multiple parameters issued for the same command are separated by commas (,).

TERMINATOR

Each command line must end with a line terminator, i.e., carriage return.

3.5 Command Summary

The controller understands many commands. The following tables list all of them, sorted first by category and then alphabetically. The tables also show the operating modes in which each command can be used. The acronyms used in the tables have the following meaning:

IMM	IMMediate mode	Controller is idle and the commands will be executed immediately.
PGM	ProGraM mode	Controller does not execute but stores all commands as part of a program. EP activates this mode and **QP** exits it.
MIP	Motion In Progress	Controller executes command on the specified axis while in motion.

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TABLE 3.5.1 – Command List by Category

GENERAL MODE SELECTION

Cmd.	Description	IMM	PGM	MIP	Page
BQ	Enable/disable DIO jog mode	♦	♦	♦	3- 39
DO	Set DAC offset	♦	♦	♦	3- 51
FP	Set position display resolution	♦	♦	♦	3- 58
LC	Lock/Unlock keyboard	♦	♦		3- 92
MF	Power OFF	♦	♦	♦	3- 95
MO	Power ON	♦	♦	♦	3- 96
QD	Update Unidriver amplifier	♦	♦	♦	3- 111
RS	Reset the controller	♦		♦	3- 121
TJ	Set trajectory mode	♦	♦		3- 137
ZA	Set amplifier configuration	♦	♦		3- 155
ZB	Set feedback configuration	♦	♦		3- 158
ZE	Set E-stop configuration	♦	♦		3- 160
ZF	Set following error configuration	♦	♦		3- 162
ZH	Set hardware limit configuration	♦	♦		3- 164
ZS	Set software limit configuration	♦	♦		3- 166
ZU	Get ESP system configuration	♦		♦	3- 168
ZZ	Set system configuration	♦	♦		3- 170

STATUS FUNCTIONS

Cmd.	Description	IMM	PGM	MIP	Page
DP	Get target position	♦		♦	3- 52
DV	Get working speed	♦		♦	3- 53
ID	Get stage model and serial number	♦		♦	3- 83
MD	Get axis motion status	♦		♦	3- 94
PH	Get hardware status	♦		♦	3- 107
TB	Get error message	♦		♦	3- 135
TE	Get error number	♦		♦	3- 136
TP	Get position	♦		♦	3- 138
TS	Get controller status	♦		♦	3- 139
TV	Get velocity	♦		♦	3- 140
TX	Get controller activity	♦		♦	3- 141
VE	Get firmware version	♦		♦	3- 147
XM	Get available program memory	♦		♦	3- 153

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MOTION & POSITION CONTROL

Cmd.	Description	IMM	PGM	MIP	Page
AB	Abort motion	♦		♦	3- 21
DH	Define home	♦	♦		3- 49
MT	Move to hardware travel limit	♦	♦	♦	3- 97
MV	Move indefinitely	♦	♦	♦	3- 98
MZ	Move to nearest index	♦	♦		3- 100
OR	Origin searching	♦	♦	♦	3- 104
PA	Move absolute	♦	♦	♦	3- 106
PR	Move relative	♦	♦	♦	3- 110
ST	Stop motion	♦	♦	♦	3- 133

MOTION DEVICE PARAMETERS

Cmd.	Description	IMM	PGM	MIP	Page
FE	Set following error threshold	♦	♦	♦	3- 57
FR	Full step resolution	♦	♦	♦	3- 59
GR	Set gear ratio	♦	♦	♦	3- 60
QG	Set gear constant	♦	♦		3- 112
QI	Motor current	♦	♦		3- 113
QM	Define motor type	♦	♦		3- 114
QR	Torque reduction	♦	♦	♦	3- 116
QS	Set microstep factor	♦	♦		3- 117
QT	Define tachometer constant	♦	♦		3- 118
QV	Set motor voltage	♦	♦		3- 119
SI	Set master-slave jog update interval	♦	♦	♦	3- 126
SK	Set slave axis jog velocity coefficients	♦	♦	♦	3- 127
SL	Set left limit	♦	♦	♦	3- 128
SN	Set units	♦	♦		3- 130
SR	Set right limit	♦	♦		3- 131
SS	Set master-slave relationship	♦	♦		3- 132
SU	Set encoder resolution	♦	♦		3- 134

PROGRAMMING

Cmd.	Description	IMM	PGM	MIP	Page
DL	**Define label**		♦		3- 50
EO	Automatic execution on power on	♦		♦	3- 54
EP	Enter program download mode	♦			3- 55
EX	Execute stored program	♦	♦		3- 56
JL	Jump to label		♦	♦	3- 86

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LP	List program	♦		♦	3-	92
QP	Quit program mode	♦			3-	115
SM	Save to non-volatile memory	♦			3-	129
XM	Get available program memory	♦		♦	3-	153
XX	Delete a stored program	♦		♦	3-	154

TRAJECTORY DEFINITION

Cmd.	Description	IMM	PGM	MIP	Page	
AC	Set acceleration	♦	♦	♦	3-	22
AE	Set e-stop deceleration	♦	♦	♦	3-	24
AG	Set deceleration	♦	♦	♦	3-	27
AU	Set maximum acceleration	♦	♦	♦	3-	30
BA	Set backlash compensation	♦	♦	♦	3-	31
CO	Set linear compensation	♦	♦	♦	3-	41
JH	Set jog high speed	♦	♦	♦	3-	84
JK	Set jerk rate	♦	♦	♦	3-	85
JW	Set jog low speed	♦	♦	♦	3-	87
OL	Set home search low speed	♦	♦	♦	3-	102
OH	Set home search high speed	♦	♦	♦	3-	101
OM	Set home search mode	♦	♦	♦	3-	103
SH	Set home preset position	♦	♦	♦	3-	125
UF	Update filter parameters	♦	♦	♦	3-	142
VA	Set velocity	♦	♦	♦	3-	145
VB	Set base velocity for step motors	♦	♦	♦	3-	146
VU	Set maximum speed	♦	♦	♦	3-	149

FLOW CONTROL & SEQUENCING

Cmd.	Description	IMM	PGM	MIP	Page	
DL	Define label		♦		3-	50
JL	Jump to label		♦	♦	3-	86
RQ	Generate service request	♦	♦	♦	3-	120
SA	Set device address	♦	♦	♦	3-	122
WP	Wait for absolute position crossing	♦	♦	♦	3-	150
WS	Wait for stop	♦	♦	♦	3-	151
WT	Wait for time	♦	♦	♦	3-	152

I/O FUNCTIONS

Cmd.	Description	IMM	PGM	MIP	Page	
BG	Assign DIO bits to execute stored programs	♦		♦	3-	32
BK	Assign DIO bits to inhibit motion	♦	♦	♦	3-	33

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BL	Enable DIO bits to inhibit motion	♦	♦	♦	3-	34
BM	Assign DIO bits to notify motion status	♦	♦	♦	3-	35
BN	Enable DIO bits to notify motion status	♦	♦	♦	3-	36
BO	Set DIO Port Direction	♦	♦	♦	3-	37
BP	Assign DIO for jog mode	♦	♦	♦	3-	38
BQ	Enable/disable DIO jog mode	♦	♦	♦	3-	39
DC	Setup data acquisition	♦		♦	3-	43
DD	Get data acquisition done status	♦		♦	3-	45
DE	Enable/disable data acquisition	♦		♦	3-	46
DF	Get data acquisition sample count	♦		♦	3-	47
DG	Get acquisition data	♦		♦	3-	48
SB	Set DIO state	♦	♦	♦	3-	123
UL	Wait for DIO bit low		♦		3-	144
UH	Wait for DIO bit high		♦		3-	143

GROUP FUNCTIONS

Cmd.	Description	IMM	PGM	MIP	Page	
HA	Set group acceleration	♦	♦	♦	3-	61
HB	Read list of groups assigned	♦		♦	3-	63
HC	Move group along an arc	♦	♦	♦	3-	64
HD	Set group deceleration	♦	♦	♦	3-	66
HE	Set group E-stop deceleration	♦	♦	♦	3-	68
HF	Group motor power OFF	♦	♦	♦	3-	69
HJ	Set group jerk	♦	♦	♦	3-	70
HL	Move group along a line	♦	♦	♦	3-	71
HN	Create new group	♦	♦		3-	73
HO	Group motor power ON	♦	♦	♦	3-	75
HP	Get group position	♦		♦	3-	76
HQ	Wait for group via point buffer near empty	♦	♦	♦	3-	77
HS	Stop group motion	♦	♦	♦	3-	78
HV	Set group velocity	♦	♦	♦	3-	79
HW	Wait for group motion to stop	♦	♦	♦	3-	80
HX	Delete a group	♦	♦	♦	3-	81
HZ	Get group size	♦		♦	3-	82

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DIGITAL FILTERS

Cmd.	Description	IMM	PGM	MIP	Page
AF	Acceleration/Deceleration feed-forward gain	♦	♦	♦	3- 26
CL	Set closed loop update interval	♦	♦	♦	3- 40
DB	Set position deadband	♦	♦	♦	3- 42
KD	Set derivative gain Kd	♦	♦	♦	3- 88
KI	Set integral gain Ki	♦	♦	♦	3- 89
KP	Set proportional gain Kp	♦	♦	♦	3- 90
KS	Set saturation coefficient Ks	♦	♦	♦	3- 91
UF	Update Filter Parameters	♦	♦	♦	3- 142
VF	Set velocity feed-forward gain	♦	♦	♦	3- 148

MASTER-SLAVE MODE DEFINITION

Cmd.	Description	IMM	PGM	MIP	Page
GR	Set master-slave Ratio	♦	♦	♦	3- 60
SI	Set master-slave jog update interval	♦	♦	♦	3- 126
SK	Set slave axis jog velocity coefficients	♦	♦	♦	3- 127
SS	Set master-slave mode	♦	♦		3- 132

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TABLE 3.5.2 – Command List – Alphabetical

Cmd.	Description	IMM	PGM	MIP	Page
AB	Abort Motion	♦		♦	3- 21
AC	Set acceleration	♦	♦	♦	3- 22
AE	Set e-stop deceleration	♦	♦	♦	3- 24
AF	Set acceleration feed-forward gain	♦	♦	♦	3- 26
AG	Set deceleration	♦	♦	♦	3- 27
AP	Abort program	♦	♦	♦	3- 29
AU	Set maximum acceleration and deceleration	♦	♦	♦	3- 30
BA	Set backlash compensation	♦	♦	♦	3- 31
BG	Assign DIO bits to execute stored programs	♦		♦	3- 32
BK	Assign DIO bits to inhibit motion	♦	♦	♦	3- 33
BL	Enable DIO bits to inhibit motion	♦	♦	♦	3- 34
BM	Assign DIO bits to notify motion status	♦	♦	♦	3- 35
BN	Enable DIO bits to notify motion status	♦	♦	♦	3- 36
BO	Set DIO port A, B, C direction	♦	♦	♦	3- 37
BP	Assign DIO bits for jog mode	♦	♦	♦	3- 38
BQ	Enable DIO bits for jog mode	♦	♦	♦	3- 39
CL	Set closed loop update interval	♦	♦	♦	3- 40
CO	Set linear compensation	♦	♦	♦	3- 41
DB	Set position deadband	♦	♦	♦	3- 42
DC	Setup data acquisition	♦		♦	3- 43
DD	Get data acquisition done status	♦		♦	3- 45
DE	Enable/disable data acquisition	♦		♦	3- 46
DF	Get data acquisition sample count	♦		♦	3- 47
DG	Get acquisition data	♦		♦	3- 48
DH	Define home	♦	♦	♦	3- 49
DL	Define label	♦	♦	♦	3- 50
DO	Set DAC offset	♦	♦	♦	3- 51
DP	Read desired position	♦		♦	3- 52
DV	Read desired velocity	♦		♦	3- 53
EO	Automatic execution on power on	♦		♦	3- 54
EP	Enter program mode	♦			3- 55
EX	Execute a program	♦	♦		3- 56
FE	Set maximum following error threshold	♦	♦	♦	3- 57

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TABLE 3.5.2 – Command List – Alphabetical (Continued)

Cmd.	Description	IMM	PGM	MIP	Page
FP	Set position display resolution	♦	♦	♦	3- 58
FR	Set full step resolution	♦	♦	♦	3- 59
GR	Set master-slave reduction ratio	♦	♦	♦	3- 60
HA	Set group acceleration	♦	♦	♦	3- 61
HB	Read list of groups assigned	♦		♦	3- 63
HC	Move group along an arc	♦	♦	♦	3- 64
HD	Set group deceleration	♦	♦	♦	3- 66
HE	Set group e-stop deceleration	♦	♦	♦	3- 68
HF	Group motor power off	♦	♦	♦	3- 69
HJ	Set group jerk	♦	♦	♦	3- 70
HL	Move group along a line	♦	♦	♦	3- 71
HN	Create new group	♦	♦		3- 73
HO	Group on	♦	♦	♦	3- 75
HP	Read group position	♦		♦	3- 76
HQ	Wait for group command buffer level	♦	♦	♦	3- 77
HS	Stop group motion	♦	♦	♦	3- 78
HV	Set group velocity	♦	♦	♦	3- 79
HW	Wait for group motion stop	♦	♦	♦	3- 80
HX	Delete group	♦	♦	♦	3- 81
HZ	Read group size	♦	♦	♦	3- 82
ID	Read stage model and serial number	♦		♦	3- 83
JH	Set jog high speed	♦	♦	♦	3- 84
JK	Set jerk rate	♦	♦	♦	3- 85
JL	Jump to label		♦	♦	3- 86
JW	Set jog low speed	♦	♦	♦	3- 87
KD	Set derivative gain	♦	♦	♦	3- 88
KI	Set integral gain	♦	♦	♦	3- 89
KP	Set proportional gain	♦	♦	♦	3- 90
KS	Set saturation level of integral factor	♦	♦	♦	3- 91
LP	List program	♦		♦	3- 92
LC	Lock/unlock keyboard	♦	♦		3- 92
MD	Read motion done status	♦		♦	3- 94
MF	Motor power off	♦	♦	♦	3- 95
MO	Motor power on	♦	♦	♦	3- 96
MT	Move to hardware travel limit	♦	♦	♦	3- 97
MV	Move indefinitely	♦	♦	♦	3- 986
MZ	Move to nearest index	♦	♦	♦	3- 100
OH	Set home search high speed	♦	♦	♦	3- 101
OL	Set home search low speed	♦	♦	♦	3- 102
OM	Set home search mode	♦	♦	♦	3- 103

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TABLE 3.5.2 – Command List – Alphabetical (Continued)

In a PDF format you may click on a page number to automatically be connected to the corresponding Command Page

Cmd.	Description	IMM	PGM	MIP	Page
OR	Search for home	♦	♦		3-104
PA	Move to absolute position	♦	♦	♦	3-106
PH	Get hardware status	♦		♦	3-107
PR	Move to relative position	♦	♦	♦	3-110
QD	Update motor driver settings	♦	♦		3-111
QG	Set gear constant	♦	♦		3-112
QI	Set maximum motor current	♦	♦		3-113
QM	Set motor type	♦	♦		3-114
QP	Quit program mode	♦			3-115
QR	Reduce motor torque	♦	♦	♦	3-116
QS	Set microstep factor	♦	♦		3-117
QT	Set tachometer gain	♦	♦		3-118
QV	Set average motor voltage	♦	♦		3-119
RQ	Generate service request	♦	♦	♦	3-120
RS	Reset the controller	♦		♦	3-121
SA	Set device address	♦	♦	♦	3-122
SB	Set/get DIO port A, B, C bit status	♦	♦	♦	3-123
SH	Set home preset position	♦	♦	♦	3-125
SI	Set master-slave jog velocity update interval	♦	♦	♦	3-126
SK	Set master-slave jog velocity scaling coefficients	♦	♦	♦	3-127
SL	Set level travel limit	♦	♦	♦	3-128
SM	Save settings to non-volatile memory	♦			3-129
SN	Set axis displacement units	♦	♦		3-130
SR	Set right travel limit	♦	♦		3-131
SS	Define master-slave relationship	♦	♦		3-132
ST	Stop motion	♦	♦	♦	3-133
SU	Set encoder resolution	♦	♦		3-134
TB	Read error message	♦		♦	3-135
TE	Read error code	♦		♦	3-136
TJ	Set trajectory mode	♦	♦		3-137
TP	Read actual position	♦		♦	3-138
TS	Get controller status	♦		♦	3-139
TV	Get actual velocity	♦		♦	3-140
TX	Get controller activity	♦		♦	3-141
UF	Update servo filter	♦	♦	♦	3-142
UH	Wait for DIO bit high		♦		3-143

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TABLE 3.5.2 – Command List – Alphabetical (Continued)

In a PDF format you may click on a page number to automatically be connected to the corresponding Command Page

Cmd.	Description	IMM	PGM	MIP	Page
UL	Wait for DIO bit low		♦		3-144
VA	Set velocity	♦	♦	♦	3-145
VB	Set base velocity for step motors	♦	♦	♦	3-146
VE	Read controller firmware version	♦		♦	3-147
VF	Set velocity feed-forward gain	♦	♦	♦	3-148
VU	Set maximum velocity	♦	♦	♦	3-149
WP	Wait for absolute position crossing	♦	♦	♦	3-150
WS	Wait for motion stop	♦	♦	♦	3-151
WT	Wait	♦	♦	♦	3-152
XM	Get available program memory	♦		♦	3-153
XX	Delete a stored program	♦		♦	3-154
ZA	Set amplifier I/O configuration	♦	♦		3-155
ZB	Set feedback configuration	♦	♦		3-158
ZE	Set E-stop configuration	♦	♦		3-160
ZF	Set following error configuration	♦	♦		3-162
ZH	Set hardware limit configuration	♦	♦		3-164
ZS	Set software limit configuration	♦	♦		3-166
ZU	Get ESP system configuration	♦		♦	3-168
ZZ	Set system configuration	♦	♦		3-170

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3.6 Description of Commands

The extensive ESP301 controller command set exists to facilitate application development for wide range of application and needs. However, most simple positioning can be done with just a few commands:

VA – set velocity
AC – set acceleration
AG – set deceleration
PR – position relative
PA – position absolute
TP – tell position
WS – wait for stop

NOTE

Most of the commands take an axis number as a parameter (xx). For such commands, the valid range of axis number is from 1 to MAX AXES, where MAX AXES is dependent on the configuration of the ESP301 motion controller.

Commands related to coordinated motion and contouring (group commands) take a group number as a parameter. For such commands, the valid range of group number is from 1 to MAX GROUPS, where MAX GROUPS is one-half the MAX AXES.

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AA – (command mnemonic) **(brief definition) (motor type) ***

(diamonds mark which mode the command can be used in)

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xxAAnn (generic syntax format)

PARAMETERS

Description

xx [int] -- (description of parameter)
Nn [float] -- (description of parameter)
(parameter could be **int**eger number, **float**ing point number, **char**acter or **str**ing)

Range

xx -- **(minimum value** to **maximum value)**
nn -- **(minimum value** to **maximum value)**

Units

xx -- (units description)
nn -- (units description)

Defaults

xx missing: (default or error if parameter is missing)
out of range: (default or error if parameter is out of range)
nn missing: (default or error if parameter is missing)
out of range: (default or error if parameter is out of range)

DESCRIPTION (detailed description of the command)
Note:
(notes, reminders and things to consider when using the command, if any)

RETURNS **(Type,** format and description of the return the command is Generating, if any)

ERRORS (Error Code) – (description of errors the command could Generate if misused)

REL. COMMANDS (brief definition of related commands)

EXAMPLE (Command Discussed) | *(description)*
(Other command) | *(description)*
(Controller return) | *(description)*

***(motor type)** – if the command is specific for a motor type (DC or stepping) it will be labeled here, otherwise this field is blank,
** The mode mnemonics has the following meanings:
IMMediate mode – controller is in idle mode and the commands are executed immediately.

Pro**G**ra**M** mode – controller does not execute but stores all commands as part of a program.

Motion **I**n **P**rogress – controller is executing a motion on all or the specified axis.

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AB abort motion

USAGE **IMM** PGM **MIP**

SYNTAX **AB**

PARAMETERS None.

DESCRIPTION This command should be used as an emergency stop. On reception of this command, the controller invokes emergency stop event processing for each axis as configured by **ZE** (e-stop event configuration) command.

By default axes are configured to turn motor power OFF, however, individual axes can be configured to stop using emergency deceleration rate set by **AE** command and maintain motor power.
It should be used only as an immediate command, not in a program.

Note
This command affects all axes, however the action taken is determined by each individual's axis **ZE** command configuration.

RETURNS none

REL. COMMANDS

ST	-	stop motion
AE	-	e-stop deceleration
ZE	-	e-stop deceleration
MF	-	motor OFF
MO	-	motor ON

EXAMPLE **AB** | used as an immediate command to stop all motion

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AC set acceleration

USAGE

IMM	PGM	MIP
..	..	..

SYNTAX xx**AC**nn or xx**AC**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	acceleration value
Range	**xx**	-	**1** to **MAX AXES**
	N	-	**0** to the maximum programmed value in **AU** command or **?** to read current setting
Units	**xx**	-	none
	nn	-	predefined units / second^2
Defaults	**xx**	missing:	error 37, AXIS NUMBER MISSING
		out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error xx11, MAXIMUM ACCELERATION EXCEEDED

DESCRIPTION

This command is used to set the acceleration value for an axis. Its execution is immediate, meaning that the acceleration is changed when the command is processed, even while a motion is in progress.

It can be used as an immediate command or inside a program. If the requested axis is a member of a group, the commanded acceleration becomes effective only after the axis is removed from the group. (Refer to Advanced Capabilities section for a detailed description of grouping and related commands)

Avoid changing the acceleration during the acceleration or deceleration periods. For better predictable results, change acceleration only when the axis is not moving or when it is moving with a constant speed.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

VA	-	set velocity
PA	-	execute an absolute motion
PR	-	execute a relative motion
AU	-	set maximum acceleration and deceleration
AG	-	set deceleration

EXAMPLE

2AU?	| *read maximum allowed acceleration/deceleration of axis # 2*
10	| *controller returns a value of 10 units/s^2*
2AC9	| *set acceleration to 9 units/s^2*

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2AG6	| *set deceleration to 6 units/s^2*
2AU15	| *set axis # 2 maximum acceleration/deceleration to 15 units/s^2*
2AU?	| *read maximum allowed acceleration & deceleration of axis # 2*
15	| *controller returns a value of 15 units*

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AE set e-stop deceleration

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**AE**nn or xx**AE**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	e-stop deceleration value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	current normal deceleration value to **2e9 * encoder resolution** or **?** to read current setting
Units	**xx**	-	none
	nn	-	predefined units / second^2
Defaults	**xx**	missing:	error 37, AXIS NUMBER MISSING
		out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error 1, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to set the e-stop deceleration value for an axis. Its execution is immediate, meaning that the e-stop deceleration value is changed when the command is processed, even while a motion is in progress.

It can be used as an immediate command or inside a program. If the requested axis is a member of a group, the commanded e-stop deceleration becomes effective only after the axis is removed from the group. (Refer to Advanced Capabilities section for a detailed description of grouping and related commands)

E-stop deceleration is invoked upon a local e-stop condition (e.g., front panel Stop All pushbutton, Interlock, etc..) has occurred, if configured to do so, or if the AB (abort motion) command is processed.

Note:
E-stop deceleration value cannot be set lower than the normal deceleration value. Refer the description of "**AG**" command for range of deceleration values.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

VA	-	set velocity
PA	-	execute an absolute motion
PR	-	execute a relative motion
AU	-	set maximum acceleration and deceleration

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AG	-	set deceleration
AC	-	set acceleration

EXAMPLE

2AE?	|	*read e-stop deceleration of axis # 2*
100	|	*controller returns a value of 100 units/s^2*
2AE150	|	*set e-stop deceleration to 150 units/s^2*

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AF set acceleration feed-forward gain

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**AF**nn or xx**AF**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	acceleration feed-forward gain factor
Range	**xx**	-	**1** to **MAX AXES**
	nn-	-	**0** to **2e9,** or **?** to read current setting
Units	**xx**	-	none
	nn	-	none

Defaults	**xx** missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command sets the acceleration feed-forward gain factor Af. It is active for any DC servo based motion device.

.

See the "**Feed-Forward Loops**" in Motion Control Tutorial section to understand the basic principles of feed-forward.

Note:
The command can be sent at any time but it has no effect until the UF (update filter) is received.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

KI	-	set integral gain factor
KD	-	set derivative gain factor
KP	-	set proportional gain factor
KS	-	set saturation gain factor
VF	-	set velocity feed-forward gain
UF	-	update filter

EXAMPLE

3VF1.5	*| set acceleration feed-forward gain factor for axis # 3 to 1.5*
3AF?	*| report present axis-3 acceleration feedforward setting*
0.9	*| controller returns a value of 0.9*
3AF0.8	*| set acceleration feed-forward gain factor for axis # 3 to 0.8*
3UF	*| update PID filter; only now the **AF** command takes effect*

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AG set deceleration

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**AG**nn or xx**AG**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	acceleration value
Range	**xx**	-	**1** to **MAX AXES**
	Nn	-	to the maximum programmed value in **AU** command or **?** to read current setting
Units	**xx**	-	none
	Nn	-	predefined units / second^2
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx11, MAXIMUM ACCELERATION EXCEEDED

DESCRIPTION

This command is used to set the deceleration value for an axis. Its execution is immediate, meaning that the deceleration is changed when the command is processed, even while a motion is in progress.

It can be used as an immediate command or inside a program. If the requested axis is a member of a group, the commanded deceleration becomes effective only after the axis is removed from the group. (Refer to Advanced Capabilities section for a detailed description of grouping and related commands)

Avoid changing the deceleration during the acceleration or deceleration periods. For better predictable results, change deceleration only when the axis is not moving or when it is moving with a constant speed.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

VA	-	set velocity
PA	-	execute an absolute motion
PR	-	xecute a relative motion
AU	-	set maximum acceleration and deceleration
AC	-	set acceleration

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EXAMPLE

2AU?	|	*read maximum allowed acceleration/deceleration of axis # 2*
10	|	*controller returns a value of 10 units/s^2*
2AC9	|	*set acceleration to 9 units/s^2*
2AG6	|	*set deceleration to 6 units/s^2*
2AG?	|	*read maximum current deceleration of axis # 2*
6	|	*controller returns a value of 6 units/s^2*

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AP abort program

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **AP**

PARAMETERS none

DESCRIPTION This command is used to interrupt a motion program in execution. It will not stop a motion in progress. It will only stop the program after the current command line finished executing.

It can be used as an immediate command or inside a program.

Inside a program it is useful in conjunction with program flow control commands. It could, for instance, terminate a program on the occurrence of a certain external event, monitored by an I/O bit.

RETURNS none

REL. COMMANDS **EX** - execute a program

EXAMPLE

```
3EX          | execute program # 3
  .
  .
  .
AP           | stop program execution
```


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AU set maximum acceleration and deceleration

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**AU**nn or xx**AU**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [float]	-	acceleration value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **2e+9,** or **?** to read current setting
Units	**xx**	-	none
	nn	-	predefined units / second^2
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx11, MAXIMUM ACCELERATION EXCEEDED
			error xx1, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the maximum acceleration and deceleration value for an axis. This command remains effective even if the requested axis is member of a group. In this case, two error messages "GROUP MAXIMUM ACCELERATION EXCEEDED" or "GROUP MAXIMUM DECELERATION EXCEEDED" are generated if the commanded value is less than group acceleration or deceleration respectively. (Refer to Advanced Capabilities section for a detailed description of grouping and related commands)

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

VA	-	set velocity
PA	-	execute an absolute motion
PR	-	execute a relative motion
AG	-	set deceleration
AC	-	et acceleration

EXAMPLE

AU?	| *read maximum allowed acceleration/deceleration of axis # 2*
10	| *controller returns a value of 10 units/s^2*
2AC9	| *set acceleration to 9 units/s^2*
2AG6	| *set deceleration to 6 units/s^2*
2AU15	| *set axis # 2 maximum acceleration/deceleration to 15 units/s^2*
2AU?	| *read maximum allowed acceleration & deceleration of axis # 2*
15	| *controller returns a value of 15 units/s^2*

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BA set backlash compensation

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**BA**nn or xx**BA**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	backlash compensation value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	to **distance equivalent to 10000 encoder counts**
Units	**xx**	-	none
	nn	-	user units

Defaults	**xx**	missing:	error 37, AXIS NUMBER MISSING
		out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error 7, PARAMETER OUT OF RANGE

DESCRIPTION This command initiates a backlash compensation algorithm when motion direction is reversed. The controller keeps track of the motion sequence and for each direction change it adds the specified **nn** correction. Setting **nn** to zero disables the backlash compensation.

NOTE: The command is affective only after a home search (**OR**) or define home (**DH**) is performed on the specified axis.

RETURNS If "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS None

EXAMPLE

1BA0.0012	|	*Set backlash compensation value for axis #1 to 0.0012 units*
1BA?	|	*Query backlash compensation value for axis #1*
0.0012	|	*Controller returns a value of 0.0012 units*
1OR	|	*Perform home search on axis #1*
1PA10	|	*Move axis #1 to absolute 10 units*
1PA0	|	*Move axis #1 to absolute 0 units*

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BG assign DIO bits to execute stored programs

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **xxBGnn or xxBG?**

PARAMETERS

Description	**xx** [int]	-	bit number used to trigger stored program execution
	nn [char]	-	name of stored program to be executed
Range	**xx**	-	**0** to **15**
	nn	-	None or **?** to read current setting
Units	None		
Defaults	**xx**	missing:	error 7, PARAMETER OUT OF RANGE
		out of range:	error 7, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to assign DIO bits for initiating the execution of a desired stored program. Execution of the stored program begins when the specified DIO bit changes its state from HIGH to LOW logic level.

Note: Each DIO bit has a pulled-up resistor to +5V. Therefore, all bits will be at HIGH logic level if not connected to external circuit and configured as input.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

BO	-	Set DIO port A, B direction
EP	-	Enter program mode
EX	-	Execute stored program
AP	-	Abort stored program execution

EXAMPLE

```
BO 04H      | Set DIO ports A and B to input
0 BG 1      | Start execution of a stored program 1 when DIO bit #0 changes
            | state from HIGH to LOW
```


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BK assign DIO bits to inhibit motion

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **xxBKnn1, nn2 or xxBK?**

PARAMETERS

Description

xx [int]	-	axis number
nn1 [int]	-	bit number for inhibiting motion
nn2 [int]	-	bit level when axis motion is inhibited

Range

xx	-	**1** to **MAX AXES**
nn1	-	**0** to **15**
nn2	-	**0 = LOW** and **1 = HIGH** or **?** to read current setting

Units None

Defaults

xx	missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
nn1	missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx1, PARAMETER OUT OF RANGE
nn2	missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx1, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to assign DIO bits for inhibiting the motion of a selected axis. If the selected axis is already in motion, and DIO bit is asserted, e-stop is executed per E-stop configuration (Refer "**ZE**" command for further details). If the axis is not moving, any new move commands are refused as long as the DIO bit is asserted. In either case, "DIGITAL I/O INTERLOCK DETECTED" error is generated.

Note: The direction of the DIO port (A, B) the desired bit belongs to, should be set to "input" in order for the DIO bit to be read accurately. Refer "**BO**" command for further details.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current assignment.

REL. COMMANDS

BL	-	Enable DIO bits to inhibit motion
BO	-	Set DIO port A, B direction
BM	-	Assign DIO bits to notify motion status

EXAMPLE

```
BO 04H      | Set DIO ports A, B to input
2BK 1, 1    | Use DIO bit #1 to inhibit motion of axis #2. This DIO bit should be
            | HIGH when axis #2 motion is inhibited
2BL 1       | Enable inhibition of motion using DIO bits for axis #2
2BK?        | Query the DIO bit assignment for axis #2
1, 1        | The controller responds with the assigned values
```


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BL enable DIO bits to inhibit motion

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **xxBLnn or xxBL?**

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	disable or enable
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** = disable, and **1** = enable or **?** to read current setting
Units	None		
Defaults	**xx**	missing:	error 37, AXIS NUMBER MISSING
		out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error xx1, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to disable or enable motion inhibition of requested axes through DIO bits.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current status.

REL. COMMANDS

BK	-	Assign DIO bits to inhibit motion.
BO	-	Set DIO port A, B direction
BM	-	Assign DIO bits to notify motion status
BN	-	Enable DIO bits to notify motion status.

EXAMPLE

BO 04H	| *Set DIO ports A and B to input*
2BK 1, 1	| *Use DIO bit #1 to inhibit motion of axis #2. This DIO bit should be*
	| *HIGH when axis #2 motion is inhibited*
2BL 1	| *Enable inhibition of motion using DIO bits for axis #2*
2BK?	| *Query the DIO bit assignment for axis #2*
1, 1	| *The controller responds with the assigned values*
2BL?	| *Query the status of inhibiting motion for axis #2 through DIO*
1	| *The controller responds with 1 indicating feature is enabled*

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BM assign DIO bits to notify motion status

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **xxBMnn1, nn2 or xxBM?**

PARAMETERS

Description

xx [int]		-	axis number
nn1 [int]		-	bit number for notifying motion status
nn2 [int]		-	bit level when axis is not moving

Range

xx		-	**1** to **MAX AXES**
nn1		-	**0** to **15**
nn2		-	**0 = LOW** and **1 = HIGH** or **?** to read current setting

Units None

Defaults

xx	missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
nn1	missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx1, PARAMETER OUT OF RANGE
nn2	missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx1, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to assign DIO bits for notifying the motion status – moving or not moving – of a selected axis. When the selected axis is not moving, the DIO bit state changes to the level specified with this command (refer parameter **nn2**).

NOTE: The direction of the DIO port (A, B) the desired bit belongs to, should be set to "output" in order for the DIO bit to be set accurately. Refer "**BO**" command for further details.

NOTE: If a motion feature, such as origin search, involves a sequence of moves, the motion status will be set to not moving only after the entire sequence of moves has completed.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current assignment.

REL. COMMANDS

BN	-	Enable DIO bits to notify motion status
BO	-	Set DIO port A, B direction

EXAMPLE

BO 06H	| *Set DIO port A to input and port B to output*
2BM 9, 1	| *Use DIO bit #9 to indicate motion status of axis #2. This DIO bit should be HIGH when axis #2 is not moving*
2BN 1	| *Enable notification of motion using DIO bits for axis #2*
2BM?	| *Query the DIO bit assignment for axis #2*
9, 1	| *The controller responds with the assigned values*

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BN enable DIO bits to notify motion status

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **xxBNnn or xxBN?**

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	disable or enable
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** = disable, and **1** = enable or **?** to read current setting
Units	None		

Defaults	**xx**	missing:	error 37, AXIS NUMBER MISSING
		out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error xx1, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to disable or enable notification of requested axis' motion status through DIO bits.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current status.

REL. COMMANDS

BM	-	Assign DIO bits to notify motion status
BO	-	Set DIO port A, B direction
BK	-	Assign DIO bits to inhibit motion
BL	-	Enable DIO bits to inhibit motion

EXAMPLE

BO 06H	| *Set DIO port A to input and port B to output*
2BM 9, 1	| *Use DIO bit #9 to indicate motion status of axis #2. This DIO bit*
	| *should be HIGH when axis #2 is not moving*
2BN 1	| *Enable notification of motion using DIO bits for axis #2*
2BM?	| *Query the DIO bit assignment for axis #2*
9, 1	| *The controller responds with the assigned values*
2BN?	| *Query the status of notifying motion status of axis #2 through DIO bits*
1	| *The controller responds with 1 indicating feature is enabled*

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BO set DIO port A, B, C direction

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **BO**nn or **BO**?

PARAMETERS

Description	**nn** [int]	-	hardware limit configuration
Range	**nn**	-	**0 to 05H (hexadecimal with leading zero(0))** or **?** to read current setting
Units	**nn**	-	None
Defaults	**nn**	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to set digital I/O (DIO) port A and B direction where bit-0 corresponds to port A and B, bit-1 to port B. If any bit is set to zero(0) then its corresponding port will become an input only. If any bit is set to one(1) then its corresponding port will becomes an output only.

A DIO within a port configured as an input can only report its present HIGH or LOW logic level. Whereas a DIO bit within a port configured as an output can set(1) or clear(0) the corresponding DIO hardware to HIGH or LOW logic level. Reading the status of a port configured as output returns its present output status.

NOTE: All direction bits are automatically zeroed, or cleared, after a system reset. Therefore all DIO ports default to input by default.

NOTE: Each DIO bit has a pulled-up resistor to +5V. Therefore, all bits will be at HIGH logic level if not connected to external circuit and configured as input.

BIT#	VALUE	DEFINITION
*0	0	port A (DIO bit-0 through bit-7) assigned as input
0	1	port A (DIO bit-0 through bit-7) assigned as output
*1	0	port B (DIO bit-8 through bit-15) assigned as input
1	1	port B (DIO bit-8 through bit-15) assigned as output
		* default setting after system reset

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting in hexadecimal notation.

REL. COMMANDS **SB** - set/clear DIO bits

EXAMPLE BO?

```
                | read DIO port direction configuration
0H              | controller returns a value of 0H (all ports are input)
BO 1H           | configure DIO port A as output
SB 0FFH         | set all port A DIO output HIGH
```


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BP assign DIO bits for jog mode

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **xxBPnn1,nn2 or xxBP?**

PARAMETERS

Description	**xx** [int]	-	axis number
	nn1 [int]	-	bit number for jogging in negative direction
	nn2 [int]	-	bit number for jogging in positive direction
Range	**xx**	-	**1** to **MAX AXES**
	nn$_i$	-	**0** to **15**
Units	**xx**	-	none
	nn$_i$	-	none

Defaults	**xx**	missing:	error 37, AXIS NUMBER MISSING
		out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to assign DIO bits for jogging axes in either negative or positive directions.

RETURNS If "?" sign is issued along with command, the controller returns the DIO bits used for jogging in negative and positive directions respectively.

REL. COMMANDS **BO** - enable usage of DIO bits for jogging axes

EXAMPLE

1BP3, 4	| *set DIO bit #3 to jog axis #1 in negative direction and DIO bit #4 to jog axis #1 in positive direction*
1BP?	| *query the DIO bits assigned for jogging*
3,4	| *controller returns the bit assignment*
1BQ1	| *enable axis #1 jogging through DIO bits.*

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BQ enable DIO bits for jog mode

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **xxBQ**nn or **BQ**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	disable or enable
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** = disable, and **1** = enable
Units	**xx**	-	none
	nn	-	one

Defaults	**xx**	missing:	error 37, AXIS NUMBER MISSING
		out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to disable or enable jogging of a requested axis through DIO bits.

RETURNS If "?" sign is issued along with command, the controller returns the status of jog through DIO bits.

REL. COMMANDS **BP** - assign DIO bits for jog mode

EXAMPLE

```
1BP3,4      | set DIO bit #3 to jog axis #1 in negative direction and
            | DIO bit #4 to jog axis #1 in positive direction
1BP?        | query the DIO bits assigned for jogging
3,4         | controller returns the bit assignment
1BQ1        | enable axis #1 jogging through DIO bits.
```


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CL set closed loop update interval

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **xxCLnn or xxCL?**

PARAMETERS

Description	**xx** { int]	-	axis number
	nn [int]	-	closed loop update interval
Range	**xx**	-	**0** to **MAX AXES**
	nn	-	**0** to **60000**
Units	**xx**	-	none
	nn	-	milliseconds
Defaults	**xx**	missing:	error 37, AXIS NUMBER MISSING
		out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to set the closed loop update interval for an axis. This will be the time duration between position error corrections during closed loop stepper positioning. Note that this command is effective only for steeper motors.

Furthermore, note that encoder feedback and closed loop positioning must be enabled for this command to be effective. Refer to feedback configuration (**ZB**) command for enabling these features in the case of stepper motors.

If "0" is used as an axis number, this command will set the specified interval to all the axes.

RETURNS

If "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

ZB	-	set feedback configuration
DB	-	set position deadband value

EXAMPLE

3ZB300	| *enable encoder feedback and closed loop positioning of axis #3*
3DB1	| *set position deadband value to 1 encoder count*
3DB?	| *query deadband value*
1	| *controller returns a value of 1 encoder count*
3CL100	| *set closed loop update interval to 100 milliseconds*
3CL?	| *query closed loop update interval*
100	| *controller returns a value of 100 milliseconds*

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CO set linear compensation

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**CO**nn or xx**CO**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	linear compensation value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **2e+9**
Units	**xx**	-	none
	nn	-	none

Defaults

xx missing: error 37, AXIS NUMBER MISSING
out of range: error 9, AXIS NUMBER OUT OF RANGE

nn missing: error 38, COMMAND PARAMETER MISSING
out of range: error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command allows users to compensate for linear positioning errors due to stage inaccuracies. Such errors decrease or increase actual motion linearly over the travel range.

The linear compensation value, **nn** is calculated according to the formula given below:

$$nn = \frac{error}{travel}$$

where,

travel = measured travel range
error = error accumulated over the measured travel range

NOTE: The command is affective only after a home search (**OR**) or define home (**DH**) is performed on the specified axis.

RETURNS

If "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

None

EXAMPLE

If a stage has a travel range of 100 mm and it accumulates an error of 0.003 mm over the complete travel range,

$$nn = \left(\frac{0.003}{100}\right) = 0.00003$$

1CO0.00003	*Set linear compensation value for axis #1 to 0.00003*
1CO?	*Query linear compensation value for axis #1*
0.00003	*Controller returns a value of 0.00003*
1OR	*Perform home search on axis #1*
1PA10	*Move axis #1 to absolute 10 units*

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DB set position deadband

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**DB**nn or xx**DB**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	deadband value
Range	**xx**	-	**0** to **MAX AXES**
	nn	-	to **2e9**
Units	**xx**	-	none
	nn	-	encoder counts
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING

DESCRIPTION

This command is used to set the position deadband value for an axis. Since a majority of electro-mechanical systems have mechanical backlash or frictional hysterisis, closed-loop positioning can at times lead to oscillation or limit cycling of the systems around a desired position. In such situations, setting position deadband value judiciously can avoid limit cycling of the systems.

Note that this command is effective only during position regulation (holding position) as opposed to moving.

Furthermore, note that encoder feedback and closed loop positioning must be enabled for this command to be effective. Refer to feedback configuration (**ZB**) command for enabling these features in the case of stepper motors.

If "0" is used as an axis number, this command will set the specified deadband value to all the axes.

RETURNS

If "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

ZB	-	set feedback configuration
CL	-	set closed loop update interval

EXAMPLE

ZB300	|	*enable encoder feedback and closed loop positioning of axis#3*
3DB1	|	*set position deadband value to 1 encoder count*
3DB?	|	*query deadband value*
1	|	*controller returns a value of 1 encoder count*
3CL100	|	*set closed loop update interval to 100 milliseconds*
3CL?	|	*query closed loop update interval*
100	|	*controller returns a value of 100 milliseconds*

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DC setup data acquisition

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **DC**nn1,nn2,nn3,nn4,nn5,nn6

PARAMETERS
Description

nn1	[int]	-	data acquisition mode
nn2	[int]	-	axis used to trigger data acquisition
nn3	[int]	-	data acquisition parameter 3
nn4	[int]	-	data acquisition parameter 4
nn5	[int]	-	data acquisition rate
nn6	[int]	-	number of data samples to be acquired

Range

nn1	-	**0:** Start data acquisition immediately **1:** Start data acquisition when trigger axis starts motion **2:** Start data acquisition when trigger axis reaches slew speed
nn2	-	**1** to **MAX AXES**
nn3	-	Refer table below
nn4	-	Refer table below
nn5	-	**0** to **1000**
nn6	-	to **1000**

Units None

Defaults

nn	missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to setup data acquisition—analog data acquisition (ADC) as well as acquisition of certain trace variables—using ESP motion controller.

PARAMETER nn1: Data acquisition modes 0—2 support different ways in which analog data can be collected.

PARAMETER nn2: Data acquisition is triggered by the motion of an axis specified through this parameter. Exceptions to this requirement are in the case of data acquisition mode 0. For thiscases enabling data acquisition is sufficient to start the data acquisition process. For all other modes, two conditions—enabling of data acquisition and any mode dependent conditions such as trigger axis starting motion or reaching slew speed—must be met in order to start the data acquisition process.

PARAMETER nn3: set this value to 0.

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PARAMETER nn4: This parameter is used to identify the position feedback channels to be collected. Please refer to table below.

nn4	Position feedback channels collected
0	none
1	channel 1
2	channel 2
3	channel 1 & 2
4	channel 3
5	channel 1 & 3
6	channel 2 & 4
7	channel 1,2,3

PARAMETER nn5: The rate at which data is to be acquired is specified through this parameter. The rate specified is in multiples of the (400 µs) rate. For example, a value of 0 implies data acquisition every servo cycle (400 µs), a value of 1 implies every other servo cycle (400 µs), and so on.

PARAMETER nn6: The number of samples of data to be acquired is specified through this parameter. Data acquisition process is considered to be "done" only after the number of samples specified by this parameter are acquired by the controller. The status of data acquisition process may be found by issuing ASCII command, **DD**. Once the data acquisition is done, ASCII command, **DG** may be used to collect the data from the controller.
Note: The controller responds with a servo cycle (400 µs) tick count along with every data sample collected.

RETURNS

None.

REL. COMMANDS

DD - get data-acquisition done status
DE - enable / disable data-acquisition
DF - get data-acquisition status – number of samples collected
DG - get data-acquisition data

EXAMPLE

DC10,1,1,1,0,1000 | *Acquire trace variable data for axis 1, in scaled integer format. Collect 1000 samples, one sample / servo cycle (400 µs)*
DE1 | *Enable data acquisition*
DD | *Query data-acquisition done status*
1 = true, 0 = false.
If true,
DE0 | *Disable trace variable data acquisition*
DG | *Get data collected*

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DD get data acquisition done status

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **DD**

PARAMETERS **none**

DESCRIPTION This command returns the status of a data acquisition request.

RETURNS **aa,** where: **aa** = **1** for True, **0** for False

REL. COMMANDS

DC	-	setup data acquisition request
DG	-	get acquired data
DF	-	data acquisition status, returns # of samples collected
DE	-	enable / disable data acquisition

EXAMPLE

DC10,1,1,1,0,1000 | *Acquire trace variable data for axis 1, in scaled integer format. Collect 1000 samples, one sample / servo cycle (400 µs)*
DE1 | *Enable trace variable data acquisition*
DD | *Query data-acquisition done status*
1 = true, 0 = false.
If true,
DE0 | *Disable trace variable data acquisition*
DG | *Get data collected*

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DE enable/disable data acquisition

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **DE**nn

PARAMETERS
Description
nn [int] - True | False

Range **nn** - **1** for True, **0** for False

DESCRIPTION
This command is used to enable / disable the data acquisition request.

Note: This command cannot be issued when:
1. An axis is being homed (refer ASCII command, **OR**).
2. An axis is being moved to a travel limit (refer ASCII command, **MT**).
3. An axis is being moved to an index (refer ASCII command, **MZ**).

RETURNS None

REL. COMMANDS
DC - setup data acquisition request
DG - get acquired data
DF - data acquisition status, returns # of samples collected
DD - data acquisition done status

EXAMPLE

```
DC10,1,1,1,0,1000     | Acquire trace variable data for axis 1, in scaled integer
                      | format.  Collect 1000 samples, one sample / servo
                      cycle (400 µs)
DE1                   | Enable trace variable data acquisition
DD                    | Query data-acquisition done status
                        1 = true, 0 = false.
If true,
DE0                   | Disable trace variable data acquisition
DG                    | Get data collected
```


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DF get data acquisition sample count

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **DF**

PARAMETERS **none**

DESCRIPTION This command returns the number of a data acquisition collected to the point of this request.

RETURNS **aa,** where: **aa = number of samples**

REL. COMMANDS

DC - setup data acquisition request
DG - get acquired data
DD - data acquisition done status
DE - enable / disable data acquisition

EXAMPLE

```
DC10,1,1,1,0,1000      | Acquire trace variable data for axis 1, in scaled integer
                       | format.  Collect 1000 samples, one sample / servo
                       cycle (400 µs)
DE1                    | Enable trace variable data acquisition
DD                     | Query data-acquisition done status
                   1 = true, 0 = false.
If true,
DE0                    | Disable trace variable data acquisition
DG                     | Get data collected
```


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DG get acquisition data

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **DG**

PARAMETERS None

DESCRIPTION This command is used to retrieve data acquired from a data acquisition request.

RETURNS This command returns byte wide binary data. Each four bytes represents one DSP 32 bit word. The number of bytes returned depends on the setup request. (See **DC** command).

REL. COMMANDS

DC - setup data acquisition request
DE - enable / disable data acquisition
DF - data acquisition status, returns # of samples collected
DD - data acquisition done status

EXAMPLE

```
DC10,1,1,1,0,1000     | Acquire trace variable data for axis 1, in scaled integer
                      | format.  Collect 1000 samples, one sample / servo
                      cycle (400 µs)
DE1                   | Enable trace variable data acquisition
DD                    | Query data-acquisition done status
                        1 = true, 0 = false.
If true,
DE0                   | Disable trace variable data acquisition
DG                    | Get data collected
```


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DH define home

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**DH**nn

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	position value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to ± **2e+9**
Units	**xx**	-	none
	nn	-	predefined units
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to define current position, HOME position. This means that the current position will be preset to the value defined by parameter ‘nn’.

RETURNS If the “?” sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS **OR** - execute a home search cycle

EXAMPLE

```
3OR1          | perform a home search on axis # 3
   .
   .
   .
3DH           | define current position on axis # 3 HOME as 0 units
   .
   .
   .
3DH 20.0      | define current position on axis # 3 HOME as 20.0 units
```


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DL define label

	IMM	PGM	MIP
USAGE		♦	

SYNTAX xx**DL**

PARAMETERS

Description	**xx** [int]	-	label number
Range	**xx**	-	**1** to **100**
Units	**xx**	-	none
Default	**xx** missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command defines a label inside a program. In combination with JL (jump to label) command, they offer significant program flow control.

The operation of the DL / JL command pair is similar to commands in other computer languages that allow conditional jumps (or GOTO's) to predefined labels in a program.

Note:
This command does not generate an error when not used inside a program. Since it can not do any harm, it is only ignored.

RETURNS none

REL. COMMANDS **JL** - jump to label

EXAMPLE

```
3XX     | clear program 3 from memory, if any
3EP     |  create program 3
1DL     |  define label 1
.
.
.
1JL 5   | jump to label 1 five(5) times
QP      | end entering program and quit programming mode
3EX     | run stored program number 3
```


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DO set dac offset

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**DO**nn or xx**DO**?

PARAMETERS

Description	**xx** [int]	-	DAC channel number
	nn [float]	-	DAC offset value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**-10.0** to **10.0** or **?** to read the current setting
Units	**xx**	-	None
	nn	-	Volts
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx16, MAXIMUM DAC OFFSET EXCEEDED

DESCRIPTION

This command is used to set the DAC offset compensation for the specified DAC channel. There are two DAC channels associated with every axis: DAC channels 1 and 2 are associated with axis #1, DAC channels 3 and 4 with axis #2 etc.

In order for the DAC offset to take affect, this command must be followed by the ASCII command, **UF** (Update Filter). This offset may be saved to non-volatile flash memory by issuing the ASCII command, **SM**. This will cause the DSP to automatically use the saved value after system reset or reboot.

NOTE: DAC offset compensation is necessary on servo axes to prevent motor drift during motor off conditions.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

None

EXAMPLE 1DO0.05

	|	*Set the offset for DAC channel #1 to 0.05V*
1UF	|	***Update the filter settings***
SM	|	*Save parameters to non-dvolatile flash memory*

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DP read desired position

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**DP?**

PARAMETERS

Description	**xx** [int]	-	axis number
Range	**xx**	-	**1** to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx**	missing:	error 37, AXIS NUMBER MISSING
		out of range:	error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION This command is used to read the desired positionIt returns the instantaneous desired position.

The command could be sent at any time but its real use is while a motion is in progress.

RETURNS **nn** where **nn** = desired position, in pre-defined units

REL. COMMANDS

PA	-	move to an absolute position
PR	-	move to a relative position
TP	-	read actual position

EXAMPLE

3TP?	| *read position on axis # 3*
5.32	| *controller returns position 5.32 for axis # 3*
3PR2.2	| *start a relative motion of 2.2 on axis # 3*
3DP?	| *read desired position on axis # 3*
7.52	| *controller returns desired position 7.52 for axis # 3*

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DV read desired velocity

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX xx**DV**

PARAMETERS

Description			
	xx [int]	-	axis number
Range	**xx**	-	**1** to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION This command is used to read the desired velocity of an axis. The command can be sent at any time but its real use is while motion is in progress.

RETURNS **nn,** where **nn** = desired velocity of the axis in pre-defined units.

REL. COMMANDS

PA	-	move to an absolute position
PR	-	move to a relative position

EXAMPLE

3TP?	| *read position on axis # 3*
5.32	| *controller returns position 5.32 units for axis # 3*
3PR2.2	| *start a relative motion of 2.2 units on axis # 3*
3DV	| *read desired velocity on axis #3*
0.2	| *controller returns velocity 0.2 units/sec for axis #3*
3DP?	| *read desired position on axis # 3*
7.52	| *controller returns desired position 7.52 units for axis # 3*

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EO automatic execution on power on

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX xx**EO**nn or xx**EO**?

PARAMETERS

Description	**xx** [int]	-	program number
	nn [int]	-	number of times of execution
Range	**xx**	-	**1** to **100**
	nn	-	**1** to **2e9**
Units	**xx**	-	none
	nn	-	none
Defaults	**None**		

DESCRIPTION This command sets the program number that is automatically executed on power on. If **nn** is missing, the **xx** numbered program is executed once.

RETURNS If the sign **"?"** takes place of **nn** value, this command reports the number of the program that is executed on power on and the number of times of execution.

REL. COMMANDS

QP	-	quit programming mode
EX	-	execute stored program
AP	-	abort stored program execution
XX	-	erase program

EXAMPLE

3EO	| *set program #3 to be executed once on power on*
EO?	| *query the program number executed on power on*
EO,3,1	| *controller returns program #3 executed once on power on*
EO	| *Reset automatic program execution – no program is executed on power on*

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EP enter program mode

	IMM	PGM	MIP
USAGE	♦		

SYNTAX xx**EP**

PARAMETERS

Description	**xx** [int]	-	program number
Range	**xx**	-	**1** to **100**
Units	**xx**	-	none
Defaults	**xx** missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command sets the controller in programming mode. All the commands following this one will not be executed immediately but stored in memory as part of program number **xx**. To exit program entry mode and return to immediate mode, use QP command.
Programs can be entered in any order. If a program already exists then it must be first deleted using XX command.
Note:
Programs are automatically stored into non-volatile memory when created.

RETURNS none

REL. COMMANDS

QP	-	quit programming mode
EX	-	execute stored program
AP	-	abort stored program execution
XX	-	erase program

EXAMPLE

```
3XX          | clear program 3 from memory, if any
3EP          | activate program mode and enter following commands as
             | program 3
   .
   .
   .
QP           | end entering program and quit programming mode
3EX          | run stored program number 3
```


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EX execute a program

	IMM	PGM	MIPO
USAGE	♦	♦	

SYNTAX xx**EX**nn

PARAMETERS

Description	**xx** [int]	-	program number
	nn [int]	-	number of times to execute the program
Range	**xx**	-	**1** to **100**
	nn	-	**1** to **2147385345**
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error 7, PARAMETER OUT OF RANGE
	nn missing:		1 assumed
	out of range:		error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to start executing a program. When the command is received the controller executes the program line by line or according to the flow control instructions.

During program execution, only commands that ask for information and that stop the motion are still allowed. Any of the following commands will terminate a program, in one way or another: AB, AP, MF, RS and ST. Most natural way to just stop a program execution is by using the AP command, the other ones having a more drastic effect.

RETURNS none

REL. COMMANDS

QP	-	quit programming mode
EP	-	enter program mode
AP	-	abort stored program execution
XX	-	erase program

EXAMPLE

```
3XX          | clear program 3 from memory, if any
3EP          | activate program mode and enter following commands as
             | program 3
   .
   .
   .
QP           | end entering program and quit programming mode
3EX          | run stored program number 3
```


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FE set maximum following error threshold

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**FE**nn or xx**FE**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	maximum allowed following error
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to**(2e9 * encoder resolution),** or **?** to read current setting
Units	**xx**	-	none
	nn	-	predefined units
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command sets the maximum allowed following error threshold for an axis. This error is defined as the difference between the real position and the theoretical position of a motion device. The real position is the one reported by the position sensing device (encoder, scale, etc.) and the theoretical position is calculated by the controller each servo cycle (400 µs). If , for any axes and any servo cycle (400 µs), the following error exceeds the preset maximum allowed following error, the controller invokes the following error event handling process which is defined with the **ZF** command. By default motor power is turned OFF.

Note

Using the **ZF** command each axis can be individually configured to either turn motor power OFF, abort motion using e-stop deceleration, or ignore the error.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

ZF - set following error event configuration

EXAMPLE

```
3FE ?      | read maximum following error for axis # 3
0.5        |  controller returns for axis # 3 following error of 0.5 unit
3FE 1.0    | set maximum following error for axis # 3 to 1 unit
```


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FP set position display resolution

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**FP**nn or xx**FP**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	display resolution
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **7**
			or **?** to read present setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the display resolution of position information. For instance, if **nn = 4**, the display will show values as low as 0.0001 units. If **nn = 7**, the display will show values in exponential form. If the user units (refer SN command) are in encoder counts or stepper increments, the position information is displayed in integer form, independent of the value set by this command.

RETURNS If "?" sign takes the place of **nn** value, this command reports current setting.

REL. COMMANDS None

EXAMPLE

1FP?	*read position display resolution for axis #1*
4	*controller returns a value of 4*
1TP	*read actual position of axis #1*
5.0001	*controller returns position value*
1FP2	*set position display resolution for axis #1 to 2*
1TP	*read actual position of axis #1*
5.00	*controller returns position value*
1FP7	*set position display resolution for axis #1 to 7*
1TP	*read actual position of axis #1*
5.000000E+0	*controller returns position value*

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FR set encoder full-step resolution

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**FR**nn or xx**FR**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	encoder full step resolution
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**2e-9** to **2e+9** in user defined units or **?** to read present setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the encoder full step resolution for a Newport Unidrive compatible programmable driver with step motor axis.

RETURNS If "?" sign takes the place of **nn** value, this command reports current setting.

REL. COMMANDS
QS - set microstep factor
SU - set encoder resolution

EXAMPLE

2FR?	*read encoder full-step resolution setting of axis # 2*
0.0001	*controller returns a value of 0.0001 units for axis #2*
2FR0.0005	*set encoder full-step resolution to 0.0005 units for axis #2*
SM	*save all controller settings to non-volatile memory*

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GR set master-slave reduction ratio

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**GR**nn or xx**GR**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	reduction ratio
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	±1,000,000
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command sets the master-slave reduction ratio for a slave axis. The trajectory of the slave is the desired trajectory or actual position of the master scaled by reduction ratio. Refer to the **TJ** command to specify the desired trajectory mode for a slave axis.

Note:
Use this command very carefully. The slave axis will have its speed and acceleration in the same ratio as the position. Also, ensure that the ratio used for the slave axis does not cause overflow of this axis' parameters (speed, acceleration), especially with ratios greater than 1.

RETURNS

If "?" sign is issued along with command, the controller returns master-slave reduction ratio.

REL. COMMANDS

SS - define master-slave relationship

EXAMPLE

2SS1	*| set axis 2 to be the slave of axis 1*
2SS?	*| query the master axis number for axis 2*
1	*| controller returns a value of 1*
2TJ5	*| set axis 2 trajectory mode to 5*
2GR0.5	*| set the reduction ratio of axis 2 to 0.5*
2GR?	*| query the reduction ratio of axis 2*
0.5	*| controller returns a value of 0.5*

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HA set group acceleration

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HA**nn or xx**HA**?

PARAMETERS

Description	**xx** [int]	-	group number
	nn [float]	-	vector acceleration value
Range	**xx**	-	**1** to **MAX GROUPS**
	nn	-	**0** to minimum of the maximum acceleration values of all axes assigned to this group.
Units	**xx**	-	none
	nn	-	predefined units / second^2

Defaults	**xx** missing:	error 13, GROUP NUMBER MISSING
	out of range:	error 14, GROUP NUMBER OUT OF RANGE
	not assigned:	error 15, GROUP NUMBER NOT ASSIGNED
	floating point:	truncated
	nn missing:	error 7, PARAMETER OUT OF RANGE
	negative:	error 22, GROUP PARAMETER OUT OF RANGE
	out of range:	error 24, GROUP MAXIMUM ACCELERATION EXCEEDED

DESCRIPTION

This command is used to set the vectorial acceleration value for a group. This value will be used during coordinated motion of axes assigned to the group. It will override any original acceleration values specified for individual axes using **AC** command. The axes' original values will be restored when the group to which they have been assigned is deleted.

This command takes effect immediately. It can be executed when controller is idling or motion is in progress or inside a program.

Note:
Avoid changing acceleration during acceleration or deceleration phases of a move. For better predictable results, change acceleration only when all the axes assigned to this group are not in motion.

RETURNS

If "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

AU	-	set maximum acceleration and deceleration for an axis
HN	-	create a new group
HD	-	set vectorial deceleration for a group

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EXAMPLE

1HN1,2	*| create a new group (#1) with physical axes 1 and 2*
1AU?	*| query maximum acceleration of axis #1*
50	*| controller returns a value of 50 units/second²*
2AU?	*| query maximum acceleration of axis #2*
60	*| controller returns a value of 60 units/second²*
1HA50	*| set vectorial acceleration of group #1 to 50 units/second²*
1HA?	*| query vectorial acceleration of group #1*
50	*| controller returns a value of 50 units/second²*

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HB read list of groups assigned

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **HB**

PARAMETERS None

DESCRIPTION This command is used to read the group numbers that have already been created or assigned.

RETURNS This command reports the current setting. If no groups have been created, controller returns error number 15, GROUP NUMBER NOT ASSIGNED.

REL. COMMANDS

HN - create a new group
HX - delete a group

EXAMPLE

1HN1,2	*| create a new group (#1) with physical axes 1 and 2*
1HN?	*| read axes assigned to group #1*
1,2	*| controller returns the axes assigned to group #1*
2HN3,4	*| create a new group (#2) with physical axes 3 and 4*
2HN?	*| read axes assigned to group #2*
3,4	*| controller returns the axes assigned to group #2*
HB	*| read list of groups created*
1 2	*| controller returns 1 and 2*

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HC move group along an arc

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HC**nn$_1$, nn$_2$, nn$_3$ **or** xx**HC**?

PARAMETERS

Description

xx	[int]	-	group number
nn$_1$	[float]	-	first coordinate of arc center
nn$_2$	[float]	-	second coordinate of arc center
nn$_3$	[float]	-	arc sweep angle

Range

xx	-	**1** to **MAX GROUPS**
nn$_1$, nn$_2$	-	any position within the travel limits
nn$_3$	-	any angle

Units

xx	-	none
nn$_1$, nn$_2$	-	predefined units
nn$_3$	-	degrees

Defaults

xx missing:	error 13, GROUP NUMBER MISSING
out of range:	error 14, GROUP NUMBER OUT OF RANGE
not assigned:	error 15, GROUP NUMBER NOT ASSIGNED
floating point:	truncated
nn$_i$	
Missing parameter:	error 21, GROUP PARAMETER MISSING

DESCRIPTION

This command initiates motion of a group along an arc. It causes all axes assigned to the group to move with predefined vectorial (tangential) velocity, acceleration and deceleration along an arc. The group target position is determined based on the position of axes at the beginning of move, center of arc and sweep angle.

If this command is received while a group move is in progress, the new command gets enqueued into a “via point” buffer. Please refer to Advanced Capabilities section for a detailed description of via point buffer implementation. The enqueued commands get executed on a FIFO basis when the move already in progress has reached its destination. The group does not come to a stop at the end of last move. Instead, there will be a smooth transition to the new move command, just as if it were one compound move (combination of multiple moves).

Note:
Only trapezoid velocity profile is employed linear interpolation motion.

Note:

The transition from last move to new move will be smooth if tangential velocity at the end of last move is the same as that at the beginning of new move.

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RETURNS

If "?" sign takes the place of **nn** values, this command reports the commanded center position of arc and sweep angle.

REL. COMMANDS

HN	-	create a new group
HV	-	set vectorial velocity for a group
HA	-	set vectorial acceleration for a group
HD	-	set vectorial deceleration for a group
HO	-	enable a group
HF	-	disable a group
HL	-	move a group of axes to desired position along a line.

EXAMPLE

1HN1,2	| *create a new group (#1) with physical axes 1 and 2*
1HV10	| *set vectorial velocity of group #1 to 10 units/second*
1HA50	| *set vectorial acceleration of group #1 to 50 units/second^2*
1HD50	| *set vectorial deceleration of group #1 to 50 units/second^2*
1HO	| *enable group #1*
1HP?	| *query current group position*
50,50	| *controller returns axis #1 = 50 units and axis #2 = 50 units*
1HC40,60,180	| set axis #1 arc center = 40 units *set axis #2 arc center = 60 units* *set sweep angle of arc = 180 degrees*
1HC?	| *query target position of the commanded move*
40, 60, 180	| *controller returns axis #1 arc center = 40 units, axis #2 arc center = 70 units and arc sweep angle = 180 degrees*

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HD set group deceleration

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HD**nn or xx**HD**?

PARAMETERS

Description	**xx** [int]	-	group number
	nn [float]	-	vector deceleration value
Range	**xx**	-	**1** to **MAX GROUPS**
	nn	-	**0** to minimum of the maximum deceleration values of all axes assigned to this group.
Units	**xx**	-	none
	nn	-	predefined units / second^2
Defaults	**xx** missing:		error 13, GROUP NUMBER MISSING
	out of range:		error 14, GROUP NUMBER OUT OF RANGE
	not assigned:		error 15, GROUP NUMBER NOT ASSIGNED
	floating point:		truncated
	nn missing:		error 7, PARAMETER OUT OF RANGE
	negative:		error 22, GROUP PARAMETER OUT OF RANGE
	out of range:		error 25, GROUP MAXIMUM DECELERATION EXCEEDED

DESCRIPTION

This command is used to set the vectorial deceleration value for a group. This value will be used during coordinated motion of axes assigned to the group. It will override any original deceleration values specified for individual axes using **AG** command. The axes' original values will be restored when the group to which they have been assigned is deleted.

This command takes effect immediately. It can be executed when controller is idling or motion is in progress or inside a program.

Note:
Avoid changing deceleration during acceleration or deceleration phases of a move. For better predictable results, change deceleration only when all the axes assigned to this group are not in motion.

RETURNS

If "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

AU	-	set maximum acceleration and deceleration for an axis
HN	-	create a new group
HA	-	set vectorial acceleration for a group

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EXAMPLE

1HN1,2	*| create a new group (#1) with physical axes 1 and 2*
1AU?	*| query maximum deceleration of axis #1*
50	*| controller returns a value of 50 units/second^2*
2AU?	*| query maximum deceleration of axis #2*
60	*| controller returns a value of 60 units/second^2*
1HD50	*| set vectorial deceleration of group #1 to 50 units/second^2*
1HD?	*| query vectorial deceleration of group #1*
50	*| controller returns a value of 50 units/second^2*

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HE set group e-stop deceleration

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HE**nn or xx**HE**?

PARAMETERS

Description

xx	[int]	-	group number
nn	[float]	-	vector e-stop deceleration value

Range

xx	-	**1** to **MAX GROUPS**
nn	-	maximum of deceleration values assigned to all axes in the group to **2e9 * encoder resolution.**

Units

xx	-	none
nn	-	predefined units / second^2

Defaults

xx	missing:	error 13, GROUP NUMBER MISSING
	out of range:	error 14, GROUP NUMBER OUT OF RANGE
	not assigned:	error 15, GROUP NUMBER NOT ASSIGNED
	floating point:	truncated
nn	missing:	error 7, PARAMETER OUT OF RANGE
	negative:	error 22, GROUP PARAMETER OUT OF RANGE
	out of range:	error 22, GROUP PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to set the vectorial e-stop deceleration value for a group. This value will be used during coordinated motion of axes assigned to the group. It will override any original e-stop deceleration values specified for individual axes using **AE** command. The axes' original values will be restored when the group to which they have been assigned is deleted.

This command takes effect immediately. It can be executed when controller is idling or motion is in progress or inside a program.

E-stop deceleration is invoked upon a local e-stop condition (e.g., front panel "Stop All" push button, interlock, etc…) has occurred, if configured to do so, or if the AB (abort motion) command is processed.

RETURNS

If "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

HN	-	create a new group
HV	-	set vectorial velocity for a group
HA	-	set vectorial acceleration for a group
HD	-	set vectorial deceleration for a group

EXAMPLE

1HN1,2	*| create a new group (#1) with physical axes 1 and 2*
1HE100	*| set vectorial e-stop deceleration of group #1 to 100 units/second^2*
1HE?	*| query vectorial e-stop deceleration of group #1*
100	*| controller returns a value of 100 units/second^2*

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HF group off

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HF** or xx**HF**?

PARAMETERS

Description			
	xx [int]	-	group number
Range	**xx**	-	**1** to **MAX GROUPS**
Units	**xx**	-	none
Defaults	**xx** missing:		error 13, GROUP NUMBER MISSING
	out of range:		error 14, GROUP NUMBER OUT OF RANGE
	not assigned:		error 15, GROUP NUMBER NOT ASSIGNED
	floating point:		truncated

DESCRIPTION This command turns power OFF of all axes assigned to a group. Refer **MF** command to turn the power OFF of individual axes. The group power is assumed to be OFF if power to any one of the axes in the group is OFF.

RETURNS If "?" sign is issued along with command, the controller returns:

1 - group power is ON
0 - group power is OFF

REL. COMMANDS

HN - create a new group
HO - turn group power ON

EXAMPLE

1HN1,2 | *create a new group (#1) with physical axes 1 and 2*
1HO | *turn group #1 power ON*
1HF? | *query group #1 power status*
1 | *controller returns a value of 1*
1HF | *turn group #1 power OFF*
1HF? | *query group #1 power status*
0 | *controller returns a value of 0*

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HJ set group jerk

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HJ**nn or xx**HJ**?

PARAMETERS

Description	**xx** [int]	-	group number
	nn [float]	-	vector jerk value
Range	**xx**	-	**1** to **MAX GROUPS**
	nn	-	**0** to **2e9**
Units	**xx**	-	none
	nn	-	predefined units / second^3

Defaults

xx	missing:	error 13, GROUP NUMBER MISSING
	out of range:	error 14, GROUP NUMBER OUT OF RANGE
	not assigned:	error 15, GROUP NUMBER NOT ASSIGNED
	floating point:	truncated
nn	missing:	error 7, PARAMETER OUT OF RANGE
	negative:	error 22, GROUP PARAMETER OUT OF RANGE
	out of range:	error 22, GROUP PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to set the vectorial jerk value for a group. This value will be used during coordinated motion of axes assigned to the group. It will override any original jerk values specified for individual axes using **JK** command. The axes' original values will be restored when the group to which they have been assigned is deleted.

If vectorial jerk is set to zero, a trapezoid velocity profile is employed during motion. Otherwise, an S-curve velocity profile is employed.

This command takes effect immediately. It can be executed when controller is idling or motion is in progress or inside a program.

Note:
Avoid changing jerk during acceleration or deceleration phases of a move. For better predictable results, change jerk only when all the axes assigned to this group are not in motion.

RETURNS If "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

HN	-	create a new group
HV	-	set vectorial velocity for a group
HA	-	set vectorial acceleration for a group
HD	-	set vectorial deceleration for a group
HK	-	set vectorial e-stop jerk for a group

EXAMPLE

1HN1,2	*| create a new group (#1) with physical axes 1 and 2*
1HJ50	*| set vectorial jerk of group #1 to 50 units/second^3*
1HJ?	*| query vectorial deceleration of group #1*
50	*| controller returns a value of 50 units/second^3*

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HL move group along a line

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HL**nn_1, nn_2, …nn_i **or** xx**HL**?

PARAMETERS

Description

xx [int]	-	group number
nn_1 [float]	-	target position of first axis in a group
nn_2 [float]	-	target position of second axis in a group
nn_i [float]	-	target position of *i*th axis in a group, where *i* can vary from 1 to 6

Range

xx	-	**1** to **MAX GROUPS**
nn_i	-	any position within the travel limits

Units

xx	-	none
nn_i	-	redefined units

Defaults

xx missing:	error 13, GROUP NUMBER MISSING
out of range:	error 14, GROUP NUMBER OUT OF RANGE
not assigned:	error 15, GROUP NUMBER NOT ASSIGNED
floating point:	truncated
nn_i	
Missing parameter:	error 21, GROUP PARAMETER MISSING

DESCRIPTION

This command initiates motion of a group along a line. It causes all axes assigned to the group to move with predefined vectorial (tangential) velocity, acceleration and deceleration along a line. A trapezoid velocity profile is employed when vectorial jerk is set to zero. Otherwise, an S-curve velocity profile is employed.

If this command is received while a group move is in progress, the new command gets enqueued into a "via point" buffer. Please refer Advanced Capabilities section for a detailed description of via point buffer implementation. The enqueued commands get executed on a FIFO basis when the move already in progress has reached its destination. The group does not come to a stop at the end of last move. Instead, there will be a smooth transition to the new move command, just as if it were one compound move (combination of multiple moves).

Note:

The transition from last move to new move will be smooth if tangential velocity at the end of last move is the same as that at the beginning of new move.

RETURNS

If "?" sign takes the place of **nn** values, this command reports the target positions of axes assigned to the group.

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REL. COMMANDS	**HN**	-	create a new group
	HV	-	set vectorial velocity for a group
	HA	-	set vectorial acceleration for a group
	HD	-	set vectorial deceleration for a group
	HO	-	enable a group
	HF	-	disable a group
	HC	-	move a group of axes to desired position along an arc.

EXAMPLE	1HN1,2	| *create a new group (#1) with physical axes 1 and 2*
	1HV10	| *set vectorial velocity of group #1 to 10 units/second*
	1HA50	| *set vectorial acceleration of group #1 to 50 units/second^2*
	1HD50	| *set vectorial deceleration of group #1 to 50 units/second^2*
	1HO	| *enable group #1*
	1HP?	| *query current group position*
	0,0	| *controller returns axis #1 = 0 units and axis #2 = 0 units*
	1HL50, 50	| move axis #1 to a target position = 50 units *move axis #2 to a target position = 50 units*
	1HL?	| *query target position of the commanded move*
	50,50	| *controller returns axis #1 = 50 units and axis #2 = 50 units*

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HN create new group

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**HN**nn_1, nn_2, …nn_i **or** xx**HN**?

PARAMETERS

Description	**xx** [int]	-	group number
	nn_1 [int]	-	physical axis number to be assigned as first axis in this group
	nn_2 [int]	-	physical axis number to be assigned as second axis in this group
	nn_i [int]	-	physical axis number to be assigned as *i*th axis in this group
Range	**xx**	-	**1** to **MAX GROUPS**
	nn_i	-	**1** to **MAX AXES**
Units	**xx**	-	none
	nn_i	-	none

Defaults	**xx** missing:	error 13, GROUP NUMBER MISSING
	out of range:	error 14, GROUP NUMBER OUT OF RANGE
	not assigned:	error 15, GROUP NUMBER NOT ASSIGNED
	already assigned:	error 16, GROUP NUMBER ALREADY ASSIGNED
	floating point:	truncated
	nn_i	
	out of range:	error 17, GROUP AXIS OUT OF RANGE
	already assigned:	error 18, GROUP AXIS ALREADY ASSIGNED
	duplicated:	error 19, GROUP AXIS DUPLICATED
	Missing parameter:	error 21, GROUP PARAMETER MISSING

DESCRIPTION

This command is used to create a new group. A few rules are in place to facilitate easy management of groups.

- A group has to be created with at least two axes assigned to it before any command related to groups can be issued. The controller returns error 15, GROUP NUMBER NOT ASSIGNED, if, for instance, one tries to set velocity for group #1, before creating group #1.
- A group has to be deleted (refer **HX** command) before axes assigned to the group can be changed. The controller returns error 16, GROUP NUMBER ALREADY ASSIGNED, if one attempts to change axes assigned to a group already created. Please see the following table for correct method to change axes assigned to a group:

Correct Method	Incorrect Method
1HN1,2	1HN1,2
1HX	1HN2,3
1HN2,3	

- An axis cannot be a member of (or assigned to) different groups at the same time. The controller returns error 18, GROUP AXIS ALREADY ASSIGNED, if one attempts to assign an axis under such circumstances. Refer HX command to delete a group.

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- An axis cannot be assigned more than once in a group. The controller returns error 19, GROUP AXIS DUPLICATED, if one attempts to assign an axis more than once to a group.
- The order in which axes are assigned to a group is very important. This is because it specifies the frame of reference in which coordinated motion of axes takes place. For instance, the command **1HN1,2** assigns axis numbers 1 and 2 to group number 1, where axis #1 is equivalent to X-axis and axis #2 is equivalent to Y-axis in a traditional cartesian coordinate system. Reversing the ordering of axes (viz. **1HN2,1**) reverses the axis assignment.
- If a group has more than two axes assigned to it, and the group was commanded to make an arc (refer to HC command), the first two axes in the group are used to make the desired move.

RETURNS

If "?" sign takes the place of **nn** values, this command reports the axes assigned to the group in the order of their assignment.

REL. COMMANDS

HV - set vectorial velocity for a group
HA - set vectorial acceleration for a group
HD - set vectorial deceleration for a group
HO - enable a group
HF - disable a group
HC - move a group of axes to desired position along an arc.
HL - move a group of axes to desired position along a line.

EXAMPLE

1HN1,2 | *create a new group (#1) with physical axes 1 and 2*
1HN? | *query axis assigned to group #1*
1,2 | *controller returns the axes assigned to group #1*
1HN2,3 | *create a new group (#1) with physical axes 1 and 2*
1HN? | *query axis assigned to group #1*
1,2 | *controller returns the axes assigned to group #1*
TB? | *read error message*
0, 450322, GROUP NUMBER ALREADY ASSIGNED
1HX | *delete group #1*
1HN2,3 | *create a new group (#1) with physical axes 1 and 2*
1HN? | *query axis assigned to group #1*
2,3 | *controller returns the axes assigned to group #1*
2HN? | *query axis assigned to group #2*
TB? | *read error message*
0, 475322, GROUP NUMBER NOT ASSIGNED
2HN3,4 | *create a new group (#2) with physical axes 3 and 4*
2HN? | *query axis assigned to group #2*
TB? | *read error message*
0, 500322, GROUP AXIS ALREADY ASSIGNED
2HN4,4,5 | *create a new group (#2) with physical axes 4, 4 and 5*
2HN? | *query axis assigned to group #2*
TB? | *read error message*
0, 525322, GROUP AXIS DUPLICATED

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HO group on

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HO** or xx**HO**?

PARAMETERS

Description			
	xx [int]	-	group number
Range	**xx**	-	**1** to **MAX GROUPS**
Units	**xx**	-	none
Defaults	**xx** missing:		error 13, GROUP NUMBER MISSING
	out of range:		error 14, GROUP NUMBER OUT OF RANGE
	not assigned:		error 15, GROUP NUMBER NOT ASSIGNED
	floating point:		truncated

DESCRIPTION This command turns power ON of all axes assigned to a group. Refer **MO** command to turn the power ON of individual axes. The group power is assumed to be ON if power to all axes in the group is ON.

RETURNS If "?" sign is issued along with command, the controller returns:

1	-	group power is ON
0	-	group power is OFF

REL. COMMANDS

HN	-	create a new group
HF	-	turn group power OFF

EXAMPLE

1HN1,2	| *create a new group (#1) with physical axes 1 and 2*
1HO	| *turn group #1 power ON*
1HO?	| *query group #1 power status*
1	| *controller returns a value of 1*
1HF	| *turn group #1 power OFF*
1HO?	| *query group #1 power status*
0	| *controller returns a value of 0*

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HP read group position

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX xx**HP**

PARAMETERS

Description			
	xx [int]	-	group number
Range	**xx**	-	**1** to **MAX GROUPS**
Units	**xx**	-	none
Defaults	**xx** missing:		error 13, GROUP NUMBER MISSING
	out of range:		error 14, GROUP NUMBER OUT OF RANGE
	not assigned:		error 15, GROUP NUMBER NOT ASSIGNED
	floating point:		truncated

DESCRIPTION This command is used to read the actual position, the instantaneous real position of all axes assigned to a group.

RETURNS $\mathbf{nn_1}$, $\mathbf{nn_2}$, … $\mathbf{nn_i}$ where $\mathbf{nn_i}$ = actual position of *i*th axis in the group.

REL. COMMANDS

HN	-	create a new group
HC	-	move a group of axes to desired position along an arc.
HL	-	move a group of axes to desired position along a line.

EXAMPLE

1HN1,2	*| create a new group (#1) with physical axes 1 and 2*
1HP	*| read position of group #1*
10,50	**|** *controller returns axis #1 = 10 units, axis #2 = 50 units*

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HQ wait for group command buffer level

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HQ**nn or xx**HQ**?

PARAMETERS

Description

xx [int] - group number
nn [float] - level in group via point buffer

Range

xx - **1** to **MAX GROUPS**
nn - to **10** (default for maximum targets in via point buffer)

Units

xx - none
nn - milliseconds

Defaults

xx missing: error 13, GROUP NUMBER MISSING
out of range: error 14, GROUP NUMBER OUT OF RANGE
not assigned: error 15, GROUP NUMBER NOT ASSIGNED
floating point:truncated
nn
Missing parameter: error 21, GROUP PARAMETER MISSING

DESCRIPTION

This command stops enqueuing new commands into the via point buffer until the buffer level equals **nn**. As commands in the buffer get executed on a FIFO basis and the buffer level equals **nn**, commands issued subsequent to this one get executed.

RETURNS

If "?" sign takes the place of **nn** value, the controller returns the room available in via point buffer for more commands.

REL. COMMANDS

HN - create a new group
HL - move group to target position along a line
HC - move group to target position along an arc

EXAMPLE

```
1HN1,2      | create a new group (#1) with physical axes 1 and 2
1HV10       | set vectorial velocity of group #1 to 10 units/second
1HA50       | set vectorial acceleration of group #1 to 50 units/second2
1HD50       | set vectorial deceleration of group #1 to 50 units/second2
1HO         | enable group #1
1HL10,10    | move group #1 to target pos. 10,10 (ax. #1 = 10, #2 = 10 units)
1HL20,20    | move group #1 to target pos. 20,20 (ax. #1 = 20, #2 = 20 units).
            | This command gets enqueued in the via point buffer if it was
            | received prior completion of the previous move command.
1HL50,50    | move group #1 to target pos. 50,50 (ax. #1 = 50, #2 = 50 units).
1HQ10       | wait until the via point buffer level equals 10 commands
1HC40,60,180 | move group #1 along an arc with center of arc at (40,60) units,
            | by a sweep angle of 180 deg. from current position.
```


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HS stop group motion

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HS or** xx**HS**?

PARAMETERS

Description			
	xx [int]	-	group number
Range	**xx**	-	**1** to **MAX GROUPS**
Units	**xx**	-	none
Defaults	**xx** missing:		error 13, GROUP NUMBER MISSING
	out of range:		error 14, GROUP NUMBER OUT OF RANGE
	not assigned:		error 15, GROUP NUMBER NOT ASSIGNED
	floating point:		truncated

DESCRIPTION This command stops the motion of all axes assigned to a group using vector deceleration set using **HD** command.

RETURNS If "?" sign is supplied along with the command, the controller returns:

1	-	group motion is stopped
0	-	group motion is in progress

REL. COMMANDS

HN	-	create a new group
HC	-	move a group of axes to desired position along an arc.
HL	-	move a group of axes to desired position along a line.

EXAMPLE

1HN1,2	| *create a new group (#1) with physical axes 1 and 2*
1HV10	| *set vectorial velocity of group #1 to 10 units/second*
1HA50	| *set vectorial acceleration of group #1 to 50 units/second^2*
1HD50	| *set vectorial deceleration of group #1 to 50 units/second^2*
1HO	| *enable group #1*
1HP?	| *query current group position*
0,0	| *controller returns axis #1 = 0 units and axis #2 = 0 units*
1HL50, 50	| *move axis #1 to a target position = 50 units* *move axis #2 to a target position = 50 units*
1HS?	| *query if motion of group #1 is stopped*
0	| *controller returns 0, meaning group #1 is in motion*
1HS	| *stop motion of group #2*
1HS?	| *query if motion of group #1 is stopped*
1	| *controller returns 1, meaning group #1 motion has stopped*

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HV set group velocity

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HV**nn or xx**HV**?

PARAMETERS

Description	**xx** [int]	-	group number
	nn [float]	-	vector velocity value
Range	**xx**	-	**1** to **MAX GROUPS**
	nn	-	**0** to minimum of the maximum velocity values of all axes assigned to this group.
Units	**xx**	-	none
	nn	-	predefined units / second

Defaults	**xx** missing:	error 13, GROUP NUMBER MISSING
	out of range:	error 14, GROUP NUMBER OUT OF RANGE
	not assigned:	error 15, GROUP NUMBER NOT ASSIGNED
	floating point:	truncated
	nn missing:	error 7, PARAMETER OUT OF RANGE
	negative:	error 22, GROUP PARAMETER OUT OF RANGE
	out of range:	error 23, GROUP MAXIMUM VELOCITY EXCEEDED

DESCRIPTION

This command is used to set the vectorial velocity value for a group. This value will be used during coordinated motion of axes assigned to the group. It will override any original acceleration values specified for individual axes using **VA** command. The axes' original values will be restored when the group to which they have been assigned is deleted.

This command takes effect immediately. It can be executed when controller is idling or motion is in progress or inside a program.

Note:
Avoid changing velocity during acceleration or deceleration phases of a move. For better predictable results, change velocity only when all the axes assigned to this group are not in motion.

RETURNS

If "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

VU	-	set maximum velocity for an axis
HN	-	create a new group

EXAMPLE

1HN1,2	| *create a new group (#1) with physical axes 1 and 2*
1VU?	| *query maximum velocity of axis #1*
10	| *controller returns a value of 10 units/second*
2VU?	| *query maximum velocity of axis #2*
15	| *controller returns a value of 15 units/second*
1HV10	| *set vectorial velocity of group #1 to 10 units/second*
1HV?	| *query vectorial velocity of group #1*
10	| *controller returns a value of 10 units/second*

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HW wait for group motion stop

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HW**nn

PARAMETERS

Description	**xx** [int]	-	group number
	nn [float]	-	delay after group motion is complete
Range	**xx**	-	**1** to **MAX GROUPS**
	nn	-	**0** to **60000**
Units	**xx**	-	none
	nn	-	milliseconds

Defaults

xx	missing:	error 13, GROUP NUMBER MISSING
	out of range:	error 14, GROUP NUMBER OUT OF RANGE
	not assigned:	error 15, GROUP NUMBER NOT ASSIGNED
	floating point:	truncated
nn	missing:	error 7, PARAMETER OUT OF RANGE
	negative:	error 22, GROUP PARAMETER OUT OF RANGE
	out of range:	error 26, MAXIMUM WAIT DURATION EXCEEDED

DESCRIPTION

This command stops execution of any commands subsequent to it until the one prior to it has been completed. For instance, if a command preceding it is a group move command such as **HL** or **HC**, it stops execution of any commands following it until the group has reached target position. If **nn** is not equal to zero, the controller waits an additional **nn** milliseconds after the group motion is complete before executing any further commands.

RETURNS none

REL. COMMANDS

HN	-	create a new group
HL	-	move group to target position along a line

EXAMPLE

```
1HN1,2                          | create a new group (#1) with physical axes 1 and 2
2HN3,4                          | create a new group (#2) with physical axes 3 and 4
1HV10                           | set vectorial velocity of group #1 to 10 units/second
1HA50                           | set vectorial acceleration of group #1 to 50 units/second²
1HD50                           | set vectorial deceleration of group #1 to 50 units/second²
2HV10                           | set vectorial velocity of group #2 to 10 units/second
2HA50                           | set vectorial acceleration of group #2 to 50 units/second²
2HD50                           | set vectorial deceleration of group #2 to 50 units/second²
1HO                             | enable group #1
2HO                             | enable group #2
1HL50, 50; 1HW500; 2HL30,20     | move group #1 to a target position = 50, 50
                                | units (axis #1 = 50 units and axis #2 = 50 units), wait for the
                                | group to reach target position, wait an additional 500 ms, and
                                | then move group #2 to a target position = 30, 20 units (axis #3
                                | = 30 units and axis #4 = 20 units)
```


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HX delete group

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HX**

PARAMETERS

Description			
	xx [int]	-	group number
Range	**xx**	-	**1** to **MAX GROUPS**
Units	**xx**	-	none
Defaults	**xx** missing:		error 13, GROUP NUMBER MISSING
	out of range:		error 14, GROUP NUMBER OUT OF RANGE
	not assigned:		error 15, GROUP NUMBER NOT ASSIGNED

DESCRIPTION This command deletes a group and makes available any axes that were assigned to it for future assignments.

RETURNS none

REL. COMMANDS **HN** - reate a new group

EXAMPLE

1HN1,2 | *create a new group (#1) with physical axes 1 and 2*
1HN? | *query axes assigned to group #1*
1,2 | *controller returns the axes assigned to group #1*
1HX | *delete group #1*
1HN? | *query axis assigned to group #1*
TB? | *read error message*
0, 475322, GROUP NUMBER NOT ASSIGNED

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HZ read group size

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**HZ**

PARAMETERS

Description	**xx** [int]	-	group number
Range	**xx**	-	**1** to **MAX GROUPS**
Units	**xx**	-	none
Defaults	**xx** missing:		error 13, GROUP NUMBER MISSING
	out of range:		error 14, GROUP NUMBER OUT OF RANGE
	not assigned:		error 15, GROUP NUMBER NOT ASSIGNED

DESCRIPTION This command is used to read the number of axes assigned to a group.

RETURNS This command reports the current setting.

REL. COMMANDS

HN	-	create a new group
HX	-	delete a group

EXAMPLE

1HN1,2	| *create a new group (#1) with physical axes 1 and 2*
1HN?	| *read axes assigned to group #1*
1,2	| *controller returns the axes assigned to group #1*
1HZ	| *read size of group #1*
2	| *controller returns 2*

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ID read stage model and serial number

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **ID ?**

PARAMETERS

Description	**xx** [int]	-	axis number
Range	**xx**	-	**1** to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	timeout:		error 2, RS-232 COMMUNICATION TIME-OUT

DESCRIPTION This command is used to read Newport ESP compatible positioner (stage) model and serial number.

Note:
An important information needed when asking for help with the motion control system or when reporting a problem is the stage model and serial number. Use this command to determine the positioner model and serial number.

RETURNS **xx,yy**
where: **xx** = model number
yy = serial number

REL. COMMANDS none

EXAMPLE

1 ID ?	*read axis-1 positioner model and serial number*
TS50DC.5, SN1263	*controller returns model and serial number*

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JH set jog high speed

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**JH**nn or xx**JH**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	high speed value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to maximum value allowed by VU command or **?** to read present setting
Units	**xx**	-	none
	nn	-	preset units/second
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx10, MAXIMUM VELOCITY EXCEEDED

DESCRIPTION This command is used to set the high speed for jogging an axis. Its execution is immediate, meaning that the value is changed when the command is processed, including when motion is in progress. It can be used as an immediate command or inside a program.

RETURNS If "?" sign takes the place of **nn** value, this command reports current setting.

REL. COMMANDS

JW	-	set jog low speed
VU	-	set maximum velocity

EXAMPLE

2VU?	*read maximum velocity allowed axis # 2*
10	*controller returns a value of 10.0 units/second for axis #2*
2JH7.5	*set jog high speed to 7.5 units/second for axis #2*
2JH?	*read jog high speed value for axis #2*
7.5	*controller returns a value of 7.5 units/second for axis #2*

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JK set jerk rate

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**JK**nn or xx**JK**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	jerk value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **2e9**
Units	**xx**	-	none
	nn	-	preset units / second^3 or **?** to read current setting

Defaults	**xx** missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx15, MAXIMUM JERK EXCEEDED

DESCRIPTION

This command is used to set the jerk (i.e., rate of change in acceleration) value for an axis. Its execution is immediate, meaning that the jerk is altered when the command is processed and trajectory mode is set to S-curve, even while a motion is in progress. It can be used as an immediate command or inside a program.

Note:
Avoid changing the jerk during the acceleration or deceleration periods. For better predictable results, change jerk only when the axis is not moving.

RETURNS

none

REL. COMMANDS

AC	-	set acceleration
TJ	-	set trajectory mode
VA	-	set velocity

EXAMPLE

2**JK**?	| *read desired velocity of axis # 2*
10.5	| *controller returns a velocity value of 10.5 units/s^3*
2**JK**15	| set axis #2 jerk to 15 *units/s^3*

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JL jump to label

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**JL**nn

PARAMETERS
Description
xx [int] - label number
nn [int] - loop count

Range
xx - **1** to **100**
nn - **1** to **65535**

Units
xx - none
nn - none

Default
xx missing: error 38, COMMAND PARAMETER MISSING
out of range: error xx2, PARAMETER OUT OF RANGE

nn missing: assume infinite
out of range: error xx2, PARAMETER OUT OF RANGE

DESCRIPTION
This command changes the flow of the program execution by jumping to a predefined label **xx**. This a flow control command that alters the normal sequential flow of a program. It must be used in conjunction with the DL command which defines a label.
Parameter **nn** determines the number of times to repeat the jump before allowing the program to flow passed.

RETURNS
none

REL. COMMANDS
JL - jump to label

EXAMPLE

```
3XX      | clear program 3 from memory, if any
3EP      | create program 3
1DL      | define label 1
   .
   .
   .
1JL 5    | jump to label 1 five(5) times
QP       | end entering program and quit programming mode
3EX      | run stored program number 3
```


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JW set jog low speed

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**JW**nn or xx**JW**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	low speed value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to maximum value allowed by VU command or **?** to read present setting
Units	**xx**	-	none
	nn	-	reset units/second
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx10, MAXIMUM VELOCITY EXCEEDED

DESCRIPTION This command is used to set the low speed for jogging an axis. Its execution is immediate, meaning that the value is changed when the command is processed, including when motion is in progress. It can be used as an immediate command or inside a program.

RETURNS If "?" sign takes the place of **nn** value, this command reports current setting.

REL. COMMANDS

JH	-	set jog high speed
VU	-	set maximum velocity

EXAMPLE

2VU?	| *read maximum velocity allowed axis # 2*
10	| *controller returns a value of 10.0 units/second for axis #2*
2JW2.5	| *set jog low speed to 2.5 units/second for axis #2*
2JW?	| *read jog low speed value for axis #2*
2.5	| *controller returns a value of 2.5 units/second for axis #2*

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KD set derivative gain

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**KD**nn or xx**KD**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	derivative gain factor Kd
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **2e9,** or **?** to read current setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command sets the derivative gain factor Kd of the PID closed loop. It is active for any DC servo based motion device that has been selected to operate in closed loop.
The command can be sent at any time but it has no effect until the UF (update filter) is received.

.

See the "**Servo Tuning**" chapter on how to adjust the PID filter parameters.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

KI	-	set integral gain factor
KP	-	set proportional gain factor
KS	-	set saturation gain factor
UF	-	update filter

EXAMPLE

3KD0.01 | *set derivative gain factor for axis # 3 to 0.01*
.
.
.
3UF | *update PID filter; only now the **KD** command takes effect*

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KI set integral gain

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**KI**nn or xx**KI**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	integral gain factor Ki
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **2e9,** or **?** to read current setting
Units	**xx**	-	none
	nn	-	one

Defaults

xx missing:		error 37, AXIS NUMBER MISSING
out of range:		error 9, AXIS NUMBER OUT OF RANGE
nn missing:		error 38, COMMAND PARAMETER MISSING
out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command sets the integral gain factor Ki of the PID closed loop. It is active for any DC servo based motion device that has been selected to operate in closed loop.
The command can be sent at any time but it has no effect until the UF (update filter) is received.

.

See the "**Servo Tuning**" chapter on how to adjust the PID filter parameters.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

KD	-	set integral gain factor
KP	-	set proportional gain factor
KS	-	set saturation gain factor
UF	-	update filter

EXAMPLE

3KI 0.01 | *set integral gain factor for axis # 3 to 0.01*
.
.
.
3UF | *update PID filter; only now the **KI** command takes effect*

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KP set proportional gain

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**KP**nn or xx**KP**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	roportional gain factor Kp
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **2e9,** or **?** to read current setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		rror xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command sets the proportional gain factor Kp of the PID closed loop. It is active for any DC servo based motion device that has been selected to operate in closed loop.
The command can be sent at any time but it has no effect until the UF (update filter) is received.

.

See the "**Servo Tuning**" chapter on how to adjust the PID filter parameters.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

KI	-	set integral gain factor
KD	-	set proportional gain factor
KS	-	set saturation gain factor
UF	-	update filter

EXAMPLE

3KP0.01 | *set proportional gain factor for axis # 3 to 0.01*

.
.
.

3UF | *update PID filter; only now the **KP** command takes effect*

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KS set saturation level of integral factor

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**KS**nn or xx**KS**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	saturation level of integrator KS
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **2e9,** or **?** to read current setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command sets the saturation level of the integral factor of the PID closed loop and is useful for preventing integral wind-up. It is active for any DC servo based motion device that has been selected to operate in closed loop.
The command can be sent at any time but it has no effect until the UF (update filter) is received.

.

See the "**Servo Tuning**" chapter on how to adjust the PID filter parameters.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

KI	-	set integral gain factor
KP	-	set proportional gain factor
KD	-	set derivative gain factor
UF	-	update filter

EXAMPLE

3KS0.01 | *set saturation level for axis # 3 to 0.01*
.
.
.
3UF | *update PID filter; only now the **KS** command takes effect*

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LC lock / unlock keyboard

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX LC nn

PARAMETERS

Description	**nn** [int]	-	Lock option
Range	**nn**	-	**0 – 2** (0 = unlocked; 1 = all but "Motor ON/OFF" locked; 2 = all locked
Units	**nn**	-	none
Defaults	**nn** missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx01, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to lock / unlock the keyboard of the ESP301. The parameter value means :

- 0 : unlock the keyboard
- 1 : lock all buttons but the "Motor ON/OFF"
- 2 : lock all buttons

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

EXAMPLE

LC1	| *lock the keyboard*
LC?	| *get lock status*
1	| *returns current setting*

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LP list program

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX xx**LP**

PARAMETERS

Description	**xx** [int]	-	rogram number
Range	**xx**	-	**1** to **100**
Units	**xx**	-	none
Defaults	**xx**	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command reads a specified program from non-volatile memory and sends it to the selected communication port (RS232 or IEEE488). During the transmission no other command should be sent to the controller.

Note

The program list always terminates with the word “END”

RETURNS program listing

REL. COMMANDS **EP** - enter program mode

EXAMPLE

```
3LP       | list program number 3
3MO       | enable axis 3 motor power
1DL       | define return label 1
3PR+10    | move axis 3  relative +10 units
3WS500    | wait 500ms after axis 3 stops
3PR-10    | move axis 3  relative -10 units
3WS500    | wait 500ms after axis 3 stops
1JL5      | jump to label 1 location 5 times
END       | end of program list
```


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MD read motion done status

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX xx**MD?**

PARAMETERS

Description	**xx** [int]	-	axis number
Range	**xx**	-	**1** to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION This command is used to read the motion status for the specified axis **n**. The MD command can be used to monitor Homing, absolute, and relative displacement move completion status.

RETURNS **nn** - **0** or **1** where 0 = motion not done (FALSE)
1 = motion done (TRUE)

REL. COMMANDS

PA	-	move to an absolute position
PR	-	move to a relative position
OR	-	move to home position

EXAMPLE

3MD?	*| read axis #3 move done status*
1	*| controller returns status 1 (motion done) for axis # 3*
3PR2.2	*| start a relative motion of 2.2 on axis # 3*
3MD?	*| read axis #3 move done status*
0	*| controller returns status 0 (motion not done) for axis # 3*

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MF motor off

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**MF** or xx**MF**?

PARAMETERS

Description	**xx** [int]	-	axis number
Range	**xx**	-	**1** to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION This command turns power OFF of the specified motor (axis).

RETURNS If "?" sign is issued along with command, the controller returns:

1	-	motor power is ON
0	-	motor power is OFF

REL. COMMANDS

AB	-	abort motion
ST	-	stop motion
MO	-	urn motor power ON

EXAMPLE

2MF	| *turn axis #2 motor power OFF*
2MF?	| *query axis #2 motor power status*
0	| *controller returns a value of 0*
2MO	| *turn axis #2 motor power ON*
2MF?	| *query axis #2 motor power status*
1	| *controller returns a value of 1*

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MO motor on

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**MO** or xx**MO**?

PARAMETERS

Description			
	xx [int]	-	axis number
Range	**xx**	-	to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION This command turns power ON of the specified motor (axis).

RETURNS If "?" sign is issued along with command, the controller returns:

1	-	motor power is ON
0	-	motor power is OFF

REL. COMMANDS

AB	-	abort motion
ST	-	stop motion
MF	-	urn motor power OFF

EXAMPLE

MO	| *turn axis #2 motor power ON*
2MO?	| *query axis #2 motor power status*
1	| *controller returns a value of 1*
2MF	| *turn axis #2 motor power OFF*
2MO?	| *query axis #2 motor power status*
0	| *controller returns a value of 0*

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MT move to hardware travel limit

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**MT**nn or xx**MT**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [char]	-	direction of motion
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	+ for positive direction or – for negative direction
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		positive direction

DESCRIPTION This command is used to move an axis to its limit (positive or negative). It uses the home search speed during travel to hardware limit.

Note: This command cannot be issued after enabling DAQ (refer ASCII command, **DE**).

RETURNS If "?" sign takes the place of **nn** value, this command reports **1** if motion is done, or **0** if motion is in progress.

REL. COMMANDS

OR	-	home location search
OH	-	set home search speed

EXAMPLE

3MT+	| *move axis #3 to positive travel limit*
3MT?	| *query motion status*
0	| *controller returns 0 indicating motion is in progress*

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MV move indefinitely

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**MV**nn or xx**MV**?

PARAMETERS

Description

xx [int] - axis number
nn [char] - direction of motion

Range

xx - **1** to **MAX AXES**
nn - + for positive direction or – for negative direction

Units

xx - none
nn - none

Defaults

xx	missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
nn	missing:	positive direction
	out of range:	error xx04, POSITIVE HARDWARE LIMIT EXCEEDED
	out of range:	error xx05, NEGATIVE HARDWARE LIMIT EXCEEDED
	out of range:	error xx06, POSITIVE SOFTWARE LIMIT EXCEEDED
	out of range:	error xx07, NEGATIVE SOFTWARE LIMIT EXCEEDED

DESCRIPTION

This command initiates infinite motion. When received, the selected axis **xx** will move indefinitely, with the predefined acceleration and velocity, in the direction specified by **nn**. If the requested axis is member of a group, this command does not initiate the desired motion. Instead, error xx31, " COMMAND NOT ALLOWED DUE TO GROUP ASSIGNMENT" is generated. Refer HL and HC commands to move along a line or an arc.

If this command is issued when trajectory mode for this axis is not in trapezoidal or s-curve mode, the controller returns error xx32, “INVALID TRAJECTORY MODE FOR MOVING”.

Note:

Although the command is accepted while a motion is in progress, care should be taken not to reverse direction of motion.

RETURNS

If the “?” sign takes the place of **nn** value, this command reports the motion done status.

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REL. COMMANDS	**PA**	-	move to absolute position
	PR	-	move to relative position
	ST	-	stop motion
	MD	-	move done status
EXAMPLE	**3MV+**		*| move axis #3 indefinitely in positive direction*
	3MV?		*| query status of move*
	0		*| controller returns 0 meaning, motion is in progress*
	3ST		*| stop axis #3 motion*
	3MV–		*| move axis #3 indefinitely in negative direction*

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MZ move to nearest index

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**MZ**nn or xx**MZ**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [char]	-	direction of motion
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	+ for positive direction or – for negative direction
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		ositive direction

DESCRIPTION This command is used to move an axis to its nearest index (positive or negative). It uses the home search speed during travel to nearest index.

Note: This command cannot be issued after enabling DAQ (refer ASCII command, **DE**).

RETURNS If "?" sign takes the place of **nn** value, this command reports **1** if motion is done, or **0** if motion is in progress.

REL. COMMANDS

OR	-	home location search
OH	-	set home search speed

EXAMPLE

3MZ+	| *move axis #3 to nearest index in positive direction*
3MZ?	| *query motion status*
0	| *controller returns 0 indicating motion is in progress*

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OH set home search high speed

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**OH**nn or xx**OH**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [float]	-	high speed value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to maximum value allowed by VU command or **?** to read present setting
Units	**xx**	-	none
	nn	-	reset units/second
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx10, MAXIMUM VELOCITY EXCEEDED error xx24, SPEED OUT OF RANGE

DESCRIPTION This command sets the high speed used to search for home location for an axis. Its execution is immediate, meaning that the value is changed when the command is processed, including when motion is in progress. It can be used as an immediate command or inside a program.

RETURNS If "?" sign takes the place of **nn** value, this command reports current setting.

REL. COMMANDS

OR	-	search for home
OL	-	set home search low speed

EXAMPLE

3OH10	| *set home search high speed of axis # 3 to 10 units/sec*
3OH?	| *query home search high speed of axis #3*
10	| *controller returns a value of 10.0 units/second*

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OL set home search low speed

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**OL**nn or xx**OL**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [float]	-	low speed value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to maximum value allowed by VU command or **?** to read present setting
Units	**xx**	-	none
	nn	-	preset units/second
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx10, MAXIMUM VELOCITY EXCEEDED error xx24, SPEED OUT OF RANGE

DESCRIPTION This command sets the low speed used to search for home location for an axis. Its execution is immediate, meaning that the value is changed when the command is processed, including when motion is in progress. It can be used as an immediate command or inside a program.

RETURNS If "?" sign takes the place of **nn** value, this command reports current setting.

REL. COMMANDS

OR	-	search for home
OH	-	set home search high speed
OL	-	set home search low speed

EXAMPLE

3OL2	| *set home search low speed of axis # 3 to 2 units/sec*
3OL?	| *query home search low speed of axis #3*
2	| *controller returns a value of 2 units/second*

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OM set home search mode

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	home search mode
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **6**
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command selects the home search type without invoking the home search sequence (see the description of OR command for more information on home search). The seven home search types are +0 Position Count, Home Switch and Index Signals, Home Switch Signal, Positive Limit Signal, Negative Limit Signal, Positive Limit and Index Signals and Negative Limit and Index Signals.

If **nn** = **0** and the front panel HOME search push button is pressed, the axes will search for zero position count. If **nn** = **1** and the front panel HOME search push button is pressed, the axis will search for combined Home and Index signal transitions. The controller responds similarly for other values of **nn**.

The **nn** parameter is overwritten by the **OR** command parameter.

RETURNS

If "?" sign takes the place of **nn** value, this command reports current setting.

REL. COMMANDS

OR - search for home

EXAMPLE

3OM1 | *set axis #3 home search mode to 1*
3OR | *start home search on axis #3 using mode 1*

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OR search for home

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**OR**nn

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	home mode
Range	**xx**	-	**0** to **MAX AXES**
	nn	-	**0** to **6** where: 0 = Find +0 Position Count 1 = Find Home and Index Signals 2 = Find Home Signal 3 = Find Positive Limit Signal 4 = Find Negative Limit Signal 5 = Find Positive Limit and Index Signals 6 = Find Negative Limit and Index Signals
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command executes a Home search routine on the axis specified by **xx**. If **xx** = **0**, a home search routine is initiated sequentially on all installed axes. If **nn** is missing, the axes will search for home using the mode specified using **OM** command. If **nn** = **0**, the axes will search for zero position count. If **nn** = **1**, the axis will search for combined Home and Index signal transitions. If **nn** = **2**, the axes will search for Home signal transition only. If **nn = 3**, the axes will search for positive limit signal transition. If **nn = 4**, the axes will search for negative limit signal transition. If **nn = 5**, the axes will search for positive limit and index signal transition. If **nn = 6**, the axes will search for negative limit and index signal transition.

At the end of a home search routine, the position of axes is reset to the value specified using **SH** command.

The home search motion status can be monitored with the Motion Done (**MD**) status command. If a fault condition such as E-stop occurs while home search is in progress or if this command is issued to an axis before enabling it, the controller returns error xx20, “HOMING ABORTED”.

For a detailed description of the home search routine see the **Home - The Axis Origin** chapter in the **Motion Control Tutorial** section.

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Note: This command should be executed once every time the controller power is turned ON or the controller performs a complete system reset. There is no need to issue this command in any other case since the controller always keeps track of position, even when the motor power is OFF.

Note: This command cannot be issued after enabling DAQ (refer ASCII command, **DE**).

RETURNS none

REL. COMMANDS

DH	**-**	define home
OH	**-**	set home search speed
OM	-	set home search mode
MD	**-**	read motion done status
SH	-	set home preset position

EXAMPLE

3MO	|	*turn axis #3 motor power ON*
3SH0	|	*set axis #3 home position to 0 units*
3OR1	|	*perform a home search on axis # 3*
3MD?	|	*query axis #3 motion status*
1	|	*controller returns a value of 1, when motion is done*
3TP	|	*query axis #3 position*
0	|	*controller returns a value of 0 units*

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PA move to absolute position

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**PA**nn or xx**PA**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	absolute position destination
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	any position within the travel limits and within ±2e9 * encoder resolution.
Units	**xx**	-	none
	nn	-	defined motion units

Defaults	**xx** missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx04, POSITIVE HARDWARE LIMIT EXCEEDED
	out of range:	error xx05, NEGATIVE HARDWARE LIMIT EXCEEDED
	out of range:	error xx06, POSITIVE SOFTWARE LIMIT EXCEEDED
	out of range:	error xx07, NEGATIVE SOFTWARE LIMIT EXCEEDED

DESCRIPTION

This command initiates an absolute motion. When received, the selected axis **xx** will move, with the predefined acceleration and velocity, to the absolute position specified by **nn**. If the requested axis is member of a group, this command does not initiate the desired motion. Instead, error xx31, " COMMAND NOT ALLOWED DUE TO GROUP ASSIGNMENT" is generated. Refer HL and HC commands to move along a line or an arc.

If this command is issued when trajectory mode for this axis is not in trapezoidal or s-curve mode, the controller returns error xx32, “INVALID TRAJECTORY MODE FOR MOVING”.

Note:

Even though the command is accepted while a motion is in progress, care should be taken not to reverse direction of motion. When this command is received, the controller verifies if it will produce a change of direction.

RETURNS

If the “?” sign takes the place of **nn** value, this command reports the current actual the same as TP?.

REL. COMMANDS

AC	-	set acceleration
PR	-	move to relative position
ST	-	stop motion
MD	-	move done status
VA	-	set velocity

EXAMPLE

3VA8	| *set velocity of axis #2 to 8 units / s*
3PA12.34	| *move axis #2 to absolute position 12.34*

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PH get hardware status

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **PH**

PARAMETERS None

DESCRIPTION This command is used to get general hardware status for all axes. This routine allows user to observe the various digital input signals as they appear to the controller.

HARDWARE STATUS REGISTER #1

BIT#	VALUE	DEFINITION
0	0	axis 1 +hardware travel limit low
0	1	axis 1 +hardware travel limit high
1	0	axis 2 +hardware travel limit low
1	1	axis 2 +hardware travel limit high
2	0	axis 3 +hardware travel limit low
2	1	axis 3 +hardware travel limit high
3	0	axis 4 +hardware travel limit low
3	1	axis 4 +hardware travel limit high
4	0	axis 5 +hardware travel limit low
4	1	axis 5 +hardware travel limit high
5	0	axis 6 +hardware travel limit low
5	1	axis 6 +hardware travel limit high
6	0	reserved
6	1	reserved
7	0	reserved
7	1	reserved
8	0	axis 1 –hardware travel limit low
8	1	axis 1 –hardware travel limit high
9	0	axis 2 –hardware travel limit low
9	1	axis 2 –hardware travel limit high
10	0	axis 3 –hardware travel limit low
10	1	axis 3 –hardware travel limit high
11	0	axis 4 –hardware travel limit low
11	1	axis 4 –hardware travel limit high
12	0	axis 5 –hardware travel limit low
12	1	axis 5 –hardware travel limit high
13	0	axis 6 –hardware travel limit low
13	1	axis 6 –hardware travel limit high
14	0	reserved
14	1	reserved
15	0	reserved
15	1	reserved

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16	0	axis 1 amplifier fault input low
16	1	axis 1 amplifier fault input high
17	0	axis 2 amplifier fault input low
17	1	axis 2 amplifier fault input high
18	0	axis 3 amplifier fault input low
18	1	axis 3 amplifier fault input high
19	0	axis 4 amplifier fault input low
19	1	axis 4 amplifier fault input high
20	0	axis 5 amplifier fault input low
20	1	axis 5 amplifier fault input high
21	0	axis 6 amplifier fault input low
21	1	axis 6 amplifier fault input high
22	0	reserved
22	1	reserved
23	0	reserved
23	1	reserved
24	0	reserved
24	1	reserved
25	0	reserved
25	1	reserved
26	0	reserved
26	1	reserved
27	0	100-pin emergency stop (unlatched) low
27	1	100-pin emergency stop (unlatched) high
28	0	auxiliary I/O emergency stop (unlatched) low
28	1	auxiliary I/O emergency stop (unlatched) high
29	0	100-pin connector emergency stop (latched) low
29	1	100-pin connector emergency stop (latched) high
30	0	auxiliary I/O conector emergency stop (latched) low
30	1	auxiliary I/O conector emergency stop (latched) high
31	0	100-pin cable interlock low
31	1	100-pin cable interlock high

HARDWARE STATUS REGISTER #2

BIT #	VALUE	DEFINITION
0	0	axis 1 home signal low
0	1	axis 1 home signal high
1	0	axis 2 home signal low
1	1	axis 2 home signal high
2	0	axis 3 home signal low
2	1	axis 3 home signal high
3	0	axis 4 home signal low
3	1	axis 4 home signal high
4	0	axis 5 home signal low
4	1	axis 5 home signal high
5	0	axis 6 home signal low
5	1	axis 6 home signal high
6	0	reserved
6	1	reserved
7	0	reserved

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7	1	reserved
8	0	axis 1 index signal low
8	1	axis 1 index signal high
9	0	axis 2 index signal low
9	1	axis 2 index signal high
10	0	axis 3 index signal low
10	1	axis 3 index signal high
11	0	axis 4 index signal low
11	1	axis 4 index signal high
12	0	axis 5 index signal low
12	1	axis 5 index signal high
13	0	axis 6 index signal low
13	1	axis 6 index signal high
14	0	reserved
14	1	reserved
15	0	reserved
15	1	reserved
16	0	digital input A low
16	1	digital input A high
17	0	digital input B low
17	1	digital input B high
18	0	digital input C low
18	1	digital input C high
		• • •
31	0	reserved
31	1	reserved

RETURNS

This command reports the current status in hexadecimal notation.

REL. COMMANDS

ZU - get ESP system configuration
ZZ - get system configuration

EXAMPLE

PH | *read hardware status*
18000404H, 4H | *controller returns the status of the two hardware regsisters*

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PR move to relative position

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**PR**nn

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	relative motion increment
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	any value that will not cause exceeding the software limits and within 2e9 * encoder resolution.
Units	**xx**	-	none
	nn	-	defined motion units
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx04, POSITIVE HARDWARE LIMIT EXCEEDED
	out of range:		error xx05, NEGATIVE HARDWARE LIMIT EXCEEDED
	out of range:		error xx06, POSITIVE SOFTWARE LIMIT EXCEEDED
	out of range:		rror xx07, NEGATIVE SOFTWARE LIMIT EXCEEDED

DESCRIPTION

This command initiates a relative motion. When received, the selected axis **xx** will move, with the predefined acceleration and velocity, to a relative position **nn** units away from the current position. If the requested axis is member of a group, this command does not initiate the desired motion. Instead, error xx31, "COMMAND NOT ALLOWED DUE TO GROUP ASSIGNMENT" is generated. Refer HL and HC commands to move along a line or an arc.

If this command is issued when trajectory mode for this axis is not in trapezoidal or s-curve mode, the controller returns error xx32, “INVALID TRAJECTORY MODE FOR MOVING”.

Note:
Even though the command is accepted while a motion is in progress, care should be taken not to reverse direction of motion.

RETURNS none

REL. COMMANDS

AC	-	set acceleration
PA	-	move to absolute position
MD	-	move done status
ST	-	stop motion
VA	-	et velocity

EXAMPLE

3VA8		*set velocity of axis # 3 to 8 units / s*
3PR2.34		*move axis # 3 2.34 units away from the current position*

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QD update motor driver settings

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**QD**

PARAMETERS

Description			
	xx [int]	-	axis number
Range	**xx**	-	**1** to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	missing Unidrive:		error xx23, UNIDRIVE NOT DETECTED

DESCRIPTION This command is used to update Newport programmable driver (i.e., Unidrive) settings into working registers.

Note: This command should not be issued during motion since the motor power is automatically turned OFF.

RETURNS none

REL. COMMANDS

QS	-	set microstep factor
QG	-	set gear constant
QT	-	set tachometer gain
QV	-	set average motor voltage

EXAMPLE

2QI?	| *read maximum motor current setting of axis # 2*
1.6	| *controller returns a value of 1.6 Amp. for axis #2*
2QI 1.2	| *set maximum motor current to 1.2Amp. for axis #2*
2QD	| *update programmable driver with latest settings for axis #2*
SM	| *save all controller settings to non-volatile memory*

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QG set gear constant

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**QG**nn or xx**QG**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [float]	-	gear constant
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **2e9**
			or **?** to read present setting
Units	**xx**	-	none
	nn	-	evolution / unit of measure
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the gear constant for a Newport Unidrive compatible programmable driver for DC servo axis. This command should be used in conjunction with **QT** (tachometer gain) command.
The gear constant is defined as the number of revolutions the motor has to make for the motion device to move one displacement.
This command must to be followed by the **QD** update driver command to take affect.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

SN	-	set displacement units
QD	-	update driver
QS	-	set microstep factor
QI	-	set motor maximum current
QV	-	et average motor voltage

EXAMPLE

2QG?	| *read gear constant setting of axis # 2*
0.3937	| *controller returns a value of 0.3937 rev / unit for axis #2*
2QG 0.25	| *set gear constant to 0.25 rev / unit for axis #2*
2QT 7.0	| *set tachometer gain to 7 V/Krpm for axis #2*
2QD	| *update programmable driver with latest settings for axis #2*

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QI set maximum motor current

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**QI**nn or xx**QI**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	motor current
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to maximum driver rating (see Specifications section) or **?** to read present setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the maximum motor current output for a Newport Unidrive compatible programmable driver axis. This command must to be followed by the **QD** update driver command to take affect.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

QG	-	set gear constant
QD	-	update driver
QS	-	set microstep factor
QT	-	set tachometer gain
QV	-	set average motor voltage

EXAMPLE

2QI?	| *read maximum motor current setting of axis # 2*
1.6	| *controller returns a value of 1.6 Amp. for axis #2*
2QI 1.2	| *set maximum motor current to 1.2Amp. for axis #2*
2QD	| *update programmable driver with latest settings for axis #2*
SM	| *save all controller settings to non-volatile memory*

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QM set motor type

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**QM**nn or xx**QM**?

PARAMETERS

Description

xx [int] - axis number
nn [int] - motor type

Range

xx - **1** to **MAX AXES**
nn - **0** to **4** where
0 = motor type undefined (default)
1 = DC servo motor (single analog channel)
2 = step motor (digital control)*
3 = commutated step motor (analog control)+
4 = commutated brushless DC servo motor
or **?** to read current setting

Units

xx - none
nn - none

Defaults

xx missing: error 37, AXIS NUMBER MISSING
out of range: error 9, AXIS NUMBER OUT OF RANGE

nn missing: error 38, COMMAND PARAMETER MISSING
out of range: error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to set the motor type the for axis **xx**. Defining motor type is necessary because the ESP needs to apply different control algorithms for different motor types.

Note:
It will not be possible to control an axis if its motor type is undefined.

* **ESP301** motion controller does not support this motor type.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

QV - set average motor voltage
QD - update driver
QI - set maximum motor current
QT - set tachometer gain
QG - et gear constant

EXAMPLE

2QM? | *read motor type of axis # 2*
0 | *controller returns a value of 0 (motor undefined) for axis #2*
2QM 1 | *set motor type to value of 1 (DC servo motor) for axis #2*
2QD | *update programmable driver with latest settings for axis #2*
SM | *save all controller settings to non-volatile memory*

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QP quit program mode

	IMM	PGM	MIP
USAGE	♦		

SYNTAX **QP**

PARAMETERS None

DESCRIPTION This command quits the controller from programming mode. All the commands following this one will be executed immediately.

RETURNS none

REL. COMMANDS

EX	-	execute stored program
AP	-	abort stored program execution
XX	-	erase program

EXAMPLE

```
3XX          | clear program 3 from memory, if any
3EP          | activate program mode and enter following commands as
             | program 3
   .
   .
   .
QP           | end entering program and quit programming mode
3EX          | run stored program number 3
```


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QR reduce motor torque

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**QR**nn1,nn2 or xx**QR**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn1 [int]	-	delay period
	nn2 [float]	-	motor current reduction percentage
Range	**xx**	-	**1** to **MAX AXES**
	nn1	-	**0** to **60000**
	nn2	-	**0** to **100**
Units	**xx**	-	none
	nn1	-	milliseconds
	nn2	-	percent of max. motor current
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	missing parameter:		error 38, COMMAND PARAMETER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION This command automatically reduces the specified step motor's current (i.e., torque) output to the requested percentage **nn2** after motion has stopped and the specified time **nn1** has expired. The purpose of this command is to help reduce the motor heating typically generated by stepper motors. If **xx** is equal to 0, the torque reduction parameters get applied to all axes.
Note: This command does not affect DC servo motors and pulse stepper motors.

RETURNS If "?" sign is issued along with command, the controller returns the torque reduction settings for the specified axis.

REL. COMMANDS

QM	-	set motor type
QI	-	et motor current

EXAMPLE

2QR1000,50	**|** *reduce motor #2 torque to 50%, 1000 msec after a move done*
2QR?	**|** *query motor #2 torque reduction settings*
1000,50	**|** *controller returns 1000 msec and 50%*

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QS set microstep factor

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**QS**nn or xx**QS**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	microstep value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**1** to **250** for step motors **1** to **1000** for commutated step motors or **?** to read current setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the microstep factor for a Newport Unidrive compatible programmable driver with step motor axis. This command must be followed by the **QD** update driver command to take affect.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

QD	-	update driver
QI	-	set maximum motor current
QT	-	set tachometer gain
QG	-	set gear constant
QV	-	set average motor voltage

EXAMPLE

2QS?	| *read microstep factor of axis # 2*
100	| *controller returns a value of 100 for axis #2*
2QS 250	| *set microstep factor to 250 for axis #2*
2QD	| *update programmable driver with latest settings for axis #2*
SM	| *save all controller settings to non-volatile memory*

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QT set tachometer gain

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**QT**nn or xx**QT**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	tachometer gain
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **20** or **?** to read present setting
Units	**xx**	-	none
	nn	-	Volts/Krpm
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the DC motor tachometer gain for a Newport Unidrive compatible programmable driver axis.
This command should be used in conjunction with **QG** (gear constant) command.
This command must to be followed by the **QD** update driver command to take affect.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

QD	-	update driver
QS	-	set microstep factor
QG	-	set gear constant
QI	-	set motor maximum current
QV	-	set average motor voltage

EXAMPLE

2QT?	*read tachometer gain setting of axis # 2*
7.0	*controller returns a value of 7.0 V/Krpm for axis #2*
2QT 6.5	*set tachometer gain value of 6.5 V/Krpm for axis #2*
2QG 0.3937	*set gear constant to 0.3937 rev / unit for axis #2*
2QD	*update programmable driver with latest settings for axis #2*
SM	*save all controller settings to non-volatile memory*

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QV set average motor voltage

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**QV**nn or xx**QV**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [float]	-	motor voltage
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to maximum driver rating (see Specifications section) or **?** to read present setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the average motor voltage output for a Newport Unidrive compatible programmable driver axis. This command must to be followed by the **QD** update driver command to take affect.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

QD	-	update driver
QI	-	set maximum motor current
QG	-	set gear constant
QS	-	set microstep factor
QT	-	set tachometer gain

EXAMPLE

2QV?	| *read average motor voltage setting of axis # 2*
48.0	| *controller returns a value of 48Volts for axis #2*
2QV 12	| *set average motor voltage to 12 Volts for axis #2*
2QD	| *update programmable driver with latest settings for axis #2*
SM	| *save all controller settings to non-volatile memory*

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RQ generate service request (SRQ)

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **RQ**nn

PARAMETERS

Description	**nn** [int]	-	interrupt number
Range	**nn**	-	**0** to **31**
Units	**nn**	-	none
Defaults	**nn** missing:		0
	out of range:		error 7, PARAMETER OUT OF RANGE

DESCRIPTION This command generates an interrupt service request to the host computer. The parameter **nn** is used to identify the RQ command which generated the interrupt. Upon receiving the interrupt, the host computer interrupt service routine should perform an IEEE 488 serial poll. If the interrupt was as a result of the **RQ** command, then bit 6 of the response is 1 and the lower five bits equal the parameter **nn**.

This command can be used to notify the host computer of the progress or flow of command execution in the motion controller.

RETURNS None

REL. COMMANDS **SA** - set device address

EXAMPLE 2PR200;2WS;1PR100;1WS;**RQ3** | *generate interrupt when RQ command is encountered and set bit 0 and 2*

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RS reset the controller

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **RS**

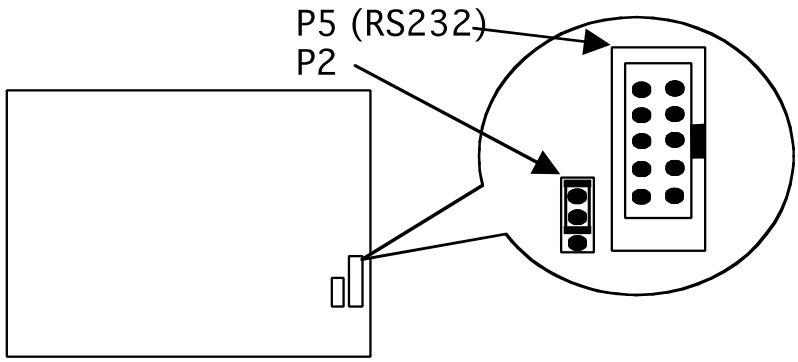
PARAMETERS None

DESCRIPTION This command is used to perform a hardware reset of the controller. It performs the following preliminary tasks before resetting the controller:

1. Stop all the axes that are in motion. The deceleration value specified using the command **AG** is used to stop the axes.
2. Wait for 500 ms to allow the axes to settle.
3. Disable all the axes by turning the power OFF.
4. Reset to the controller card.

Once the command to reset the controller is detected by the DSP, the controller will stay in reset for a minimum of 200 ms. After the reset condition has occurred (i.e., after the 200 ms reset time), the controller firmware reboots the controller. At this point, all the parameters last saved to the non-volatile flash memory on the controller will be restored. Furthermore, the controller will detect any stages (ESP compatible or otherwise) and drivers connected to the controller. This process can take anywhere up to 20 seconds depending upon the controller configuration.

NOTE: This command is affective only when the watchdog timer is enabled through appropriate jumper setting on the controller card (default factory setting is "enabled"). The following figure illustrates the jumper settings to enable the watchdog timer.



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RETURNS None

REL. COMMANDS None

EXAMPLE **RS** | *Reset the controller*

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SA set device address

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **SA**nn or **SA?**

PARAMETERS

Description	**nn** [int]	-	address number
Range	**nn**	-	**1** to **30**
Units	**nn**	-	none
Defaults	**nn** missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error 7, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set and report the device (i.e., ESP controller) address for use with IEEE-488 or USB communications (if equipped).
The address change takes affect immediately after the command is processed.

Note:
Use the SM command to save new address setting to non-volatile memory.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS none

EXAMPLE

SA 3	| *set device address to 3*
SA ?	| *read present device address setting*
3	| *controller returns device address #3*
SM	| *save all settings to non-volatile memory*

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SB set / get DIO port A, B bit status

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **SB**nn or **SB**?

PARAMETERS
Description

nn [int] - hardware limit configuration

Range

nn - **0** to **0FFFFFFH** (hexadecimal with leading zero(0))
or **?** to read current setting

Units

nn - None

Defaults

nn missing: error 38, COMMAND PARAMETER MISSING
out of range: error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to either set all digital I/O (DIO) port A, B, and C logic level or read its present status. Bits 0-7 correspond to port A, and bits 8-15 to port B. Each 8-bit port can be set as either input or output with the **BO** command.

A DIO within a port configured as an input can only report its present HIGH or LOW logic level. Whereas a DIO bit within a port configured as an output can set(1) or clear(0) the corresponding DIO hardware to HIGH or LOW logic level. Reading the status of a port configured as output returns its present output status.

NOTE: All direction bits are automatically zeroed, or cleared, after a system reset. Therefore all DIO ports default to input by default.

NOTE: Each DIO bit has a pulled-up resistor to +5V. Therefore, all bits will be at HIGH logic level if not connected to external circuit and configured as input.

BIT#	VALUE	DEFINITION
0	0	port A bit-0 at logic level 0 (LOW)
*0	1	port A bit-0 at logic level 1 (HIGH)
1	0	port A bit-1 at logic level 0 (LOW)
*1	1	port A bit-1 at logic level 1 (HIGH)
2	0	port A bit-2 at logic level 0 (LOW)
*2	1	port A bit-2 at logic level 1 (HIGH)
3	0	port A bit-3 at logic level 0 (LOW)
*3	1	port A bit-3 at logic level 1 (HIGH)
4	0	port A bit-4 at logic level 0 (LOW)
*4	1	port A bit-4 at logic level 1 (HIGH)
5	0	port A bit-5 at logic level 0 (LOW)
*5	1	port A bit-5 at logic level 1 (HIGH)

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6	0	port A bit-6 at logic level 0 (LOW)
*6	1	port A bit-6 at logic level 1 (HIGH)
7	0	port A bit-7 at logic level 0 (LOW)
*7	1	port A bit-7 at logic level 1 (HIGH)
		• • •

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting in hexadecimal notation.

REL. COMMANDS

BO - set DIO port direction

EXAMPLE

BO?	| *read DIO port direction configuration*
0H	| *controller returns a value of 0H (all ports are input)*
BO 1H	| configure *DIO port A as output*
SB 0FFH	| *set all port A DIO output HIGH*

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SH set home preset position

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**SH**nn or xx**SH?**

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	home preset position
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	any position within the travel limits
Units	**xx**	-	none
	nn	-	defined motion units

Defaults	**xx** missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx01, PARAMETER OUT OF RANGE

DESCRIPTION

This command defines the value that is loaded in the position counter when home is found. The default value for all motion devices is 0. This means that unless a new value is defined using this command, the home position will be set to 0 when a home search is initiated using the OR command or from the front panel (if available).

Note:
The change takes effect only when a subsequent home search routine is performed. To make the change permanent, use the SM command to save it in the non-volatile memory.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting.

REL. COMMANDS

DH - define home

EXAMPLE

3MO	|	*turn axis #3 motor power ON*
3SH75.0	|	*set axis #3 home position to 75.0 units*
3OR1	|	*perform a home search on axis # 3*
3MD?	|	*query axis #3 motion status*
1	|	*controller returns a value of 1, when motion is done*
3TP	|	*query axis #3 position*
75.0	|	*controller returns a value of 75.0 units*

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SI set master-slave jog velocity update interval

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **SI**nn or **SI**?

PARAMETERS

Description	**nn** [int]	-	jog velocity update interval
Range	**nn**	-	**1** to **1000**
Units	**nn**	-	milliseconds
Defaults	**nn** missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error 7, PARAMETER OUT OF RANGE

DESCRIPTION This command sets the jog velocity update interval for slave axis. The jog velocity of slave axis is computed once every interval using user specified scaling coefficients and the master axis velocity at the time of computation. Refer **SK** command to specify slave jog velocity scaling coefficients. Note that appropriate trajectory mode has to be specified using **TJ** command before this command becomes effective.

RETURNS If "?" sign is issued along with command, the controller returns slave axis jog velocity update interval.

REL. COMMANDS

SS	-	define master-slave relationship
SK	-	set slave axis jog velocity scaling coefficients

EXAMPLE

2SS1	| *set axis 2 to be the slave of axis 1*
2SS?	| *query the master axis number for axis 2*
1	| *controller returns a value of 1*
2TJ6	| *set axis 2 trajectory mode to 6*
SI10	| *set the jog velocity update interval of slave axis to 10 msec*
SI?	| *query the jog velocity update interval of slave axis*
10	| *controller returns a value of 10*
SK0.5,0	| *set the jog velocity scaling coefficients to 0.5 and 0*
SK?	| *query the jog velocity scaling coefficients*
0.5,0	| *controller returns 0.5 and 0*

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SK set master-slave jog velocity scaling coefficients

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **SK**nn1, nn2 or **SK**?

PARAMETERS

Description	**nn$_i$** [float]	-	jog velocity scaling coefficients
Range	**nn$_i$**	-	none
Units	**nn$_i$**	-	none
Defaults	**nn$_i$**	missing:	error 38, COMMAND PARAMETER MISSING

DESCRIPTION

This command sets the jog velocity scaling coefficients for slave axis. The jog velocity of slave axis is computed once every interval using user specified scaling coefficients and the master axis velocity at the time of computation. The user specified coefficients are used as follows:

$$\dot{x}_s = A\dot{x}_m + B\dot{x}_m^2 \ \mathrm{sgn}(\dot{x}_m)$$

where $\dot{x}_s$ is the jog velocity of the slave and $\dot{x}_m$ is the velocity of the master axis.

Refer **SI** command to specify slave jog velocity update interval.

Note: Appropriate trajectory mode has to be specified using **TJ** command before this command becomes effective.

RETURNS

If "?" sign is issued along with command, the controller returns slave axis jog velocity scaling coefficients.

REL. COMMANDS

SS	-	define master-slave relationship
SI	-	set slave axis jog velocity update interval

EXAMPLE

2SS1	*| set axis 2 to be the slave of axis 1*
2SS?	*| query the master axis number for axis 2*
1	*| controller returns a value of 1*
2TJ6	*| set axis 2 trajectory mode to 6*
SI10	*| set the jog velocity update interval of slave axis to 10 msec*
SI?	*| query the jog velocity update interval of slave axis*
10	*| controller returns a value of 10*
SK0.5,0	*| set the jog velocity scaling coefficients to 0.5 and 0*
SK?	*| query the jog velocity scaling coefficients*
0.5,0	*| controller returns 0.5 and 0*

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SL set left travel limit

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**SL**nn or xx**SL**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	left (negative) software limit
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**-2e9 * encoder resolution** to 0
Units	**xx**	-	none
	nn	-	predefined motion units

Defaults	**xx** missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command defines the value for the negative (left) software travel limit. It should be used to restrict travel in the negative direction to protect the motion device or its load. For instance, if traveling full range, a stage could push its load into an obstacle. To prevent this, the user can reduce the allowed travel by changing the software travel limit.
Since a motion device must be allowed to find its home position, the home switch and/or sensor must be inside the travel limits. This means that both positive and negative travel limits cannot be set on the same side of the home position. A more obvious restriction is that the negative limit cannot be greater than the positive limit. If any of these restrictions is not respected, the controller will return PARAMETER OUT OF RANGE.

Note:
If the command is issued for an axis in motion, the new limit should not be set inside the current travel.

Note:
Be careful when using this command. The controller does not know the real hardware limits of the motion device. Always set the software limits inside the hardware limits (limit switches). In normal operation, a motion device should never hit a limit switch.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS	**OR**	-	search for home
	SR	-	set right software limits

EXAMPLE **1SL41.4** | *set negative travel limit of axis #1 to 41.4 units*

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SM save settings to non-volatile memory

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX **SM**

PARAMETERS none

DESCRIPTION This command is used to save system and axis configuration settings from RAM to non-volatile flash memory. It should be used after modifying system and/or axis parameters and settings to assure that the new data will not be lost when the controller is powered off.

Note:

User programs created with EP command are automatically saved to non-volatile memory.

RETURNS none

REL. COMMANDS none

EXAMPLE

```
3VA12.5      | set axis 3 velocity to 12.5 units/sec
3AC50.0      | set axis 3 acceleration to 50 unit/sec^2
   .
   .
   .
SM           | save changes to non-volatile memory
```


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SN set axis displacement units

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**SN**nn or xx**SN**?

PARAMETERS

Description

xx [int] - axis number

nn [int] - displacement units

Range

xx - **1** to **MAX AXES**

nn - **0** to **10** where

0 = encoder count	6 = micro-inches
1 = motor step	7 = degree
2 = millimeter	8 = gradian
3 = micrometer	9 = radian
4 = inches	10 = milliradian
5 = milli-inches	11 = microradian

or **?** to read present setting

Units

xx - none

nn - none

Defaults

xx missing: error 37, AXIS NUMBER MISSING

out of range: error 9, AXIS NUMBER OUT OF RANGE

nn missing: error 38, COMMAND PARAMETER MISSING

out of range: error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to set the displacement units for the for axis **xx**.

Note:

The unit of measure as used with this controller is intended as a label only. It is the user's responsibility to convert and resend all affected parameters (e.g., velocity, acceleration, etc…) when switching from one unit of measure to another.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

FR - set full-step resolution

SU - set encoder resolution

EXAMPLE

2SN | *read displacement unit setting of axis # 2*

2 | *controller returns a value 2 (millimeter) for axis #2*

2SN 0 | *set displacement unit to 0 (encoder count) for axis #2*

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SR set right travel limit

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**SR**nn or xx**SR**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	right (positive) software limit
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**+2e9 * encoder resolution** to 0
Units	**xx**	-	none
	nn	-	defined motion units
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command defines the value for the positive (right) software travel limit. It should be used to restrict travel in the positive direction to protect the motion device or its load. For instance, if traveling full range, a stage could push its load into an obstacle. To prevent this, the user can reduce the allowed travel by changing the software travel limit.
Since a motion device must be allowed to find its home position, the home switch and/or sensor must be inside the travel limits. This means that both positive and negative travel limits cannot be set on the same side of the home position. A more obvious restriction is that the negative limit cannot be greater than the positive limit. If any of these restrictions is not respected, the controller will return PARAMETER OUT OF RANGE

Note:
If the command is issued for an axis in motion, the new limit should not be set inside the current travel.

Note:
Be careful when using this command. The controller does not know the real hardware limits of the motion device. Always set the software limits inside the hardware limits (limit switches). In normal operation, a motion device should never hit a limit switch.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

OR	-	search for home
SL	-	set left software limit

EXAMPLE **1SR41.4** | *set positive travel limit of axis #1 to 41.4 units*

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SS define master-slave relationship

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**SS**nn or xx**SS**?

PARAMETERS

Description	**xx** [int]	-	axis number to be defined as a slave
	nn [int]	-	axis number to be defined as a master
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**1** to **MAX AXES**
Units	**xx**	-	none
	xx	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION

This command defines master-slave relationship between any two axes. A few rules are in place for ease of use.

- The trajectory mode for slave has to be appropriately defined before that axis follows master in a desired fashion.
- An axis cannot be assigned as its own slave if it is already in a trajectory mode that is specific to master-slaving.
- A slave axis cannot be moved individually using **PA** or **PR** commands if its trajectory mode is specific to master-slaving.

This command gets executed immediately, and can also be called from within a program.

RETURNS

If "?" sign is issued along with command, the controller returns master axis number.

REL. COMMANDS

TJ	-	set trajectory mode
GR	-	set master-slave reduction ratio

EXAMPLE

2SS1	| *set axis 2 to be the slave of axis 1*
2SS?	| *query the master axis number for axis 2*
1	**|** *controller returns a value of 1*
2TJ5	**|** *set axis 2 trajectory mode to 5*
2GR1.0	**|** *set the reduction ratio of axis 2 to 1.0*
1MO	**|** *turn axis 1 motor power ON*
2MO	**|** *turn axis 2 motor power ON*
1PA10	**|** *move axis 1 to absolute 10 units*
2PA20	**|** *move axis 2 to absolute 10 units*
TB	**|** *read error messages*
232, 242000, AXIS-2 INVALID TRAJECTORY MODE FOR MOVING	
	| controller returns appropriate error message

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ST stop motion

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**ST**

PARAMETERS

Description	**xx** [int]	-	axis number
Range	**xx**	-	**1** to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx**	out of range:	error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION This command stops a motion in progress using deceleration rate programmed with **AG** (set deceleration) command on the specified axes. If the ST command is sent with no axis parameter, all axes are stopped.

RETURNS none

REL. COMMANDS

AB	-	abort motion
AG	-	set deceleration
MF	-	motor power off

EXAMPLE

2PA40	| *move axis # 2 to absolute position 40*
2ST	| *stop motion on axis # 2*

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SU set encoder resolution

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**SU**nn or xx**SU**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	encoder resolution
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**2e-9** to **2e+9** in user defined units or **?** to read present setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the encoder resolution for axis **xx**.
Note:
The encoder resolution can only be changed when encoder feedback is enabled. See ZB command.

RETURNS If "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

FR	-	set full-step resolution
SU	-	set encoder resolution
QD	-	update driver
ZB	-	set feedback configuration

EXAMPLE

2SU?	| *read encoder resolution setting of axis # 2*
0.0001	| *controller returns a value of 0.0001 units for axis #2*
2SU0.0005	| *set encoder resolution to 0.0005 units for axis #2*
2QD	| *update programmable driver with latest settings for axis #2*
SM	| *save all controller settings to non-volatile memory*

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TB read error message

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **TB**?

PARAMETERS questions mark (?)

Defaults

DESCRIPTION This command is used to read the error code, timestamp, and the associated message.
The error code is one numerical value up to three(3) digits long. (see Appendix for complete listing)
In general, non-axis specific errors numbers range from 1-99. Axis-**1** specific errors range from **1**00-**1**99, Axis-**2** errors range from **2**00-**2**99 and so on.

The timestamp is in terms of servo cycle (400 µs) ticks accumulated since the last System Reset, incrementing at the servo interrupt interval (400us default). The message is a description of the error associated with it. All arguments are separated by commas.

Note:
Errors are maintained in a FIFO buffer ten(10) elements deep. When an error is read using TB or TE, the controller returns the last error that occurred and the error buffer is cleared by one(1) element. This means that an error can be read only once, with either command.

RETURNS **aa, bb, cc**
where: **aa** = error code **cc** = error message
bb = timestamp (see Appendix for complete listing)

REL. COMMANDS **TE** - read error code

EXAMPLE

```
TB?              | read error message
                 0, 451322, NO ERROR DETECTED
                 | controller returns no error
8PA12.3          | move axis #8 to position 12.3
TB?              | read error message
                 9, 451339, AXIS NUMBER NOT AVAILABLE
                 | controller returns error code, timestamp, and description
```


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TE read error code

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **TE?**

PARAMETERS questions mark (?)

Defaults timeout: error 2, RS-232 COMMUNICATION TIME-OUT

DESCRIPTION This command is used to read the error code.

The error code is one numerical value up to three digits long. (see Appendix for complete listing)
In general, non-axis specific errors numbers range from 1-99. Axis-**1** specific errors range from **1**00-**1**99, Axis-**2** errors range from **2**00-**2**99 and so on.

Note:
Errors are maintained in a FIFO buffer ten(10) elements deep. When an error is read using TB or TE, the controller returns the last error that occurred and the error buffer is cleared by one(1) element. This means that an error can be read only once, with either command.

RETURNS **aa**

where: **aa** = error code number (see Appendix for complete listing)

REL. COMMANDS **TB** - read error message

EXAMPLE

TE?	*read error message*
0	*controller returns no error*
8PA12.3	*move axis #8 to position 12.3*
TE?	*read error message*
9	controller returns error code 9 meaning incorrect axis number

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TJ set trajectory mode

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**TJ**nn or xx**TJ**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	trajectory mode
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**1** to **6** where 1 = trapezoidal mode 2 = s-curve mode 3 = jog mode 4 = slave to master's desired position (trajectory) 5 = slave to master's actual position (feedback) 6 = slave to master's actual velocity for jogging
Units	**xx**	-	none
	nn	-	none

Defaults	**xx** missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx2, PARAMETER OUT OF RANGE
	during motion:	error xx26, PARAMETER CHANGE NOT ALLOWED DURING MOTION

DESCRIPTION

This command sets the trajectory mode **nn** on the axis specified by **xx.**

Changing trajectory during motion is not allowed. Change trajectory mode only when the axis is not moving.

If the requested axis is member of a group, the controller returns error xx31, "COMMAND NOT ALLOWED DUE TO GROUP ASSIGNMENT".

For a detailed description of motion profiles see the **Motion Control Tutorial** section.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

JK	-	set s-curve jerk rate
GR	-	set master/slave gear ratio

EXAMPLE

1TJ?	| *report current trajectory mode setting on axis #1*
1	| *controller returns trajectory mode 1 (trapezoidal) for axis #1*
1TJ2	| *set trajectory mode on axis #1 to 2 (s-curve)*

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TP read actual position

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX xx**TP**

PARAMETERS

Description	**xx** [int]	-	axis number
Range	**xx**	-	**1** to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION This command is used to read the actual position. It returns the instantaneous real position of the specified axis.

RETURNS **nn** where: **nn** = actual position, in pre-defined units

REL. COMMANDS

PA	-	move to an absolute position
PR	-	move to a relative position
DP	-	read instantaneous desired position

EXAMPLE

3TP	| *read real position on axis # 3*
5.322	| controller returns real position 5.322 for axis # 3

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TS read controller status

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX TS

PARAMETERS None

DESCRIPTION This command is used to read the controller status byte. The byte returned is in the form of an ASCII character. The value of each bit in the status byte can be deduced after converting the ASCII character into a binary value. Each bit of the status byte represents a particular controller parameter, as described in the following table.
Note:
Please refer to the Appendix for a complete ASCII to binary conversion table.

INTERPRETATION OF LEFT MOST ASCII CHARACTER:

Bit #	Function	Meaning for	
		Bit LOW	Bit HIGH
0	Axis #1 motor state	Stationary	In motion
1	Axis #2 motor state	Stationary	In motion
2	Axis #3 motor state	Stationary	In motion
3	Axis #4 motor state	Stationary	In motion
4	Motor power of at least one axis	OFF	ON
5	Reserved	Default	—
6	Reserved	—	Default
7	Reserved	Default	—

INTERPRETATION OF RIGHT MOST ASCII CHARACTER:

Note: This ASCII character is returned only if the motion controller supports more than four (4) axes.

Bit #	Function	Meaning for	
		Bit LOW	Bit HIGH
0	Axis #5 motor state	Stationary	In motion
1	Axis #6 motor state	Stationary	In motion
2	Reserved	Default	—
3	Reserved	Default	—
4	Motor power of at least one axis	OFF	ON
5	Reserved	Default	—
6	Reserved	—	Default
7	Reserved	Default	—

RETURNS ASCII character representing the status byte.

REL. COMMANDS **TX** - read controller activity

EXAMPLE

```
TS      | read controller status
[P      | controller returns characters [ and P indicating axes 1, 2 and 4 are
        | in motion, and motor power of at least one axis is ON.
```


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TV read actual velocity

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX xx**TV**

PARAMETERS

Description	**xx** [int]	-	axis number
Range	**xx**	-	**1** to **MAX AXES**
Units	**xx**	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE

DESCRIPTION This command is used to read the actual velocity of an axis. The command can be sent at any time but its real use is while motion is in progress.

RETURNS **nn,** where **nn** = actual velocity of the axis in pre-defined units.

REL. COMMANDS

PA	-	move to an absolute position
PR	-	move to a relative position

EXAMPLE

3TP?	*read position on axis # 3*
5.32	*controller returns position 5.32 units for axis # 3*
3PR2.2	*start a relative motion of 2.2 units on axis # 3*
3DV	*read desired velocity on axis #3*
0.2	*controller returns velocity 0.2 units/sec for axis #3*
3TV	*read actual velocity on axis #3*
0.205	*controller returns velocity 0.205 units/sec for axis #3*
3DP?	*read desired position on axis # 3*
7.52	*controller returns desired position 7.52 units for axis # 3*

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TX read controller activity

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **TX**

PARAMETERS None

DESCRIPTION This command is used to read the controller activity register. The byte returned is in the form of an ASCII character. The value of each bit in the status byte can be deduced after converting the ASCII character into a binary value. Each bit of the status byte represents a particular parameter, as described in the following table.

Note:
Please refer to the Appendix for a complete ASCII to binary conversion table.

Bit #	Function	Meaning for	
		Bit LOW	Bit HIGH
0	At least one program is executing	NO	YES
1	Wait command is executing	NO	YES
2	Manual jog mode is active	NO	YES
3	Local mode is inactive	Default	—
4	At least one trajectory is executing	NO	YES
5	Reserved	Default	—
6	Reserved	—	Default
7	Reserved	Default	—

RETURNS ASCII character representing the status byte.

REL. COMMANDS **TS** - read controller status

EXAMPLE
TX | *read controller activity*
P | *controller returns character P indicating at least one trajectory is executing*

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UF update servo filter

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **UF**

PARAMETERS None.

DESCRIPTION This command is used to make active the latest entered PID parameters. Any new value for Kp, Ki, Kd and maximum following error are not being used in the PID loop calculation until UF command is received. This assures that the parameters are loaded simultaneously, without any transitional glitches in the loop.

If the axis specifier **xx** is missing or set to 0 , the controller updates the filters for all axes. If **xx** is a number between 1 and 4, the controller updates only the filter for the specified axis.

RETURNS none

ERRORS none

REL. COMMANDS

FE	-	set maximum following error
KD	-	set derivative gain factor
KI	-	set integral gain factor
KP	-	set proportional gain factor

EXAMPLE

3KP0.05	| *set proportional gain factor of axis # 3 to 0.05*
3KD0.07	| *set derivative gain factor of axis # 3 to 0.07*
3UF	| update servo loop of axis # 3 with the new parameters

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UH wait for DIO bit high

	IMM	PGM	MIP
USAGE		♦	

SYNTAX XxUH

PARAMETERS

Description	**xx** [int]	-	DIO bit number
Range	**xx**	-	**0** to **15**
Units	**xx**	-	none
Defaults	**xx**	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command causes a program to wait until a selected I/O input bit becomes high. It is level, not edge sensitive. This means that at the time of evaluation, if the specified I/O bit **xx** is high already, the program will continue to execute subsequent commands.

Note:
All DIO bits are pulled high on the board. Therefore, a missing signal will cause the wait to complete and subsequent commands will continue to be executed.

RETURNS none

REL. COMMANDS **UL** - Wait for DIO bit low

EXAMPLE

```
1EP      | Enter stored program #1
1MO      | Turn axis #1 motor power ON
1MV+     | Move axis #1 indefinitely in positive direction
13UH     | Wait for DIO bit #13 to go HIGH before executing any
         subsequent commands
1ST      | Stop axis #1
WT500    | Wait for 500 ms
1MV-     | Move axis #1 indefinitely in negative direction
QP       | Quit program mode
```


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UL wait for DIO bit low

	IMM	PGM	MIP
USAGE		♦	

SYNTAX Xx**UL**

PARAMETERS

Description	**xx** [int]	-	DIO bit number
Range	**xx**	-	**0** to **15**
Units	**xx**	-	none
Defaults	**xx**	missing:	error 38, COMMAND PARAMETER MISSING
		out of range:	error 7, PARAMETER OUT OF RANGE

DESCRIPTION This command causes a program to wait until a selected I/O input bit becomes low. It is level, not edge sensitive. This means that at the time of evaluation, if the specified I/O bit **xx** is low already, the program will continue to execute subsequent commands.

RETURNS none

REL. COMMANDS

UL	-	Wait for DIO bit low

EXAMPLE

1EP	| *Enter stored program #1*
1MO	| *Turn axis #1 motor power ON*
1MV+	| *Move axis #1 indefinitely in positive direction*
13UL	| *Wait for DIO bit #13 to go LOW before executing any subsequent commands*
1^{ST}	| *Stop axis #1*
WT500	| *Wait for 500 ms*
1MV-	| *Move axis #1 indefinitely in negative direction*
QP	| *Quit program mode*

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VA set velocity

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**VA**nn or xx**VA**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	velocity value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to maximum value allowed by VU command or **?** to read current setting
Units	**xx**	-	none
	nn	-	preset units / second
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx10, MAXIMUM VELOCITY EXCEEDED

DESCRIPTION

This command is used to set the velocity value for an axis. Its execution is immediate, meaning that the velocity is changed when the command is processed, even while a motion is in progress.

It can be used as an immediate command or inside a program. If the requested axis is member of a group, the commanded velocity becomes effective only after the axis is removed from the group. (Refer the Advanced Capabilities section for detailed description of grouping and related commands).

Avoid changing the velocity during the acceleration or deceleration periods. For better predictable results, change velocity only when the axis is not moving or when it is moving with a constant speed.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

AC	-	set acceleration
VU	-	set maximum velocity
PA	-	execute an absolute motion
PR	-	execute a relative motion

EXAMPLE

2VA?	| *read desired velocity of axis # 2*
10	| *controller returns a velocity value of 10 units/s*
2PA15	| *move to absolute position 15*
WT500	| *wait for 500ms*
2VA4	| *set axis # 2 velocity to 4 units/s*
2VA?	| *read velocity of axis # 2*
4	| *controller returns a velocity value of 4 units/s*

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VB set base velocity for step motors

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**VB**nn or xx**VB**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	base velocity value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to maximum value allowed by VU command or **?** to read current setting
Units	**xx**	-	none
	nn	-	preset units / second
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx10, MAXIMUM VELOCITY EXCEEDED error xx01, Axis-xx PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to set the base velocity, also referred to as start/stop velocity value for a step motor driven axis. Its execution is immediate, meaning that the velocity is changed when the command is processed, even while a motion is in progress. It can be used as an immediate command or inside a program.

Avoid changing the velocity during the acceleration or deceleration periods. For better predictable results, change velocity only when the axis is not moving or when it is moving with a constant speed.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

AC	-	set acceleration
VA	-	set velocity
VU	-	set maximum velocity
PA	-	execute an absolute motion
PR	-	execute a relative motion

EXAMPLE

2VB?	| *read desired base velocity of axis # 2*
5	| *controller returns a velocity value of 5 units/s*
2VB10	| *set axis # 2 base velocity to 10 units/s*
2VB?	| *read base velocity of axis # 2*
10	| *controller returns a velocity value of 10 units/s*

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VE read controller firmware version

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **VE ?**

PARAMETERS none

Defaults timeout: error 2, RS-232 COMMUNICATION TIME-OUT

DESCRIPTION This command is used to read the controller type and version.

Note:
Important information needed when asking for technical support for the motion control system or when reporting a problem is the controller version. Use this command to determine the controller type and in particular, the firmware version.

RETURNS **ESP301 Version xx.yy**
where: **xx.yy** = version and release number

REL. COMMANDS none

EXAMPLE

VE?	*read controller firmware version*
ESP301 Version 3.0.1 6/1/99	*controller returns model ESP301 version 3.0 and release date 6/1/99*

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VF set velocity feed-forward gain

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**VF**nn or xx**VF**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	velocity feed-forward gain factor Vf
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **2e9,** or **?** to read current setting
Units	**xx**	-	none
	nn	-	none

Defaults	**xx** missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx2, PARAMETER OUT OF RANGE

DESCRIPTION This command sets the velocity feed-forward gain factor Vf. It is active for any DC servo based motion device.

.

See the "**Feed-Forward Loops**" in Motion Control Tutorial section to understand the basic principals of feed-forward.

Note:
The command can be sent at any time but it has no effect until the UF (update filter) is received.

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

KI	-	set integral gain factor
KS	-	set saturation gain factor
KD	-	set derivative gain factor
KP	-	set proportional gain factor
AF	-	set acceleration feed-forward gain
UF	-	update filter

EXAMPLE

3AF0.8	*| set acceleration feed-forward gain factor for axis # 3 to 0.8*
3VF?	*| report present axis-3 velocity feedforward setting*
1.4	*| controller returns a value of 1.4*
3VF1.5	*| set acceleration feed-forward gain factor for axis # 3 to 1.5*
3UF	*| update PID filter; only now the **VF** command takes effect*

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VU set maximum velocity

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**VU**nn or xx**VU**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [float]	-	velocity value
Range	**xx**	-	to **MAX AXES**
	nn	-	**0** to **2e+9,** or **?** to read current setting
Units	**xx**	-	none
	nn	-	predefined units / second
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx10, MAXIMUM VELOCITY EXCEEDED
			error xx2, Axis-xx PARAMETER OUT OF RANGE

DESCRIPTION This command is used to set the maximum velocity value for an axis. This command remains effective even if the requested axis is member of a group. In this case an error message, "GROUP MAXIMUM VELOCITY EXCEEDED", is generated if the commanded value is less than group velocity. (Refer to Advanced Capabilities section for a detailed description of grouping and related commands).

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting

REL. COMMANDS

VA	-	set velocity
PA	-	execute an absolute motion
PR	-	execute a relative motion
AG	-	set deceleration
AC	-	set acceleration

EXAMPLE

2VU?	| *read maximum allowed velocity of axis # 2*
10	| *controller returns a value of 10 units/s*
2VU8	| *set axis # 2 maximum maximum to 8 units/s*
2VA6	| *set axis #2 working velocity to 6 units/s*

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WP wait for position

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**WP**nn

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [float]	-	position value
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	starting position to destination of axis number **xx**
Units	**xx**	-	none
	nn	-	predefined units
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command stops program execution until a user specified position is reached. The program continues executing any subsequent commands only after axis **xx** has reached position **nn**.

Note:
Ensure that position **nn** is within the travel range of axis **xx**. The controller cannot always detect if a value is outside the travel range of an axis to flag an error, especially while making coordinated motion of multiple axes.

Wait commands are primarily intended for use in internal program execution or in combination with the RQ command. If used in command mode, it is important to note that input command processing is suspended until the wait condition has been satisfied.

RETURNS None

REL. COMMANDS

WT	-	wait
WS	-	wait for motion stop

EXAMPLE

2PA-10; 2WS	| *move axis # 2 to position –10 units and wait for stop*
2PA10; **2WP0**; 3PA5	| *move axis #2 to position 10 units, wait for axis #2 to reach* position 0 units and then move axis #3 to position 5 units

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WS wait for motion stop

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX xx**WS**nn

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	delay after motion is complete
Range	**xx**	-	**0** to **MAX AXES**
	nn	-	**0** to **60000**
Units	**xx**	-	none
	nn	-	milliseconds

Defaults	**xx** missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command stops the program execution until a motion is completed. The program is continued only after axis **xx** reaches its destination. If **xx** is not specified, the controller waits for all motion in progress to end. If **nn** is specified different than 0, the controller waits an additional **nn** milliseconds after the motion is complete and then executes the next commands.

Note:

Wait commands are primarily intended for use in internal program execution or in combination with the RQ command. If used in command mode, it is important to note that input command processing is suspended until the wait condition has been satisfied.

RETURNS none

REL. COMMANDS

WT	-	wait
WP	-	wait for position

EXAMPLE

2PA10;**2WS500**;3PA5 | *move axis # 2 to position 10 units, wait for axis # 2 to reach destination, wait an additional 500ms and then move* axis # 3 to position 5 units

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WT wait

	IMM	PGM	MIP
USAGE	♦	♦	♦

SYNTAX **WTnn**

PARAMETERS

Description	**nn** [int]	-	wait time (delay)
Range	**nn**	-	**0** to **60000**
Units	**nn**	-	milliseconds
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command causes the controller to pause for a specified amount of time. This means that the controller will wait **nn** milliseconds before executing the next command.

Note:
Even though this command can be executed in immediate mode, its real value is as a flow control instruction inside programs.

Wait commands are primarily intended for use in internal program execution or in combination with the RQ command. If used in command mode, it is important to note that input command processing is suspended until the wait condition has been satisfied.

RETURNS none

REL. COMMANDS

WS - wait for stop
WP - wait for position

EXAMPLE

2MO;**WT400**;2PA2.3 | turn axis motor ON, *wait an additional*
| 400 ms and then move axis 2 to position 2.3 units

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XM read available memory

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX **XM**

PARAMETERS None

DESCRIPTION This command reports the amount of unused program memory. The controller has 61440 bytes of non-volatile memory available for permanently storing programs. This command reports the amount not used.

Note:
Available memory space is updated only after the stored program memory is purged using **XX** command.

RETURNS Available storage space

REL. COMMANDS

EP	-	enter program download mode
EX	-	execute a stored program
LP	-	list stored program
XX	-	delete a stored program

EXAMPLE

XM	| *read available memory*
Available storage space = 61440	| *controller reports available storage space*

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XX erase program

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX xx**XX**

PARAMETERS

Description	**xx** [int]	-	program number
Range	**xx**	-	**1** to **100**
Units	**xx**	-	none
Defaults	**xx** missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error 7, PARAMETER OUT OF RANGE

DESCRIPTION

This command makes the program **xx** loaded in controller's non-volatile memory unavailable to user. It does not delete the program from memory. Consequently, the program space does not become available to user immediately after deleting the program. It becomes available to user only after the entire stored program memory is purged by issuing the command "**0xx**".

Note:
Purging the stored program memory takes approximately 3 seconds for completion.

RETURNS None

REL. COMMANDS

EP	-	enter program download mode
EX	-	execute a stored program
LP	-	list stored program
XM	-	read available memory

EXAMPLE

1XX | *delete program #1*
XM | *read available memory*
Available storage space = 60228| *controller reports available storage space*
2XX | *delete program #2*
XM | *read available memory*
Available storage space = 60228| *controller reports available storage space*
0XX | *purge stored program memory*
XM | *read available memory*
Available storage space = 61440| *controller reports available storage space*

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ZA set amplifier I/O configuration

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**ZA**nn or xx**ZA**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	amplifier I/O configuration
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **0FFFFH** (hexadecimal with leading zero(0)) or **?** to read current setting
Units	**xx**	-	none
	nn	-	none

Defaults	**xx** missing:	error 37, AXIS NUMBER MISSING
	out of range:	error 9, AXIS NUMBER OUT OF RANGE
	nn missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx2, PARAMETER OUT OF RANGE
	critical setting:	error xx17, ESP CRITICAL SETTINGS ARE PROTECTED
	during motion:	error xx26, PARAMETER CHANGE NOT ALLOWED DURING MOTION

DESCRIPTION

This command is used to set the amplifier I/O polarity, fault checking, and event handling for axis specified with **xx**.

NOTE: If bit-0 or both bits-1 and -2 are set to zero(0) then no action will be taken by the controller.

NOTE: The controller always interprets the **nn** value as a hexadecimal number, even when the letter "H" is not appended to the desired value. Since **nn** is a hexadecimal number, it is possible that the most significant character (left most character) is an alphabet (A—F) depending on the choice of values for various bits. In order for the controller to distinguish between an ASCII command and its value, it is recommended that the users always add a leading zero (0) to the nn value. See table below for clarification:

Example:

Command Issued	Controller Interpretation
1ZA123H	nn = 123H = (0001 0010 0011)Binary
1ZA123	nn = 123H = (0001 0010 0011)Binary
1ZA0F25H	nn = F25H = (1111 0010 0101) Binary
1ZAF25H	Invalid command

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BIT #	VALUE	DEFINITION
0	0	disable amplifier fault input checking
*0	1	enable amplifier fault input checking
1	0	do not disable motor on amplifier fault event
*1	1	disable motor on amplifier fault event
*2	0	do not abort motion on amplifier fault event
2	1	abort motion on amplifier fault event
3	0	reserved
3	1	reserved
4	0	reserved
4	1	reserved
5	0	amplifier fault input active low
*5	1	amplifier fault input active high
*6	0	configure step motor control outputs for STEP / DIRECTION
6	1	configure step motor control outputs for +STEP/-STEP
*7	0	configure STEP output as active low
7	1	configure STEP output as active high
8	0	configure DIRECTION output as active low for negative move
*8	1	configure DIRECTION output as active high for negative move
*9	0	do not invert servo DAC output polarity
9	1	invert servo DAC output polarity
*10	0	amplifier enable output active low
10	1	amplifier enable output active high
*11	0	[+]stepper motor winding is FULL
11	1	[+] stepper motor winding is HALF
		• • •
31	0	reserved
31	1	reserved
		* default setting
		Any change in motor winding takes affect only when the controller is reset or power cycled. As a result, amplifier I/O configuration must be saved to memory and controller must be reset for this change to take affect.

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting in hexadecimal notation.

REL. COMMANDS

ZB - set feedback configuration
ZE - set e-stop configuration
ZF - set following error configuration
ZH - set hardware limit configuration
ZS - set software limit configuration
ZZ - set general system configuration

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EXAMPLE

2ZA?	*read amplifier I/O configuration of axis # 2*
123H	*controller returns a value of 123H for axis #2*
	123H = (0001 0010 0011)Binary
	Bits 0, 1, 5, 8 = 1. All other bits = 0
2ZA 125H	*set amplifier I/O configuration to 125H for axis #2*
	125H = (0001 0010 0101)Binary
	Bits 0, 2, 5, 8 = 1. All other bits = 0
SM	*save all controller settings to non-volatile memory*

Please refer the table above to interpret the affect of these bit values.

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ZB set feedback configuration

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**ZB**nn or xx**ZB**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [int]	-	feedback configuration
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **0FFFFH** (hexadecimal with leading zero(0)) or **?** to read current setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE
	critical setting:		error xx17, ESP CRITICAL SETTINGS ARE PROTECTED
	during motion:		error xx26, PARAMETER CHANGE NOT ALLOWED DURING MOTION

DESCRIPTION

This command is used to set the feedback configuration , fault checking, and event handling, as well as stepper closed-loop positioning for axis specified with **xx**.

NOTE: If bit-0 or both bits-1 and -2 are set to zero(0) then no action will be taken by the controller.

NOTE: The controller always interprets the **nn** value as a hexadecimal number, even when the letter "H" is not appended to the desired value. Since **nn** is a hexadecimal number, it is possible that the most significant character (left most character) is an alphabet (A—F) depending on the choice of values for various bits. In order for the controller to distinguish between an ASCII command and its value, it is recommended that the users always add a leading zero (0) to the nn value. See table below for clarification:

Example:

Command Issued	Controller Interpretation
1ZB123H	nn = 123H = (0001 0010 0011)Binary
1ZB123	nn = 123H = (0001 0010 0011)Binary
1ZB0F25H	nn = F25H = (1111 0010 0101) Binary
1ZBF25H	Invalid command

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BIT#	VALUE	DEFINITION
*0	0	disable feedback error checking
0	1	enable feedback error checking
*1	0	do not disable motor on feedback error event
1	1	disable motor on feedback error event
*2	0	do not abort motion on feedback error event
2	1	abort motion on feedback error event
*3	0	Reserved
3	1	Reserved
*4	0	Reserved
4	1	Reserved
*5	0	do not invert encoder feedback polarity
5	1	invert encoder feedback polarity
*6	0	reserved
6	1	reserved
*7	0	reserved
7	1	reserved
8	0	do not use encoder feedback for positioning
*8	1	use encoder feedback for stepper positioning
9	0	disable stepper closed-loop positioning
*9	1	enable stepper closed-loop positioning
10	0	reserved
10	1	reserved
		• • •
31	0	reserved
31	1	reserved
		* default setting

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting in hexadecimal notation.

REL. COMMANDS

ZA - set amplifier I/O configuration
ZE - set e-stop configuration
ZF - set following error configuration
ZH - set hardware limit configuration
ZS - set software limit configuration
ZZ - set general system configuration

EXAMPLE

2ZB? | *read amplifier I/O configuration of axis # 2*
100H | *controller returns a value of 100H for axis #2*
2ZB 105H | *set amplifier I/O configuration to 105H for axis #2*
SM | *save all controller settings to non-volatile memory*

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ZE set e-stop configuration

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**ZE**nn or xx**ZE**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	e-stop configuration
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **07H** (hexadecimal with leading zero(0)) or **?** to read current setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx17, ESP CRITICAL SETTINGS ARE PROTECTED

DESCRIPTION

This command is used to set the emergency stop (e-stop) configuration , fault checking, and event handling for axis specified with **xx**.

The following table shows the meaning of each bit of nn value :

BIT#	VALUE	DEFINITION
0	0	disable E-stop checking
*0	1	enable E-stop checking
*1	0	do not disable motor power on E-stop event
1	1	disable motor power on E-stop event
2	0	do not abort motion on E-stop event
*2	1	abort motion on E-stop event
3 to 31	x	reserved
		* default setting

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Below are ESP301 controller different behaviors depending on the ZE configuration (*set by xxZEnn command*) :

ZE configuration (binary notation)	Interlock cap removed		
	Axis in moving state	**Axis in stop state Motor is ON**	**Axis in stop state Motor is OFF**
……xx0	Continue moving. Motor stays ON after move.	Motor stays ON. Every motion will be executed.	Motor stays OFF. No further motion will be executed
……001 (01H)	Continue moving. Motor stays ON after move.	Motor stays ON. No further motion will be executed.	Motor stays OFF No further motion will be executed
……011 (03H) or ……111 (07H)	Motor OFF Axis is stopped.	Motor OFF No further motion will be executed	Motor stays OFF No further motion will be executed
……101 (05H)	Brake to stop. Motor stays ON after braking.	Motor stays ON No further motion will be executed	Motor stays OFF No further motion will be executed

NOTE: The controller always interprets the **nn** value as a hexadecimal number, even when the letter "H" is not appended to the desired value. Since **nn** is a hexadecimal number, it is possible that the most significant character (left most character) is an alphabet (A—F) depending on the choice of values for various bits. In order for the controller to distinguish between an ASCII command and its value, it is recommended that the users always add a leading zero (0) to the nn value. For example : 1ZE03H (OK), 1ZEA1H (NOK).

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting in hexadecimal notation.

REL. COMMANDS

ZA - set amplifier I/O configuration
ZB - set feedback configuration
ZF - set following error configuration
ZH - set hardware limit configuration
ZS - set software limit configuration
ZZ - set general system configuration

EXAMPLE

2ZE? | *read e-stop configuration of axis # 2*
3H | *controller returns a value of 3H for axis #2*
2ZE05H | *set e-stop configuration to 5H for axis #2*
SM | *save all controller settings to non-volatile memory*

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ZF set following error configuration

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**ZF**nn or xx**ZF**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	following error configuration
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **0FFFFH** (hexadecimal with leading zero(0)) or **?** to read current setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE
	critical setting:		error xx17, ESP CRITICAL SETTINGS ARE PROTECTED

DESCRIPTION

This command is used to set the following error configuration , fault checking, and event handling for axis specified with **xx**.

NOTE: If bit-0 or both bits-1 and -2 are set to zero(0) then no action will be taken by the controller.

NOTE: The controller always interprets the **nn** value as a hexadecimal number, even when the letter "H" is not appended to the desired value. Since **nn** is a hexadecimal number, it is possible that the most significant character (left most character) is an alphabet (A—F) depending on the choice of values for various bits. In order for the controller to distinguish between an ASCII command and its value, it is recommended that the users always add a leading zero (0) to the nn value. See table below for clarification:

Example:

Command Issued	Controller Interpretation
1ZF123H	nn = 123H = (0001 0010 0011)Binary
1ZF123	nn = 123H = (0001 0010 0011)Binary
1ZF0F25H	nn = F25H = (1111 0010 0101) Binary
1ZFF25H	Invalid command

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BIT#	VALUE	DEFINITION
0	0	disable motor following error checking
*0	1	enable motor following error checking
1	0	do not disable motor power on following error event
*1	1	disable motor power on following error event
*2	0	do not abort motion on following error event
2	1	abort motion on following error event
3	0	reserved
3	1	reserved
4	0	reserved
4	1	reserved
5	0	reserved
5	1	reserved
6	0	reserved
6	1	reserved
7	0	reserved
7	1	reserved
		• • •
31	0	reserved
31	1	reserved
		* default setting

RETURNS If the "?" sign takes the place of **nn** value, this command reports the current setting in hexadecimal notation.

REL. COMMANDS

ZA - set amplifier I/O configuration
ZB - set feedback configuration
ZE - set e-stop configuration
ZH - set hardware limit configuration
ZS - set software limit configuration
ZZ - set general system configuration
FE - set following error threshold

EXAMPLE

2ZF? | *read following error configuration of axis # 2*
3H | *controller returns a value of 3H for axis #2*
2ZF 5H | *set following error configuration to 5H for axis #2*
SM | *save all controller settings to non-volatile memory*

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ZH set hardware limit configuration

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**ZH**nn or xx**ZH**?

PARAMETERS

Description			
	xx [int]	-	axis number
	nn [int]	-	hardware limit configuration
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **0FFFFH** (hexadecimal with leading zero(0)) or **?** to read current setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE
	critical setting:		error xx17, ESP CRITICAL SETTINGS ARE PROTECTED

DESCRIPTION

This command is used to set the hardware limit checking, polarity, and event handling for axis specified with **xx**.

NOTE: If bit-0 or both bits-1 and -2 are set to zero(0) then no action will be taken by the controller.

NOTE: The controller always interprets the **nn** value as a hexadecimal number, even when the letter "H" is not appended to the desired value. Since **nn** is a hexadecimal number, it is possible that the most significant character (left most character) is an alphabet (A—F) depending on the choice of values for various bits. In order for the controller to distinguish between an ASCII command and its value, it is recommended that the users always add a leading zero (0) to the nn value. See table below for clarification:

Example:

Command Issued	Controller Interpretation
1ZH123H	nn = 123H = (0001 0010 0011)Binary
1ZH123	nn = 123H = (0001 0010 0011)Binary
1ZH0F25H	nn = F25H = (1111 0010 0101) Binary
1ZHF25H	Invalid command

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BIT #	VALUE	DEFINITION
0	0	disable hardware travel limit error checking
*0	1	enable hardware travel limit error checking
*1	0	do not disable motor on hardware travel limit event
1	1	disable motor on hardware travel limit event
2	0	do not abort motion on hardware travel limit event
*2	1	abort motion on hardware travel limit event
3	0	reserved
3	1	reserved
4	0	reserved
4	1	reserved
5	0	hardware travel limit input active low
*5	1	hardware travel limit input active high
6	0	reserved
6	1	reserved
7	0	reserved
7	1	reserved
		• • •
31	0	reserved
31	1	reserved
		* default setting

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting in hexadecimal notation.

REL. COMMANDS

ZA - set amplifier I/O configuration
ZE - set e-stop configuration
ZF - set following error configuration
ZB - set feedback configuration
ZS - set software limit configuration
ZZ - set general system configuration

EXAMPLE

2ZH? | *read hardware limit configuration of axis # 2*
25H | *controller returns a value of 25H for axis #2*
2ZH 23H | *set hardware limit configuration to 23H for axis #2*
SM | *save all controller settings to non-volatile memory*

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ZS set software limit configuration

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX xx**ZS**nn or xx**ZS**?

PARAMETERS

Description	**xx** [int]	-	axis number
	nn [int]	-	hardware limit configuration
Range	**xx**	-	**1** to **MAX AXES**
	nn	-	**0** to **0FFFFH** (hexadecimal with leading zero(0)) or **?** to read current setting
Units	**xx**	-	none
	nn	-	none
Defaults	**xx** missing:		error 37, AXIS NUMBER MISSING
	out of range:		error 9, AXIS NUMBER OUT OF RANGE
	nn missing:		error 38, COMMAND PARAMETER MISSING
	out of range:		error xx2, PARAMETER OUT OF RANGE
	critical setting:		error xx17, ESP CRITICAL SETTINGS ARE PROTECTED

DESCRIPTION

This command is used to set the software limit checking and event handling for axis specified with **xx**.

NOTE: If bit-0 or both bits-1 and -2 are set to zero(0) then no action will be taken by the controller.

NOTE: The controller always interprets the **nn** value as a hexadecimal number, even when the letter "H" is not appended to the desired value. Since **nn** is a hexadecimal number, it is possible that the most significant character (left most character) is an alphabet (A—F) depending on the choice of values for various bits. In order for the controller to distinguish between an ASCII command and its value, it is recommended that the users always add a leading zero (0) to the nn value. See table below for clarification:

Example:

Command Issued	Controller Interpretation
1ZS123H	nn = 123H = (0001 0010 0011)Binary
1ZS123	nn = 123H = (0001 0010 0011)Binary
1ZS0F25H	nn = F25H = (1111 0010 0101) Binary
1ZSF25H	Invalid command

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BIT #	VALUE	DEFINITION
0	0	disable software travel limit error checking
*0	1	enable software travel limit error checking
*1	0	do not disable motor on software travel limit event
1	1	disable motor on software travel limit event
2	0	do not abort motion on software travel limit event
*2	1	abort motion on software travel limit event
3	0	reserved
3	1	reserved
4	0	reserved
4	1	reserved
5	0	reserved
5	1	reserved
6	0	reserved
6	1	reserved
7	0	reserved
7	1	reserved
		• • •
31	0	reserved
31	1	reserved
		* default setting

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting in hexadecimal notation.

REL. COMMANDS

ZA - set amplifier I/O configuration
ZE - set e-stop configuration
ZF - set following error configuration
ZB - set feedback configuration
ZH - set hardware limit configuration
ZZ - set general system configuration
SL - set left limit
SR - set right limit

EXAMPLE

2ZS? | *read software limit configuration of axis # 2*
4H | *controller returns a value of 4H for axis #2*
2ZS 5H | *set software limit configuration to 5H for axis #2*
SM | *save all controller settings to non-volatile memory*

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ZU get ESP system configuration

	IMM	PGM	MIP
USAGE	♦		♦

SYNTAX ZU

PARAMETERS None

DESCRIPTION This command is used to get the present ESP system stage/driver configuration. After each system reset or initialization the ESP motion controller detects the presence of Universal drivers and ESP-compatible stages connected.

BIT #	VALUE	DEFINITION
0	0	axis-1 universal driver not detected
0	1	axis-1 universal driver detected
1	0	axis-2 universal driver not detected
1	1	axis-2 universal driver detected
2	0	axis-3 universal driver not detected
2	1	axis-3 universal driver detected
3	0	axis-4 universal driver not detected
3	1	axis-4 universal driver detected
4	0	axis-5 universal driver not detected
4	1	axis-5 universal driver detected
5	0	axis-6 universal driver not detected
5	1	axis-6 universal driver detected
6	0	reserved
6	1	reserved
7	0	reserved
7	1	reserved
8	0	axis-1 ESP-compatible motorized positioner not detected
8	1	axis-1 ESP-compatible motorized positioner detected
9	0	axis-2 ESP-compatible motorized positioner not detected
9	1	axis-2 ESP-compatible motorized positioner detected
10	0	axis-3 ESP-compatible motorized positioner not detected
10	1	axis-3 ESP-compatible motorized positioner detected
11	0	axis-4 ESP-compatible motorized positioner not detected
11	1	axis-4 ESP-compatible motorized positioner detected
12	0	axis-5 ESP-compatible motorized positioner not detected
12	1	axis-5 ESP-compatible motorized positioner detected
13	0	axis-6 ESP-compatible motorized positioner not detected
13	1	axis-6 ESP-compatible motorized positioner detected
14	0	reserved
14	1	reserved
15	0	reserved
15	1	reserved
		• • •
31	0	reserved
31	1	reserved

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RETURNS This command reports the current setting in hexadecimal notation.

REL. COMMANDS

ZA	-	set amplifier I/O configuration
ZB	-	set feedback configuration
ZE	-	set e-stop configuration
ZF	-	set following error configuration
ZH	-	set hardware limit configuration
ZS	-	set software limit configuration
ZZ	-	set system configuration

EXAMPLE

ZU	| *read ESP system configuration*
150015H	| *controller returns a value of 150015H*

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ZZ set system configuration

	IMM	PGM	MIP
USAGE	♦	♦	

SYNTAX **ZZ**nn or **ZZ**?

PARAMETERS

Description	**nn** [int] -	system configuration
Range	**nn** -	**0** to **0FFFFH** (hexadecimal with leading zero(0)) or **?** to read current setting
Units	**nn** -	none
Defaults	**nn** missing:	error 38, COMMAND PARAMETER MISSING
	out of range:	error xx2, PARAMETER OUT OF RANGE

DESCRIPTION

This command is used to configure system fault checking, event handling and general setup for all axes.

NOTE: If bit-0 or both bits-1 and -2 are set to zero(0) then no action will be taken by the controller.

NOTE: The controller always interprets the **nn** value as a hexadecimal number, even when the letter "H" is not appended to the desired value. Since **nn** is a hexadecimal number, it is possible that the most significant character (left most character) is an alphabet (A—F) depending on the choice of values for various bits. In order for the controller to distinguish between an ASCII command and its value, it is recommended that the users always add a leading zero (0) to the nn value. See table below for clarification:

Example:

Command Issued	Controller Interpretation
1ZZ123H	nn = 123H = (0001 0010 0011)Binary
1ZZ123	nn = 123H = (0001 0010 0011)Binary
1ZZ0F25H	nn = F25H = (1111 0010 0101) Binary
1ZZF25H	Invalid command

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BIT#	VALUE	DEFINITION
0	0	disable 100-pin interlock error checking
*0	1	enable 100-pin interlock error checking
1	0	do not disable all axes on 100-pin interlock error event
*1	1	disable all axes on 100-pin interlock error event
2	0	reserved
2	1	reserved
3	0	reserved
3	1	reserved
4	0	configure interlock fault as active low
*4	1	configure interlock fault as active high
5	0	reserved
5	1	reserved
6	0	reserved
6	1	reserved
*7	0	route auxiliary I/O encoder signals to counter channels **MAX AXES** + 1 and **MAX AXES** + 2
7	1	route axis 1 and 2 encoder feedback to counter channels **MAX AXES** + 1 and **MAX AXES** + 2
8	0	unprotect ESP system-critical settings
*8	1	protect ESP system-critical settings
*9	0	Enable queue purge on time expiration
9	1	Disable queue purge on time expiration
*1 0	0	Do not display units along with certain responses
10	1	Display units along with certain responses
*1 1	0	Enable timeout during homing
11	1	Disable timeout during homing
		• • •
31	0	reserved
31	1	reserved
		* default setting

RETURNS

If the "?" sign takes the place of **nn** value, this command reports the current setting in hexadecimal notation.

REL. COMMANDS

ZA	-	set amplifier I/O configuration
ZB	-	set feedback configuration
ZE	-	set e-stop configuration
ZF	-	set following error configuration
ZH	-	set hardware limit configuration
ZS	-	set software limit configuration
ZU	-	get ESP system configuration

EXAMPLE

ZZ?	| *read system configuration*
113H	| *controller returns a value of 113H*
ZZ 13H	| set system configuration to 13H

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Section 4 – Advanced Capabilities

4.1 Grouping

4.1.1 Introduction – Advanced Capabilities

Coordinated motion of multiple axes is required to produce a desired contour in a multi-dimensional space. For instance, if we want to move from one point to another along a line or along a circle, or a combination of both line and circle, we require coordinated motion of multiple axes. One way to facilitate such coordinated motion is ***"grouping"*** the axes involved in producing the desired motion. This is akin to defining the coordinate system in which the desired contour is being made.

Coordinated motion on a 2-D plane, therefore, requires a group comprised of any two axes, while a similar motion in a 3-D space requires a group consisting of any three axes. For sake of simplicity, all further discussion of coordinated motion will be restricted to a 2-D plane.

The procedure for defining a group and all the group parameters required for making coordinated motion is described in Section 4.1.3 discusses the commands that actually make the coordinated motion. The procedure for making "long" moves or contours that involve a combination of circular and linear moves is described in Section 4.1.4. Miscellaneous grouping commands are discussed in Section 4.1.5.

4.1.2 Defining a Group and Group Parameters

This subsection discusses the method for defining a group and all the group parameters.

4.1.2.1 Creating a Group

The ASCII command used to create a new group is **HN.** For instance, the command **1HN2, 3** assigns axis numbers 2 and 3 to group number 1. One such group must be defined first before those axes can be moved in a coordinated fashion. A group can comprise of axes anywhere from one to three.

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If a group has only one axis assigned to it, a linear motion of the group is similar to moving that axis from one point to another. Circular motion of a group with only one axis cannot be made.

If a group has more than two axes assigned to it, circular motion of the group is made using the first two axes in the group.

The order in which axes are assigned to a group is very important. This is because it specifies the frame of reference in which coordinated motion of axes takes place. For instance, the command **1HN2, 3** assigns axis numbers 2 and 3 to group number 1, where axis #2 is equivalent to X-axis and axis #3 is equivalent to Y-axis in a traditional Cartesian coordinate system. Reversing the order of axes (E.G., **1HN3, 2**) reverses the axis assignment.

A few rules that are in place for easy management of group are as follows:

- An axis cannot be a member of different groups at the same time.
- An axis cannot be assigned more than once in a group.
- A group has to be deleted before axes assigned to it can be changed.
- An axis assigned to a group cannot be moved individually using commands such as **PA** and **PR.** Use group linear move commands instead.

Refer to the description of this command in the *commands section* (See Section 3: Remote Mode) for correct syntax, parameter ranges, etc.

4.1.2.2 Defining Group Parameters

Group parameters such as velocity, acceleration, deceleration, jerk, and e-stop deceleration must be defined for every group following the creation of that group. These parameters are used to produce the desired coordinated motion of the group. They override any original values specified for individual axes. The axes' original values are restored when the group to which they have been assigned is deleted. Refer to the description of **HV, HA, HD, HJ,** and **HE** commands in the *commands section* (See Section 3: Remote Mode) for correct syntax, parameter ranges, etc.

4.1.3 Making Linear and Circular Moves

This subsection discusses the method for making linear and circular moves of groups. While coordinated motion of axes with different motor types and different encoder resolutions is supported, it is assumed that all axes have the same units of measure.

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4.1.3.1 Making a Linear Move

Once a group has been defined and all group parameters have been specified, the ASCII command **HL** is used to move the group from an initial position to a final position along the line. The current position of axes is the initial position of linear move. The desired final position is specified along with this command.

This command makes all axes assigned to the group move with predefined group (tangential) velocity, acceleration and deceleration along a line. A trapezoidal velocity profile is employed when group jerk is set to zero. Otherwise, an S-curve velocity profile is employed.

The linear move is a true linear interpolation, meaning:

$$(y \quad y_0) = m(x \quad x_0)$$

$$m = \frac{(y_f \quad y_0)}{(x_f \quad x_0)}$$

where: X_0 and Y_0 represent initial position of the group.
X_f and Y_f represent desired final position of the group.

4.1.3.2 Making a Circular Move

Once a group has been defined and all group parameters have been specified, the ASCII command **HC** can be used to move the group from an initial position to a final position along a circle. The current position of axes is the initial position of circular move. The final position of move is calculated based on the desired center of circle and sweep angle specified along with this command. All sweep angles are measured in degrees. The sign of angles follow the trigonometric convention: positive angles are measured counterclockwise.

This command makes all axes assigned to the group move with predefined group (tangential) velocity, acceleration and deceleration along a circle. A trapezoid velocity profile is employed to produce the desired motion.

The circular move is a true arc of a circle, meaning:

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$$r = \sqrt{(x_0 \quad x_c)^2 + (y_0 \quad y_c)^2}$$

$$= a\tan 2\ \frac{(y_0 \quad y_c)}{(x_0 \quad x_c)}$$

$${}_0[axis\#2] =$$

$${}_0[axis\#3] = \quad \overline{2}$$

$${}_f[axis\#2] = {}_0 + {}_{cmd}$$

$${}_f[axis\#3] = {}_0 + {}_{cmd}$$

$$x_f = r \quad \cos({}_f[axis\#2]) + x_c$$

$$y_f = r \quad \cos({}_f[axis\#3]) + y_c$$

where: X_0 and Y_0 represent initial position of the group.
X_c and Y_c represent desired center position of the circular move.
X_f and Y_f represent calculated final position of the group.
R is radius of the circle.
θ_0 is the base initial angle of an axis.
θ_0 is the final angle of an axis, which is dependant on the sweep angle, θ_{cmd}

Both **HL** and **HC** can initiate the desired motion if they are received while the group is holding position. On the other hand, if they are received while a group move is in progress, the new commands get queued into a "via-point" buffer. The queued commands are executed on a FIFO basis when the move already in progress has reached its destination. The group does not come to a stop at the end of last move. Instead, there will be s smooth transition to the new move command, just as if it were one compound move (combination of multiple moves). The next section details the procedure for making contours or "long" moves using "via-point" buffers.

Refer to the description of **HL** and **HC** commands in the *commands section* (See Section 3: Remote Mode) for correct syntax, parameter ranges, etc.

4.1.4 Making Contours

This subsection discusses the method for making contours. Contouring is the process of making complex trajectories or "long" moves that may involve linear and circular move segments.

These move segments can be sequenced in any order. Arcs can be followed by arcs or lines, and lines by arcs or other lines as shown in the following figures. Since there is no pre-processing of move

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segments involved in making a contour, the user must ensure that there is no change in tangential velocity at the transition from one move to another. If this constraint is not satisfied, the transition from one move segment to another may cause excessive accelerations and shocks that could damage the stages.

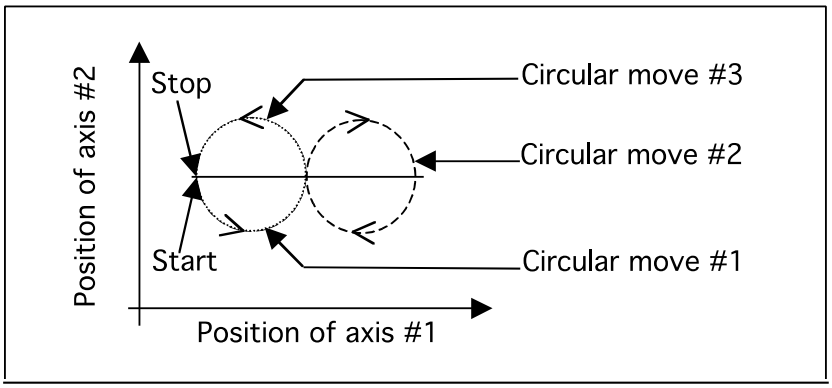


Figure 4.1: A contour with multiple circular moves

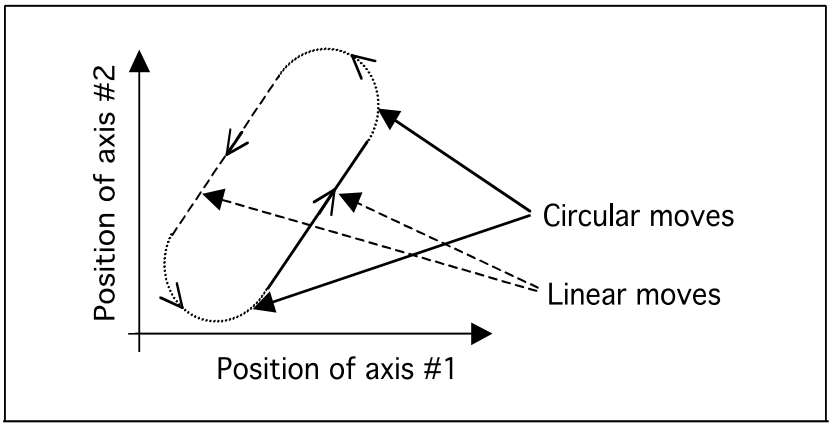


Figure 4.2: A contour with multiple linear and circular moves

In order to store the multiple move segment commands needed to make a contour, we make use of a "via point" buffer. This "via point" buffer contains group move commands essential to make a new move segment upon completion of the move segment currently in progress. The new move commands are pulled out of the buffer on a FIFO basis. The "via point" buffer can hold a maximum of 10 group move commands. If more than 10 group move commands are issued by a user, the excess commands are flow-controlled by the firmware.

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This mechanism will block the portal through which the commands were issued until all the commands issued have been executed.

It is, therefore, recommended that the user take advantage of ASCII command, **HQ** which tells the number of commands that can be put in the "via point" buffer at any given time. This allows a user to control the flow of commands manually, while ensuring the availability of that portal for other commands such as **HP, TP,** etc.

The trajectory generator checks if the "via point" buffer has a new target position (i.e., any new move segments pending?) while the current move is in progress. If "via point" buffer is empty, the group comes to a stop upon completion of current move segment. Otherwise, it begins a new move segment without stopping after completing the current move. The group transitions from current move segment to a new move segment smoothly if the tangential velocity at the transition is ensured to be constant.

The ASCII command **HQ** is used to query the available "via point" buffer space. The commands **HL** and **HC** are used to queue linear move or circular move commands into the "via point" buffer. Refer to the description of these commands in the *commands section* (See Section 3: Remote Mode) for correct syntax, parameter ranges, etc.

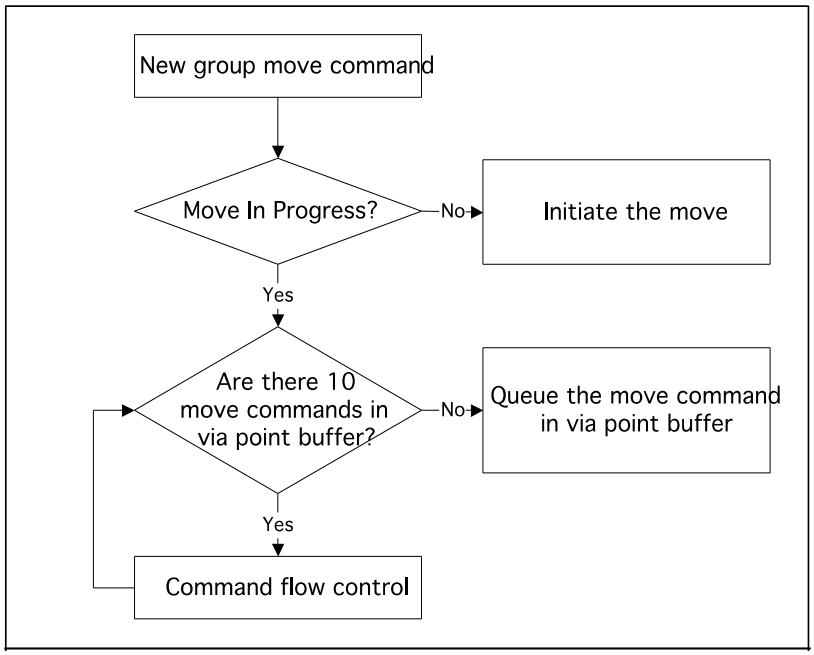


Figure 4.3: Block Diagram of Via Point Data Handling by Command Processor

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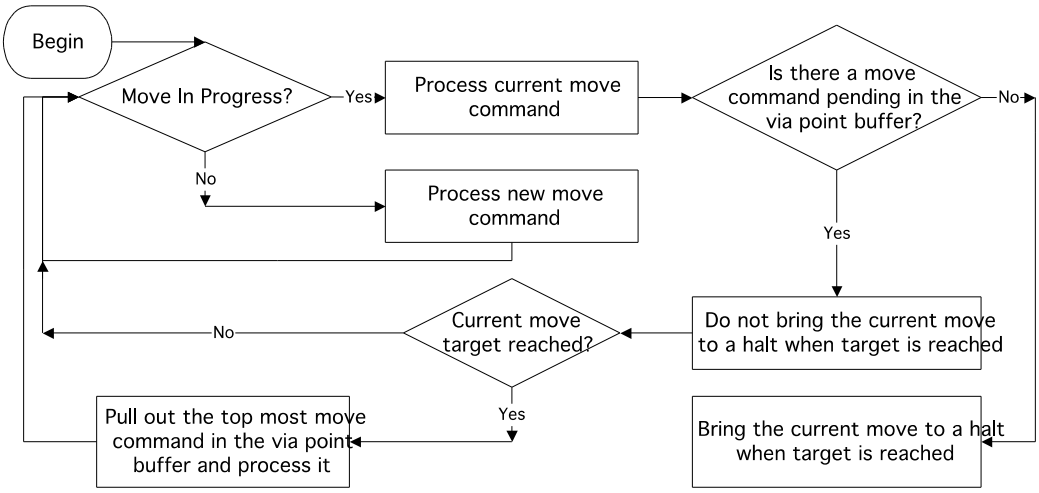


Figure 4.4: Block Diagram of Via Point Data Handling by Trajectory Generator

4.1.5 Miscellaneous Commands

The following commands are available to operate on a group of axes simultaneously:

- **HO** and **HF:** These commands are used to turn ON and turn OFF the power to all axes in a group respectively. The axes assigned to a group can be powered ON or OFF individually using **MO** and **MF** commands also. A group is considered to be ON if all axes assigned to that group are ON.
- **HP:** This command is used to read the actual position of all axes in a group.
- **HS:** This command is used to stop the group motion.
- **HW:** This command is used to wait for the group motion to stop and a user settable delay period thereafter.
- **HX:** This command is used to delete a group.
- **HZ:** This command is used to read the size or the number of axes assigned to group.

4.2 Slaving a Stage to Joystick or a Different Stage

4.2.1 Introduction – Slaving a Stage

ESP301 motion controller allow three different methods in which a slave axis can respond to a master axis. They are:

1. Slave to master's desired position (trajectory).
2. Slave to master's actual position (feedback).
3. Slave to master's actual velocity for jogging.

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The first two methods may be used when absolute or relative move commands can be issued to the master. This is the situation when both master and slave axes are driven by valid motor types. The third method may be used when move commands cannot be issued to the master. This is the situation when the slave axis is driven by a valid motor type, but the master, such as a joystick, is not.

In any case, a series of preliminary commands have to be issued before the desired master-slave response is obtained. These include defining master-slave relationship, appropriate constants and trajectory mode.

The next section outlines the steps to be taken for a slave axis to follow master's position. The subsequent section outlines the steps to be taken for a slave axis to follow master's velocity. The final section outlines the steps to be taken to jog an axis based on inputs from a digital joystick.

4.2.2 Slave to a Different Stage

The following steps may be taken for a slave axis to follow master's position. This mode may be chosen exclusively when absolute or relative move commands can be issued to the master.

Steps	Move Command	Action by Move Command
1. Define master-slave relationship	**2SS1**	Axis #2 is the slave of axis #1
2. Defines master-slave reduction ratio	**2GR0.5**	Master's position is scaled by 0.5 to obtain slave's position
3. Define slave axis trajectory mode	**2TJ4 (or 5)**	Set slave axis trajectory mode
4. Define master axis trajectory mode	**1TJ1 (or 2)**	Set master axis trajectory mode
5. Issue move commands to master axis	**1PA10** **1PR10**	Move master to absolute 10 units. Move master by relative 10 units.

Table 4.1: Slave to a Different Stage Steps

4.2.3 Slave to a Joystick

If the slave axis is required to jog based on a DIO bit status (such as through joystick), follow these steps:

Steps	Move Command	Action by Move Command
1. Assign DIO bits for jogging slave axis	**2BP0, 1**	Jog axis #2 in negative direction if DIO bit #0 is low. Jog axis #2 in positive direction if DIO bit #1 is low.
2. Enable DIO bits for jog mode	**2BQ1**	
3. Define slave axis jog velocity update interval	**2SI100**	Update slave axis jog velocity every 100 milliseconds
4. Define slave axis scaling	**2SK0.5, 0**	Specify scaling coefficients

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coefficients		
5. Define slave axis trajectory mode	**2TJ6**	Set slave axis trajectory mode
6. Change DIO bit value physically		

Table 4.2: Slave to a Joystick Steps

Refer to the description of the ASCII commands in Section 3: Remote Mode, for additional description, correct syntax, parameter ranges, etc.

4.3 Closed Loop Stepper Motor Positioning

4.3.1 Introduction – Closed Loop Stepper

Most of the electro-mechanical systems are subjected to phenomena such as backlash and friction.

Due to such physical attributes, a significant position error can be generated when systems are moved from one position to another by stepper motors without any closed loop control mechanism. This error can be further accentuated by micro-stepping and non-collection of encoders (necessary to have closed loop control) and motors. The ESP301 motion controller supports closed loop positioning of stepper motors to eliminate such errors.

The next subsection details the implementation of this feature in the ESP301.

4.3.2 Feature Implementation

While closed loop control of stepper motors can be done during tracking as well as regulation, ESP301 controllers' closed loop stepping feature is effective only during regulation, i.e., desired motion is completed and the motor is holding position. This was done in order to avoid tuning of control gains such as proportional (Kp), integral (Ki), derivative (Kd) gains, etc. Users need to only enable the feature and define two (2) parameters – desired deadband and closed loop update interval.

The following block diagram illustrates this feature. When the desired motion is completed, the controller calculates position error and evaluates if the error is within the user-specified deadband. If it is, no further corrective actions are commanded. On the other hand, if the error is larger than the desired value, the controller starts the closed loop update interval timer and issues commands to make necessary corrections.

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It then waits for the timer to reset before checking the position error again. This process is repeated until the position error reduces to the desired value (deadband). The corrective actions taken by the controller to reduce positioning error are dependent upon the way in which the stepper motors are controlled: digital (pulse generation) or analog (sinusoidal commutation).

In case of digitally controlled stepper motors, new corrective move commands are internally issued by the controller. In the case of commutated stepper motors, the electrical angle is adjusted.

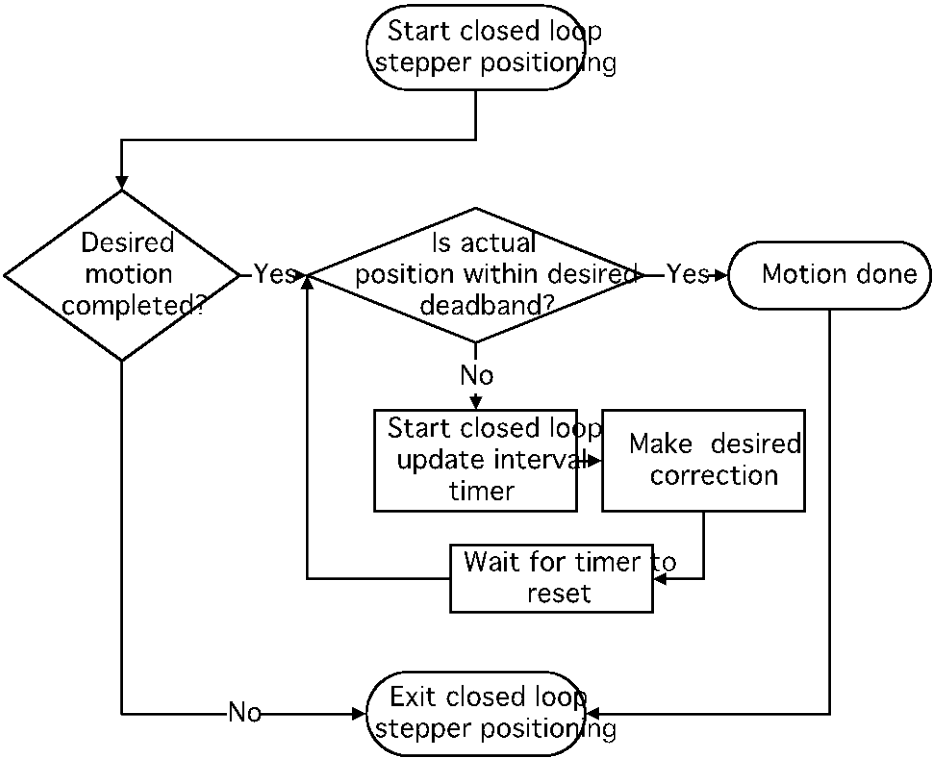


Figure 4.5: Block Diagram of Closed Loop Stepper Motor Positioning

The following steps (See **Table 4.3**) may be followed to setup the closed loop stepper motor positioning.

Steps	ASCII Command	Action by Controller
1. Set feedback configuration.	**1ZB300**	Enable encoder feedback and closed loop positioning of stepper motors for axis #1.
2. Specify deadband value.	**1DB1**	Set deadband value for axis 31 to 1 encoder count.

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3. Specify closed loop update interval.	**1CL50**	Set closed loop update interval for axis #1 to 50 milliseconds.

Table 4.3: An Example of Closed Loop Stepper Motor Positioning Setup

Commands related to closed loop stepper positioning are listed in **Table 4.4** (refer to Section 3: Remote Mode, for additional details):

Command	Description
ZB	Set feedback configuration.
DB	Specify deadband value.
CL	Specify closed loop update interval.

Table 4.4: Closed Loop Stepper Positioning Commands

4.4 Synchronize Motion to External and Internal Events

4.4.1 Introduction – Synchronize Motion

Certain applications require the use of inputs from an external source to command the motion controller to perform certain tasks. These tasks can be to either initiate motion of desired axes (written in a user's stored program) or to inhibit motion of desired axes or, more simply, to just monitor the motion status of these axes. The ESP301 motion controller addresses these issues by taking advantage of the digital I/O interface available on the controller.

The 24 digital I/O bits are divided into three (3) ports: A, B, and C (ESP301 motion controllers has access to only ports A and B). Port A covers DIO bits 0 – 7, port B covers bits 8 – 15 and port C covers bits 16 – 23.

The direction of each port can be setup to be either input or output. If a port is configured to be an input, the DIO bits that belong to that port can only report the state – HIGH or LOW logic level – of the corresponding DIO hardware. On the other hand, if the port is configured to be an output, the DIO bits in that port can be used to either set or clear the state of the corresponding hardware. Each DIO bit has a pull-up resistor to +5V. As a result, all bits will be at HIGH logic if not connected to external circuit and configured as input. Furthermore, the direction of all the ports is set to input by default following a controller reset.

The next section details the way in which these DIO bits can be used to initiate the motion of desired axes through stored programs. The subsequent sections outline the way to inhibit the motion of desired axes and to monitor the motion status of these axes using DIO bits.

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4.4.2 Using DIO to Execute Stored Programs

ESP series of motion controllers can synchronize the initiation of any motion profile to external events. In order to accomplish this task, users must write their desired motion profile as a stored program and assign this stored program to a desired DIO bit.

The direction of the DIO port bit belongs to must then be set to "input" in order for the controller to detect the external event. Once these preliminaries are completed, the controller will execute the user specified stored program whenever it detects a change in the state – HIGH to LOW logic level – of the corresponding DIO hardware. Please review the examples below for further clarifications.

Example 1:

```
EP ABS0MM          | Define stored program called "Abs0mm"
1MO; 2MO           | Turn axes 1,2 ON
1TJ1; 2TJ1         | Set trajectory mode for axes 1,2 to TRAPEZOID
1PA0; 2PA0         | Move axes 1,2 to absolute 0 units
1WS100; 2WS100     | Wait for axes 1,2 motion to complete
QP                 | End of program
0BG ABS0MM         | Assign DIO #0 to run stored program called
                   | "Abs0mm"
BO 04H             | 04H = (0100)Binary
                   | Set DIO ports A, B to input and port C to output
                   | i.e., set bits 0 – 15 to input and 16 – 23 to output
```

After the above commands are sent to the controller, the controller will execute the stored program called "Abs0mm" when DIO bit #0 changes its state from HIGH to LOW logic level.

Example 2:

```
EP CYC2MM          | Define stored program called "Cyc2mm"
1MO; 2MO           | Turn axes 1,2 ON
1TJ1; 2TJ1         | Set trajectory mode for axes 1,2 to TRAPEZOID
1PA0; 2PA0         | Move axes 1,2 to absolute 0 units
1WS100; 2WS100     | Wait for axes 1,2 motion to complete
DL LOOP            | Define a label called "LOOP"
1PR2; 2PR2         | Move axes 1,2 by relative 2 units
1WS100; 2WS100     | Wait for axes 1,2 motion to complete
1PR-2; 2PR-2       | Move axes 1,2 by relative –2 units
1WS100; 2WS100     | Wait for axes 1,2 motion to complete
JL LOOP,10         | Jump to label called "LOOP" 10 times
QP                 | End of program
1BGCYC2MM          | Assign DIO #1 to run stored program called
                   | "Cyc2mm"
BO 04H             | 04H = (0100) Binary
                   | Set DIO ports A, B to input and port C to output
                   | i.e., set bits 0 – 15 to input and 16 – 23 to output
```


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After the above commands are sent to the controller, the controller will execute "Cyc2mm" stored program when DIO bit #1 changes its state from HIGH to LOW logic level.

4.4.3 Using DIO to Inhibit Motion

The ESP301 motion controller can inhibit the motion of any axis in response to external events. In order to accomplish this task, users must define the DIO bit to be employed to inhibit the motion of a desired axis and the logic state in which that bit should be in order to inhibit motion. Once this done, the feature has to be enabled. Furthermore, the direction of the DIO port this DIO bit belongs to must be set to "input" in order for the controller to detect the external event.

At this point, if the selected axis is already in motion, and DIO bit is asserted, E-stop is executed per E-stop configuration (Refer "**ZE**" command for further details). If the axis is not moving, any new move commands are refused as long as the DIO bit is asserted. In either case, "AXIS-XX DIGITAL I/O INTERLOCK DETECTED" error is generated, where XX is the axis whose motion is inhibited through DIO. Please review the example below for further clarifications.

Example 3:

```
2BK1,1      | Use DIO bit #1 to inhibit motion of axis #2. This DIO bit
            | should be HIGH when axis #2 motion is inhibited
2BL1        | Enable inhibition of motion using DIO bits for axis #2
BO 04H      | 04H = (0100)Binary
            | Set DIO ports A,B to input
            | i.e., set bits 0 – 15 to input and 16 – 23 to output
```

After the above commands are sent to the controller, the controller will inhibit the motion of axis #2 when DIO bit is at a HIGH logical level, and generate appropriate error message.

4.4.4 Using DIO to Monitor Motion Status

User's applications can monitor motion status – desired axis is in motion or standstill – through ESP motion controller's DIO. This status bit can in turn be used to drive external processes such as turning on/off a mechanical brake, for instance. In order to accomplish this task, users must define the DIO bit to be employed to monitor the motion status of a desired axis and the logic state in which that bit should be in when the axis is not in motion. Once this is done, the feature has to be enabled. Furthermore, the direction of the DIO port this DIO bit belongs to must be set to "output" in order for the controller to report the motion status.

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At this point, if the selected axis is not in motion, the DIO bit changes its state to the level specified as described earlier. Please review the example below for further clarifications.

Example 3:

```
2BM9,1      | Use DIO bit #9 to indicate motion status of axis #2. This DIO
            | bit will be set to HIGH when axis #2 is not in motion
2BN1        | Enable notification of motion status using DIO for axis #2
BO 06H      | 06H = (0110)Binary
            | Set DIO port A, to input and ports B, C  to output
            | i.e., set bits 0 – 7 to input and 8 – 23 to output
```

After the above commands are sent to the controller, the controller will set DIO bit #9 to a HIGH logical level when axis #2 is not in motion.

Commands related to utilizing DIO for initiating/inhibiting motion of desired axis and notifying motion status of these axes are listed in the table below (refer to Section 3: Remote Mode, for additional details):

Command	Description
BG	Assign DIO bits to execute stored programs
BK	Assign DIO bits to inhibit motion
BL	Enable DIO bits to inhibit motion
BM	Assign DIO bits to notify motion status
BN	Enable DIO bits to notify motion status
BO	Set DIO port A, B direction

Table 4.5: Commands to Synchronize Motion to External Events

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Section 5 – Motion Control Tutorial

5.1 Motion Systems

A schematic of a typical motion control system is shown in **Figure 5.1.**

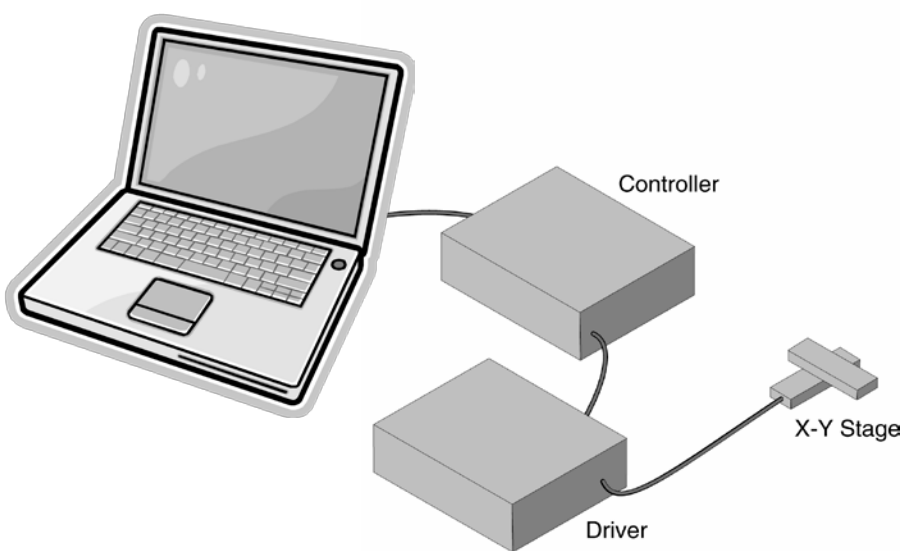


Figure 5.1: Typical Motion Control Systems

Its major components are:

Controller

An electronic device that receives motion commands from an operator directly or via a computer, verifies the real motion device position and generates the necessary control signals.

Driver

An electronic device that converts the control signals to the correct format and power needed to drive the motors.

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Motion Device

An electro-mechanical device that can move a load with the necessary specifications.

Cables

Needed to interconnect the other motion control components.

If the user is like most motion control users, they started by selecting a motion device that matches certain specifications needed for an application. Next, the user should choose a controller that can satisfy the motion characteristics required. The changes are that the user is less interested in how the components look or what their individual specs are, but want to be sure that together they perform reliably according to their needs.

We mentioned this to make a point. A component is only as good as the system lets (or helps) it to be.

For this reason, when discussing a particular system performance specification, we will also mention which components affect performance the most and, if appropriate, which components improve it.

5.2 Specification Definitions

People mean different things when referring to the same parameter name. To establish some common ground for motion control terminology, here are some general guidelines for the interpretation of motion control terms and specifications.

- As mentioned earlier, most motion control performance specifications should be considered system specifications.
- When not otherwise specified, all error-related specifications refer to the position error.
- The servo loop feedback is position-based. All other velocity, acceleration, error, etc. parameters are derived from the position feedback and the internal clock.
- To measure the absolute position, we need a reference, a measuring device, which is significantly more accurate than the device tested. In our case, dealing with fractions of microns (0.1 µm and less), even a standard laser interferometer becomes unsatisfactory.

  For this reason, all factory measurements are made using a number of high precision interferometers, connected to a computerized test station.
- To avoid unnecessary confusion and to easily understand and troubleshoot a problem, special attention must be paid to avoid

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bundling discrete errors in one general term. Depending on the application, some discrete errors are not significant. Grouping them in one general parameter will only complicate the understanding of the system performance in certain applications.

5.2.1 Following Error

The Following Error is not a specifications parameter but, because it is at the heart of the servo algorithm calculations and of other parameter definitions, it deserves our attention.

As will be described later in Section 5.3: Control Loops, a major part of the servo controller's task is to make sure that the actual motion device follows as close as possible an ideal trajectory in time. The user can imagine having an imaginary (ideal) motion device that executes exactly the motion profile they are requesting. In reality, the real motion device will find itself deviating from this ideal trajectory. Since most of the time the real motion device is trailing the ideal one, the instantaneous error is called Following Error.

To summarize, the Following Error is the instantaneous difference between the actual position as reported by the position feedback device and the ideal position, as seen by the controller. A negative following error means that the load is trailing the ideal motion device.

5.2.2 Error

Error has the same definition as the Following Error with the exception that the ideal trajectory is not compared to the position feedback device (encoder) but to an external precision-measuring device.

In other words, the Following Error is the instantaneous error perceived by the controller while the Error is the one perceived by the user.

5.2.3 Accuracy

The accuracy of a system is probably the most common parameter users want to know. Unfortunately, due to its perceived simplicity, it is also the easiest to misinterpret.

The Accuracy is a static measure of a point-to-point positioning error. Starting from a reference point, the user should command the controller to move a certain distance. When the motion is completed, the user should measure the actual distance traveled with an external precision-measuring device. The difference (the Error) represents the positioning Accuracy for that particular motion.

Because every application is different, the user needs to know the errors for all possible motions. Since this is practically impossible, an acceptable compromise is to perform the following test.

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Starting from one end of travel, the user can make small incremental moves and at every stop, the user should record the position Error. The user performs this operation for the entire nominal travel range. When finished, the Error data is plotted on a graph similar to **Figure 5.2.**

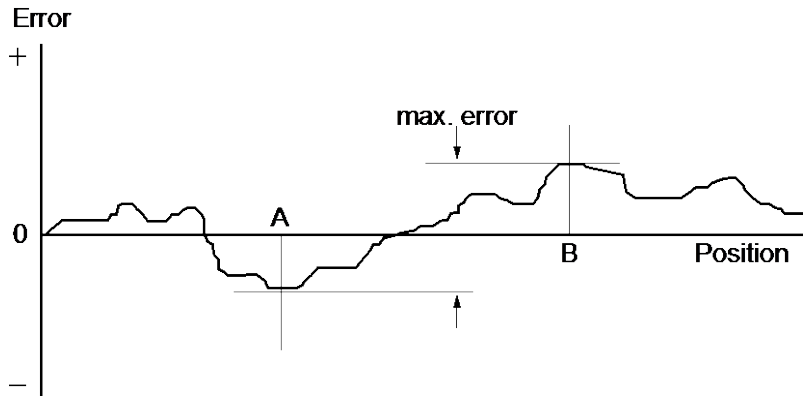


Figure 5.2: Position Error Test

The difference between the highest and the lowest points on the graph is the maximum possible Error that the motion device can have. This worst-case number is reported as the positioning Accuracy. It guaranties the user that for any application, the positioning error will not be greater than this value.

5.2.4 Local Accuracy

For some applications, it is important to know not just the positioning Accuracy over the entire travel but also over a small distance. To illustrate this case, **Figure 5.3a** and **Figure 5.3b** shows two extreme cases.

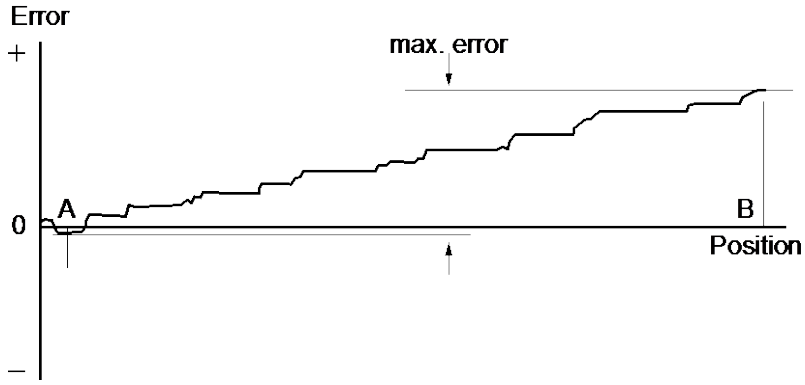


Figure 5.3a: High Accuracy for Small Motions

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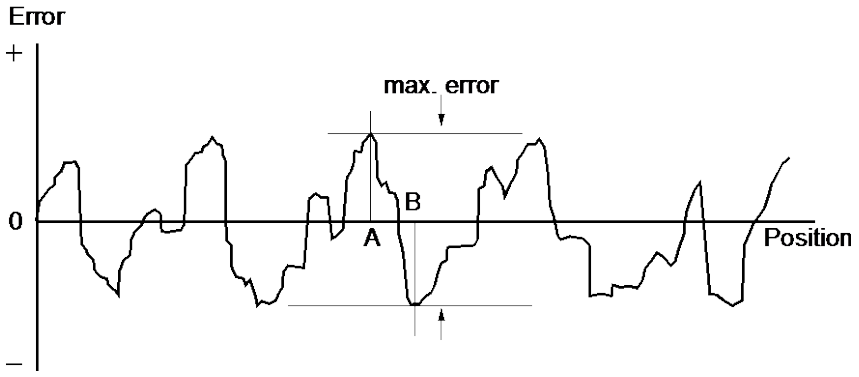


Figure 5.3b: Low Accuracy for Small Motions

Both error plots from **Figure 5.3a** and **Figure 5.3b** have a similar maximum Error. But, if the user compares the maximum Error for small distances, the system in **Figure 5.3b** shows significantly larger values.

For applications requiring high accuracy for small motions, the system in **Figure 5.3a** is definitely preferred.

"Local Error" is a relative term that depends on the application; usually no Local Error value is given with the system specifications. The user should study the error plot supplied with the motion device and determine the approximate maximum Local Error for the specific application.

5.2.5 Resolution

Resolution is the smallest motion that the controller attempts to make. For all DC motor and most all standard stepper motor driven stages supported by the ESP301, this is also the resolution of the encoder.

Keeping in mind that the servo loop is a digital loop, the Resolution can be also viewed as the smallest position increment that the controller can handle.

5.2.6 Minimum Incremental Motion

The Minimum Incremental Motion is the smallest motion that a device can reliably make, measured with an external precision-measuring device. The controller can, for instance, execute a motion equal to the Resolution (one encoder count) but in reality, the load may not move at all. The cause for this is in the mechanics.

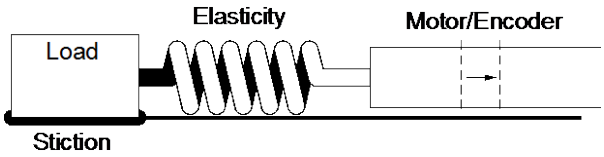


Figure 5.4: Effect of Stiction and Elasticity on Small Motions

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Figure 5.4 shows how excessive stiction and elasticity between the encoder and the load can cause the motion device to deviate from ideal motion when executing small motions.

The effect of these two factors has a random nature. Sometimes, for a small motion step of the motor, the load may not move at all. Other times, the accumulated energy in the spring will cause the load to jump a larger distance. The error plot will be similar to **Figure 5.5.**

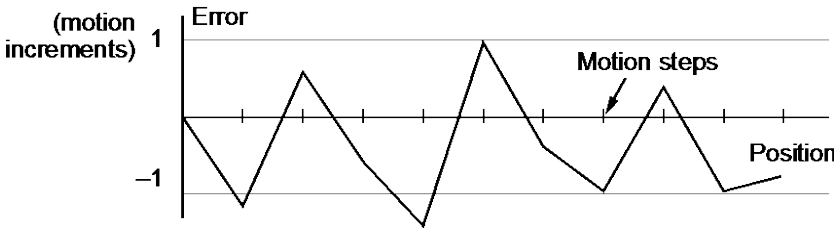


Figure 5.5: Error Plot

Once the Maximum Incremental Motion is defined, the next task is to quantify it. This more difficult for two reasons: one is its random nature and the other is in defining what a *completed motion* represents.

Assume that the user has a motion device with a 1 µm resolution. If every time the user commands a 1 µm motion the measured error is never greater than 2%, the user will probably be very satisfied and declare that the Minimum Incremental Motion is better than 1 µm.

If, on the other hand, the measured motion is sometimes as small as 0.1 µm (a 90% error), the user could not say that 1 µm is a reliable motion step. The difficulty is in drawing the line between acceptable and unacceptable errors when performing a small motion step. The most common value for the maximum acceptable error for small motions is 20%, but each application ultimately has its own standard.

One way to solve the problem is to take a large number of measurements (a few hundred at minimum) for each motion step size and present them in a format that an operator can use to determine the Minimum Incremental Motion by its own standard.

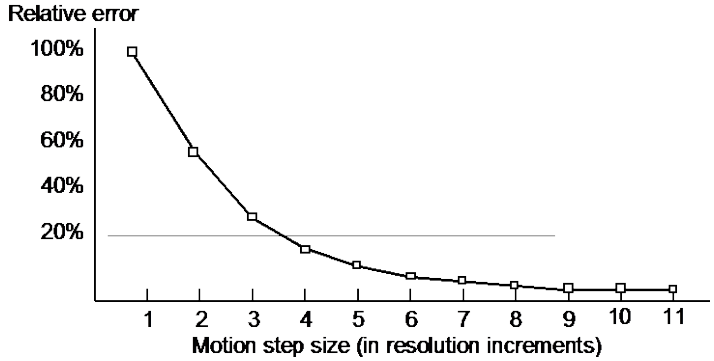


Figure 5.6: Error vs. Motion Step Size

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Figure 5.6 shows an example of such a plot. The graph represents the maximum relative error for different motion step sizes. In this example, the Minimum Incremental Motion that can be reliably performed with a maximum of 20% error is one equivalent to 4 resolution (encoder) increments.

5.2.7 Repeatability

Repeatability is the positioning variation when executing the same motion profile. Assuming that the user has a motion sequence that stops at a number of different locations, the Repeatability is the maximum position variation of all targets when the same motion sequence is repeated a large number of times. It is a relative, not absolute, error between identical motions.

5.2.8 Backlash (Hysteresis)

For all practical purposes, Hysteresis and Backlash have the same meaning for typical motion control systems; the error caused by approaching a point from a different direction. The difference is that Hysteresis refers to the compliance of the mechanical components, while Backlash represents the "play", or looseness, in the mechanical drive train.

All parameters discussed up to now that involve the positioning Error assumed that all motions were performed in the same direction. If the user tries to measure the positioning error of a certain target (destination), approaching the destination from different directions could make a significant difference.

In generating the plot in **Figure 5.2** we said that the motion device will make a large number of incremental moves, from one end of travel to the other. If the user commands the motion device to move back and stop at the same locations to take a position error measurement, the user would expect to get an identical plot, superimposed on the first one. In reality, the result could be similar to **Figure 5.7.**

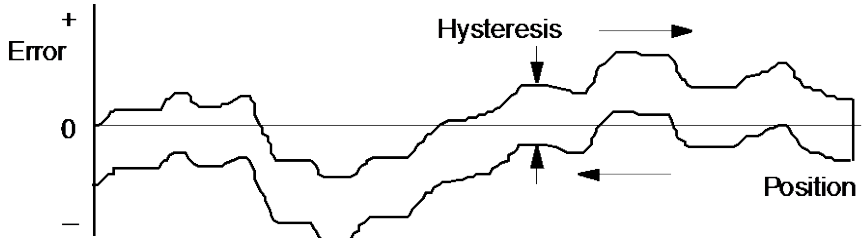


Figure 5.7: Hysteresis Plot

The error plot in reverse direction is identical with the first one but seems to be shifted down by a constant error. This constant error is the Hysteresis of the system.

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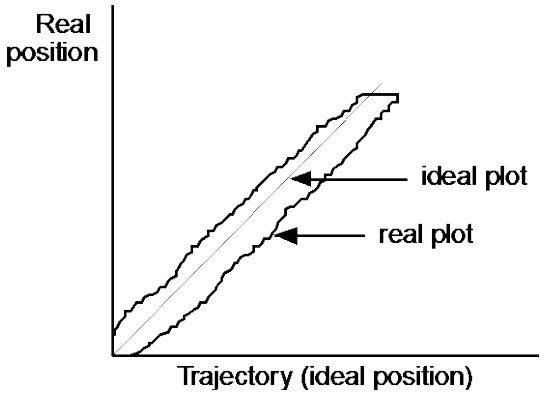


Figure 5.8: Real vs. Ideal Position

To justify a little more why we call this Hysteresis, lets do the same graph in a different format (**Figure 5.8**). Plotting the real versus the ideal position will give the user a familiar hysteresis shape.

5.2.9 Pitch, Roll and Yaw

These are the most common angular error parameters for linear translation stages. They are pure mechanical errors and represent the rotational error of a stage carriage around the three axes. A perfect stage should not rotate around any of the axes, thus the Pitch, Roll and Yaw should be zero.

The commonly used representation of the three errors is shown in **Figure 5.9.** Pitch is rotation around the Y axis, Roll is rotation around the X axis, and Yaw is rotation around the Z axis.

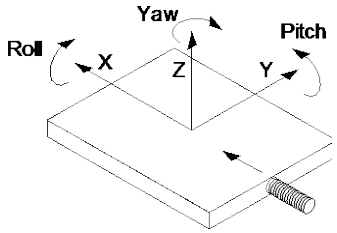


Figure 5.9: Pitch, Roll and Yaw Motion Axes

The problem with this definition is that, though correct, it is difficult to remember. A more graphical representation is presented in **Figure 5.10.** Imagine a tiny carriage driven by a giant lead screw. When the carriage rolls sideways on the lead screw pitch, we call that Pitch. And, when the carriage deviates left or right from the straight direction (on an imaginary Y trajectory), we call it Yaw.

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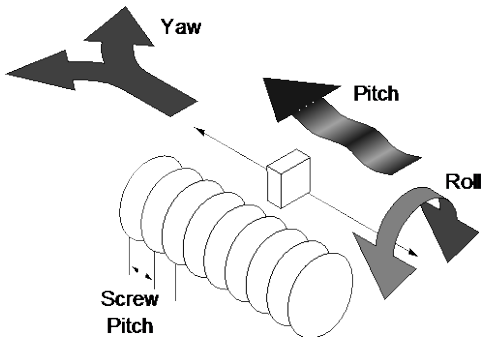


Figure 5.10: Pitch, Yaw and Roll Motion Axes

5.2.10 Wobble

This parameter applies only to rotary stages. It represents the deviation of the axis of rotation during motion. A simple form of Wobble is a constant one, where the rotating axis generates a circle (**Figure 5.11**).

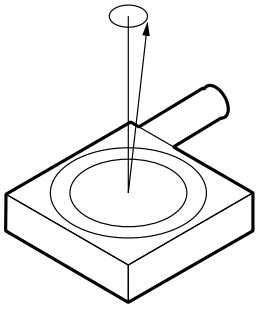


Figure 5.11: Wobble Generates a Circle

A real rotary stage may have a more complex Wobble, where the axis of rotation follows a complicated trajectory. This type of error is caused by the imperfections of stage's bearing way machining and/or ball bearings.

5.2.11 Load Capacity

There are two types of loads that are of interest for motion control applications: static and dynamic loads.

The static Load Capacity represents the amount of load that can be placed on a stage without damaging or excessively deforming it. Determining the Load Capacity of a stage for a particular application is more complicated than it may first appear. The stage orientation and the distance from the load to the carriage play a significant role. For a detailed description on how to calculate the static Load Capacity, please consult the motion control catalog tutorial section.

The dynamic Load Capacity refers to the motor's effort to move the load. The first parameter to determine is how much load the stage can

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push or pull. In some cases the two values could be different due to internal mechanical construction.

The second type of dynamic Load Capacity refers to the maximum load that the stage could move with the nominal acceleration. This parameter is more difficult to specify because it involves defining an acceptable following error during acceleration.

5.2.12 Maximum Velocity

The Maximum Velocity that could be used in a motion control system is determined by both motion device and driver. Usually it represents a lower value than the motor or driver is capable of. In most cases, including the ESP301, the default Maximum Velocity may be increased. The hardware and firmware are tuned for a particular maximum velocity that cannot be exceeded.

5.2.13 Minimum Velocity

The Minimum Velocity usable with a motion device depends on the motion control system but also on the acceptable velocity regulation. First, the controller sets the slowest rate of motion increments it can make. The encoder resolution determines the motion increment size and then, the application sets a limit on the velocity ripple.

To illustrate this, take the example of a linear stage with a resolution of 0.1 μm. If the user sets the velocity to 0.5 μm/sec, the stage will move 5 encoder counts on one second.

But, a properly tuned servo loop could move the stage 0.1 μm in about 20 ms. The position and velocity plots are illustrated in **Figure 5.12.**

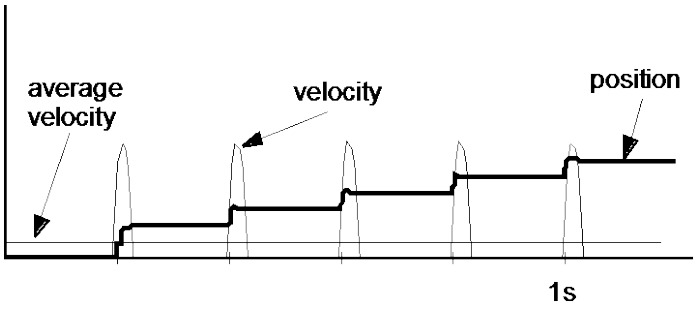


Figure 5.12: Position, Velocity and Average Velocity

The average velocity is low but the velocity ripple is very high. Depending on the application, this may be acceptable or not. With increasing velocity, the ripple decreases and the velocity becomes smoother.

This example is truer in the case of a stepper motor driven stage. The typical noise comes from a very fast transition from one step position to another. The velocity ripple in that case is significantly higher.

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In the case of a DC motor, adjusting the PID parameters to get a softer response will reduce the velocity ripple but care must be taken not to negatively affect other desirable motion characteristics.

5.2.14 Velocity Regulation

In some applications, for example scanning, it is important for the velocity to be very constant. In reality, there are a number of factors besides the controller that affect velocity.

As described in the Minimum Velocity definition, the speed plays a significant role in the amount of ripple generated, especially at low values. Even if the controller does a perfect job by running with zero following error, imperfections in the mechanics (friction, variation, transmission ripple, etc.) will generate some velocity ripple that can be translated to Velocity Regulation problems.

Depending on the specific application, one motor technology can be preferred over the other.

As far as the controller is concerned, the stepper motor version is the ideal case for a good average Velocity Regulation because the motor inherently follows precisely the desired trajectory. The only problem is the ripple caused by the actual stepping process.

The best a DC motor controller can do is to approach the stepper motor's performance in average Velocity regulation, but it has the advantage of significantly reduced velocity ripple, inherently and through PID tuning. If the DC motor implements a velocity closed loop through the use of a tachometer, the overall servo performance increases and one of the biggest beneficiary is the Velocity Regulation.

5.2.15 Maximum Acceleration

The maximum Acceleration is a complex parameter that depends as much on the motion control system as it does on application requirements. For stepper motors, the main concern is not to lose steps (or synchronization) during the acceleration. Besides the motor and driver performance, the load inertia plays a significant role.

For DC motor systems the situation is different. If the size of the following error is of no concern during the acceleration, high Maximum Acceleration values can be entered. The motion device will move with the highest natural acceleration it can (determined by the motor, driver, load inertia, etc) and the errors will consist of just a temporary larger following error and a velocity overshoot.

In any case, special consideration should be given when setting the acceleration. Through in most cases no harm will be done in setting a high acceleration value, avoid doing so if the application does not

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require it. The driver, motor, motion device and load undergo maximum stress during high acceleration.

5.2.16 Combined Parameters

Very often a user looks at an application and concludes that they need a certain overall accuracy. This usually means that the user is combining a number of individual terms (error parameters) into a single one. Some of these combined parameters even have their own name, even though not all people mean the same thing by them: Absolute Accuracy, Bi-directional Repeatability, etc. The problem with these generalizations is that, unless the term is well defined and the testing closely simulates the application, the numbers could be of little value.

The best approach is to carefully study the application, extract from the specification sheet the applicable discrete error parameters and combine them (usually add them) to get the worst-case general error applicable to the specific case. This method not only offers a more accurate value but also gives a better understanding of the motion control system performance and helps pinpoint problems.

Also, due to integrated nature of the ESP301 motion controller, many basic errors can be significantly corrected by another component of the loop. Backlash, Accuracy and Velocity Regulation are just a few examples where the controller can improve motion device performance.

5.3 Control Loops

When talking about motion control systems, one of the most important questions is the type of servo loop implemented. The first major distinction is between open and closed loop. Of course, this is of particular interest when driving stepper motors. As far as the DC servo loop, the PID type is by far the most widely used.

The ESP301 implements a PID servo loop with velocity and acceleration feed-forward.

The basic diagram of a servo loop is shown in **Figure 5.13.** Besides the command interpreter, the main two parts of a motion controller are the trajectory generator and the servo controller. The first generates the desired trajectory and the second one controls the motor to follow it as closely as possible.

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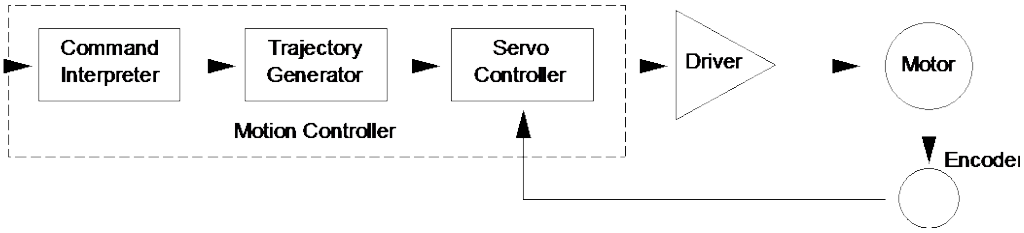


Figure 5.13: Servo Loop

5.3.1 PID Servo Loops

The PID term comes from the proportional, integral and derivative gain factors that are at the basis of the control loop calculation. The common equation given for it is:

$$K_p \bullet e + K_i \int e\,dt + K_d \bullet \frac{de}{dt}$$

where: K_p = Proportional gain factor
K_I = integral gain factor
K_d = derivative gain factor
e = instantaneous following factor

The program for most users is to get a feeling for this formula, especially when trying to tune the PID loop. Tuning the PID means changing its three gain factors to obtain a certain system response, task quite difficult to achieve without some understanding of its behavior of servo loops.

The following paragraphs explain the PID components and their operation.

P Loop

Let's start with the simplest type of closed loop, the P (proportional) loop. The diagram in **Figure 5.14** shows its configuration.

Every servo cycle (400 µs), the actual position, as reported by the encoder, is compared to the desired position generated by the trajectory generator. The difference **e** is the positioning error (the following error). Amplifying it (multiplying it by K_p) generates a control signal that, converted to an analog signal, is sent to the motor driver.

There are a few conclusions that could be drawn from studying this circuit:

- The motor control signal, thus the motor voltage, is proportional to the following error.
- There must be a following error in order to drive the motor.

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- Higher velocities need higher motor voltages and thus higher following errors.
- At stop, small errors cannot be corrected if they don't generate enough voltage for the motor to overcome friction and stiction.
- Increasing the $\mathbf{K_p}$ gain reduces the necessary following error but too much of it will generate instabilities and oscillations.

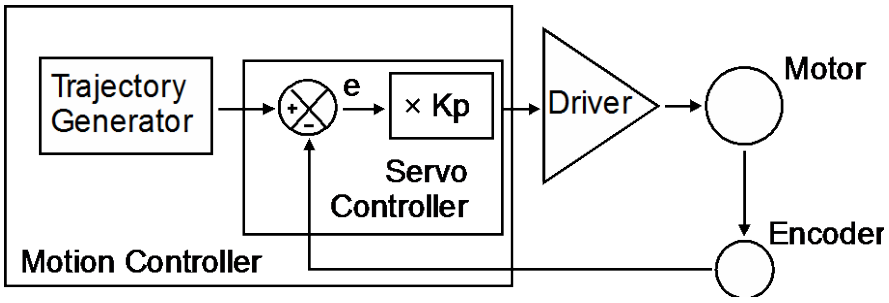


Figure 5.14: P Loop

PI Loop

To eliminate the error at stop and during long constant velocity motions (usually called steady-state error), an integral term can be added to the loop. This term integrates (adds) the error every servo cycle (400 µs) and the value, multiplied by the $\mathbf{K_i}$ gain factor, is added to the control signal (**Figure 5.15**).

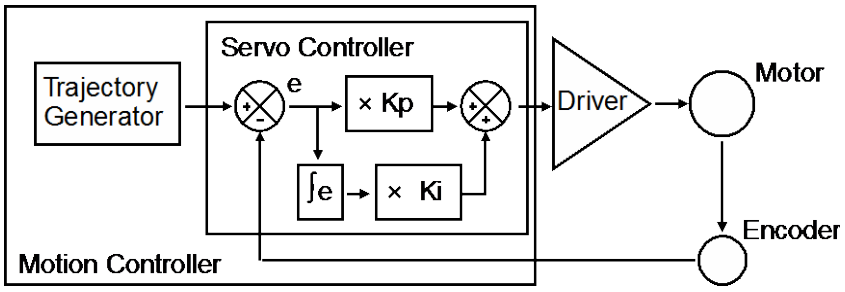


Figure 5.15: PI Loop

The result is that the integral term will increase until it drives the motor by itself, reducing the following error to zero. At stop, this has the very desirable effect of driving the positioning error to zero. During a long constant velocity motion it also brings the following error to zero, an important feature for some applications.

Unfortunately, the integral term also has a negative side, a severe de-stabilizing effect on the servo loop. In the real world, a simple PI Loop is usually undesirable.

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PID Loop

The third term of the PID Loop is the derivative term. It is defined as the difference between the following error of the current servo cycle (400 µs) and of the previous one. If the following error does not change, the derivative term is zero.

Figure 5.16 sows the PID servo loop diagram. The derivative term is added to the proportional and integral one. All three process the following error in their own way and, added together, form the control signal.

The derivative term adds a damping effect that prevents oscillations and position overshoot.

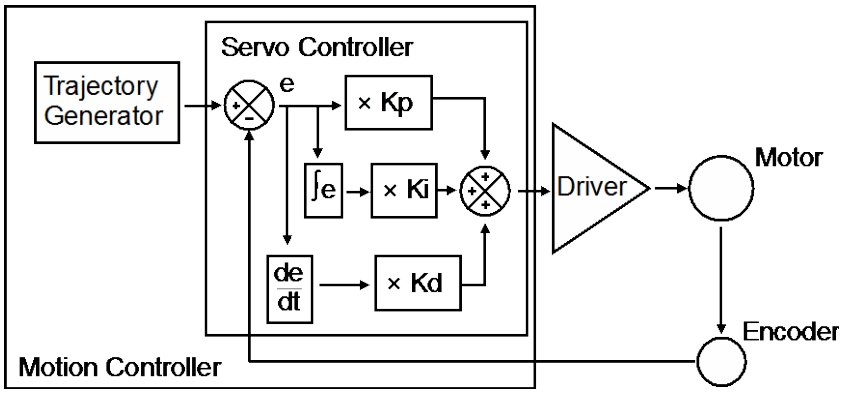


Figure 5.16: PID Loop

5.3.2 Feed-Forward Loops

As described in the previous paragraph, the main driving force in a PID loop is the proportional term. The other two correct static and dynamic errors associated with the closed loop.

Taking a closer look at the desired and actual motion parameters and at the characteristics of the DC motors, some interesting observations can be made. For a constant load, the velocity of a DC motor is approximately proportional with the voltage. This means that for a trapezoidal velocity profile, for instance, the motor voltage will have also a trapezoidal shape (**Figure 5.17**).

The second observation is that the desired velocity is calculated by the trajectory generator and is known ahead of time. The obvious conclusion is that we could take this velocity information, scale it by $\mathbf{K_{vff}}$ factor and feed it to the motor driver. If the scaling is done properly, the right amount of voltage is sent to the motor to get the desired velocities, without the need for a closed loop.

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Because the signal is derived from the velocity profile and it is being sent directly to motor driver, the procedure is called velocity feed-forward.

Of course, this looks like an open loop, and it is (**Figure 5.18**). But, adding this signal to the closed loop has the effect of significantly reducing the "work" the PID has to do, thus reducing the overall following error. The PID now has to correct only for the residual error left over by the feed-forward signal.

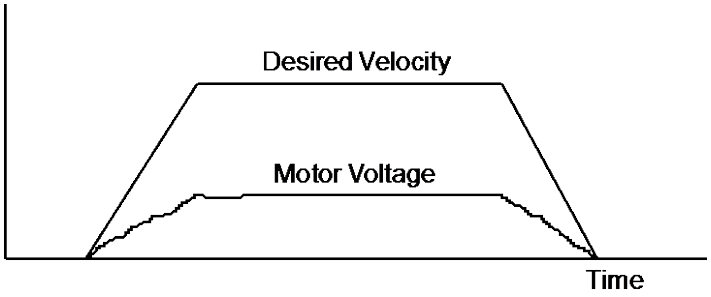


Figure 5.17: Trapezoidal Velocity Profile

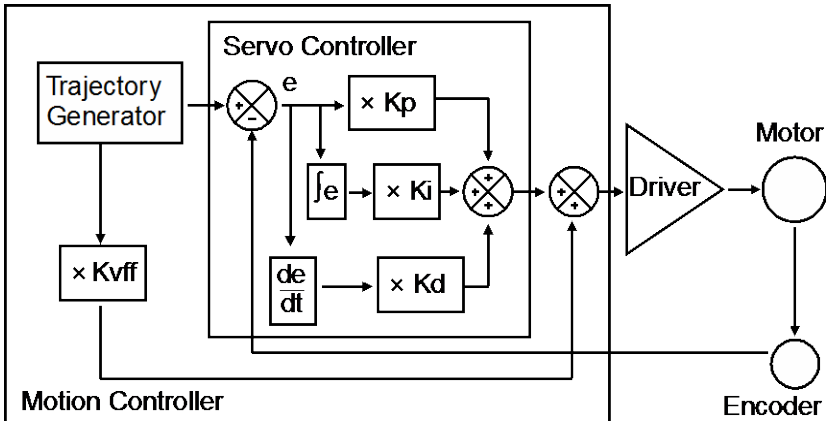


Figure 5.18: PID Loop with Feed-Forward

There is another special note that has to be made about the feed-forward method. The velocity is approximately proportional to the voltage and only for constant loads, but this true only if the driver is a simple voltage amplifier or current (torque) driver. A special case is when the driver has its own velocity feedback loop from a tachometer (**Figure 5.19**).

The tachometer is a device that outputs a voltage proportional with the velocity. Using its signal, the driver can maintain the velocity to be proportional to the control signal.

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If such a driver is used with a velocity feed-forward algorithm, by properly tuning the $\mathbf{K_{vff}}$ parameter, the feed-forward signal could perform an excellent job, leaving very little for the PID loop to do.

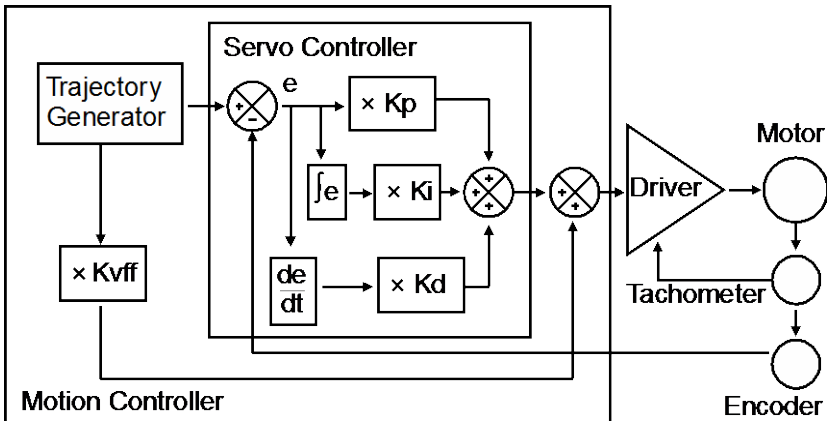


Figure 5.19: Tachometer-Driven PIDF Loop

5.4 Motion Profiles

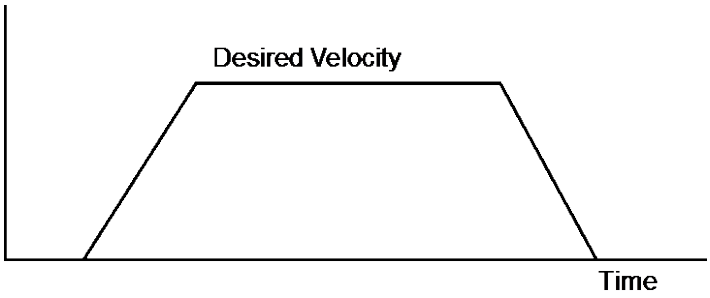
When talking about motion commands we refer to certain strings sent to a motion controller that will initiate a certain action, usually a motion. There are a number of common motion commands that are identified by name. The following paragraphs describe a few of them.

5.4.1 Move

A move is a point-to-point motion. On execution of a move motion command, the motion device moves from the current position to a desired destination. The destination can be specified either as an absolute position or as a relative distance from the current position.

When executing a move command, the motion device will accelerate until the velocity reaches a pre-defined value. Then at the proper time, it will start decelerating so that when the motor stops, the device is at the correct position. The velocity plot of this type of motion will have a trapezoidal shape (**Figure 5.20**). For this reason, this type of motion is called a trapezoidal motion.

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The position and acceleration profiles relative to the velocity are shown in **Figure 5.21.**

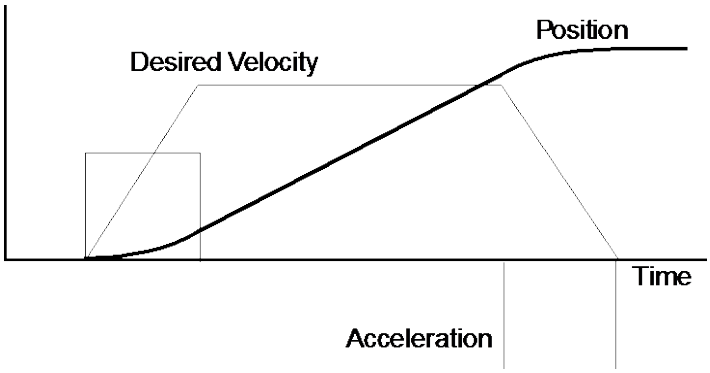


Figure 5.21: Position and Acceleration Profiles

Besides the destination, the acceleration and the velocity of the motion (the constant portion of it) can be set by the user before every move command. Advanced controllers like the ESP301 allow the user to change them even during the motion.

5.4.2 Jog

When setting up an application, it is often necessary to move stages manually while observing motion. The easy way to do this without resorting to specialized input devices such as joysticks or track-wheels is to use simple push-button switches. This type of motion is called a jog. When a jog button is pressed the selected axis starts moving with a pre-defined velocity. The motion continues only while the button is pressed and stops immediately after its release.

The ESP301 offers two jog speeds. Both high and low jog speeds are user programmable. The jog acceleration is also ten times smaller than the programmed maximum acceleration values.

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5.4.3 Home Search

Home search is a specific motion routine that is useful for most types of applications. Its goal is to find a specific point in travel relative to the mounting base of the motion device very accurately and repeatable. The need for this absolute reference point is twofold. First, in many applications it is important to know the exact position in space, even after a power-off cycle. Secondly, to protect the motion device from hitting a travel obstruction set by the application (or its own travel limits), the controller uses programmable software limits. To be efficient though, the software limits must be placed accurately in space before running the application.

To achieve this precise position referencing, the ESP301 motion controller executes a unique sequence of moves.

First, let's look at the hardware required to determine the position of a motion device. The most common (and the one supported by the ESP301) are incremental encoders. By definition, these are encoders that can tell only relative moves, not absolute position. The controller keeps track of position by incrementing or decrementing a dedicated counter according to the information received from the encoder. Since there is no absolute position information, position "zero" is where the controller was powered on (and the position counter reset).

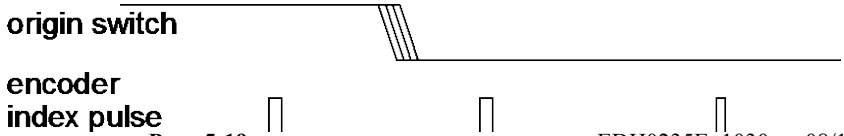
To determine an absolute position, the controller must find a "switch" that is unique to the entire travel, called a home switch or origin switch. An important requisition is that this switch must be located with the same accuracy as the encoder pulses.

If the motion device is using a linear scale as position encoder, the home switch is usually placed on the same scale and read with the same accuracy.

If, on the other hand, a rotary encoder is used, the problem becomes more complicated. To have the same accuracy, a mark on the encoder disk could be used (called index pulse) but because it repeats itself every revolution, it does not define a unique point over the entire travel.

An origin switch, on the other hand, placed in the travel of the motion device is unique but not accurate (repeatable) enough. The solution is to use both, following a search algorithm.

A home switch (**Figure 5.22**) separates the entire travel in two areas: one for which it has a high level and one for which is low. The most important part of it is the transition between the two areas. Also, looking at the origin switch level, the controller knows on which side of the transition it currently is and which way to move to find it.



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Figure 5.22: Home (Origin) Switch and Encoder Index Pulse

The task of the home search routine is to identify one unique index pulse as the absolute position reference. This is done by the first finding the home switch transition and then the very first index pulse (**Figure 5.23**).

So far, we can label the two motion segments D and E. During D the controller is looking for the origin switch transition and during E for the index pulse. To guarantee the best accuracy possible, both D and E segments are performed at a very low speed and without a stop in-between. Also, during E the display update is suppressed to eliminate any unnecessary overhead.

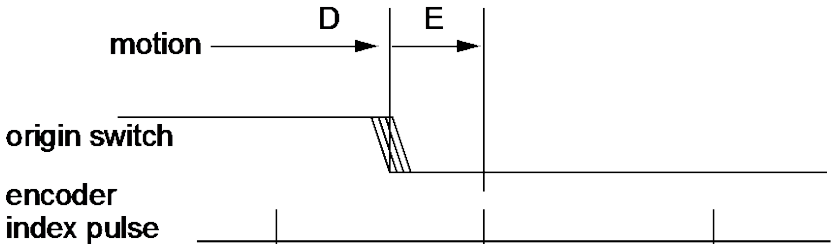


Figure 5.23: Slow-Speed Home (Origin) Switch Search

The routine described above could work but has one problem. Using the low speeds, it could take a very long time if the motion device happens to start from the opposite end of travel. To speed things up, we can have the motion device move fast in the vicinity of the home switch and then perform the two slow motions, D and E. The new sequence is shown in **Figure 5.24.**

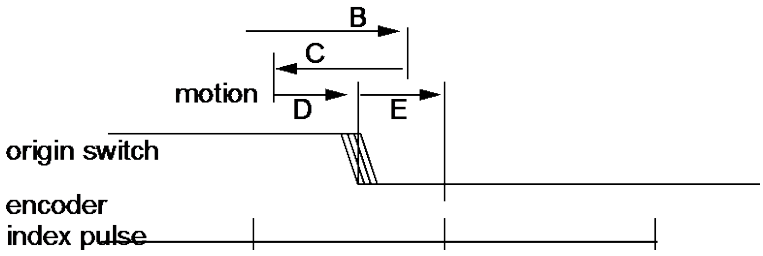


Figure 5.24: High/Low-Speed Home (Origin) Switch Search

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Motion segment B is performed at high speed, with the pre-programmed home search speed. When the home switch transition is encountered, the motion device stops (with an overshoot), reverses direction and looks for it again, this time with half the velocity (segment C).

Once found, it stops again with an overshoot, reverses direction and executes D and E with one tenth of the programmed home search speed.

In the case when the motion device starts from the other side of the home switch transition, the routine will look like **Figure 5.25.**

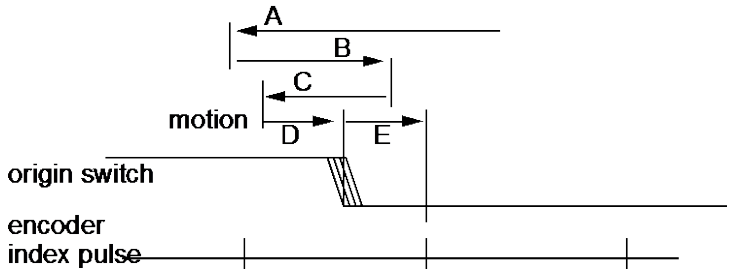


Figure 5.25: Home (Origin) Search from Opposite Direction

The ESP301 moves at high speed up to the home switch transition (segment A), and then executes B, C, D and E.

All home search routines are run so that the last segment, E, is performed in the position direction of travel.



CAUTION

The home search routine is very important for the positioning accuracy of the entire system and it requires full attention from the controller. Do not interrupt or send other commands during its execution, unless it is for emergency purposes.

5.5 Encoder

PID closed-loop motion control requires a position sensor. The most widely used technology by far, are incremental encoders.

The main characteristic of an incremental encoder is that it has a 2-bit gray code output, more commonly known as quadrature output (**Figure 5.26**).

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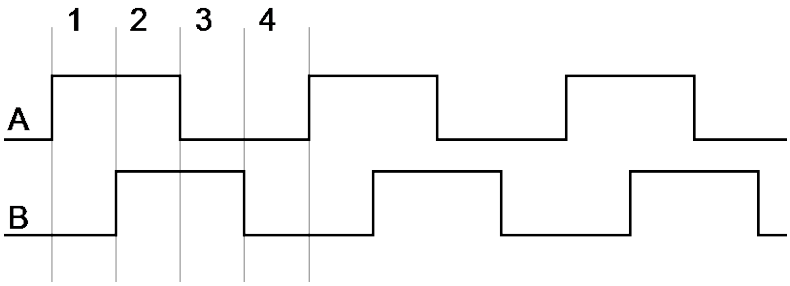


Figure 5.26: Encoder Quadrature Output

The output has two signals, commonly known as channel A and channel B. Some encoders have analog outputs (sine – cosine signals), but the digital type are more widely used. Both channels have a 50% duty cycle and are out of phase by 90°. Using both channels and an appropriate decoder, a motion controller can identify four different points within one encoder cycle. This type of decoding is called X4 (or quadrature decoding), meaning that the encoder resolution is multiplied by 4. For example, and encoder with 10 µm phase period can offer a 2.5 µm resolution when used with a X4 type decoder.

Physically, an encoder has two parts: a *scale* and a *read head.* The scale is an array of precision placed marks that are read by the head. The most commonly used encoders, optical encoders, have a scale made out of a series of transparent and opaque lines placed on a glass substrate or etched in a thin metal sheet (**Figure 5.27**).

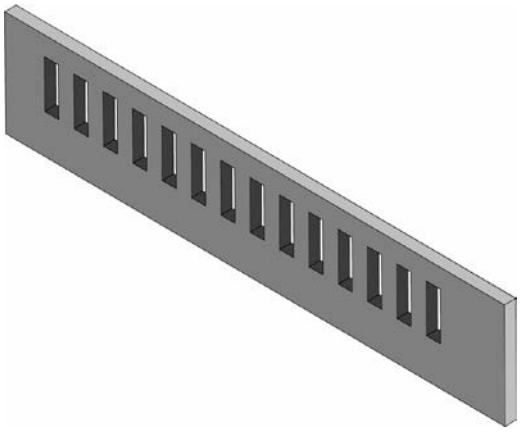


Figure 5.27: Optical Encoder Scale

The encoder read head has three major components: a light source, a mask and a detector (**Figure 5.28**). The mask is a small scale-like piece, having identically spaced transparent and opaque lines.

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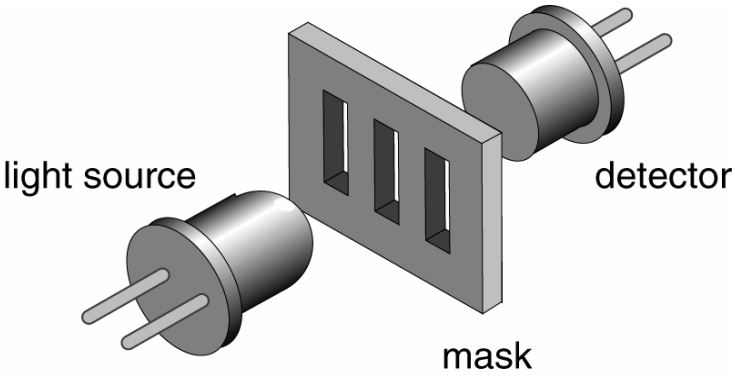


Figure 5.28: Optical Encoder Read Head

Combining the scale with the read head, when one moves relative to another, the light will pass through where the transparent areas line up or blocked when they do not line up (**Figure 5.29**).

The detector signal is similar to a sine wave. Converting it to a digital waveform, the user will get the desired encoder signal. But, this is only one phase, only half of the signal needed to get position information. The second channel is obtained the same way but from a mask that is placed 90% out of phase relative to the first one (**Figure 5.30**).

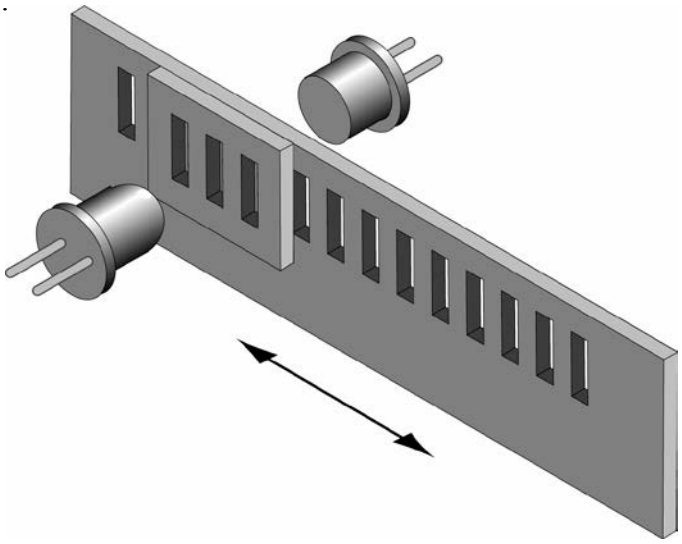


Figure 5.29: Single-Channel Optical Encoder Scale and Read Head Assembly

There are two basic types of encoders: *linear* and *rotary*. The linear encoders, also called linear scales, are used to measure linear motion directly. This means that the physical resolution of the scale will be the actual positioning resolution. This is their main drawback since technological limitations prevent them from having better resolutions than a few microns. To get higher resolutions in linear scales, a special delicate circuitry must be added, called scale interpolator.

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Other technologies like interferometry or halography can be used but they are significantly more expansive and need more space.

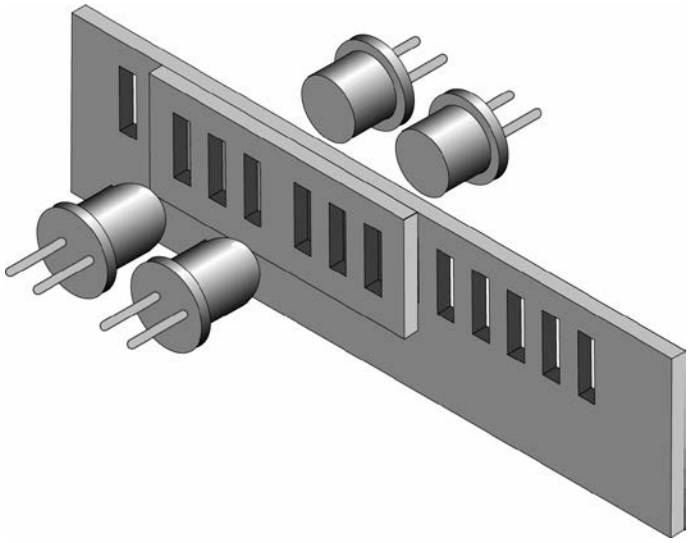


Figure 5.30: Two-Channel Optical Encoder Scale and Read Head Assembly

The most popular encoders are rotary. Using gear reduction between the encoder and the load, significant resolution increases can be obtained at low cost. But the price paid for this added resolution is higher backlash.

In some cases, rotary encoders offer high resolution without the backlash penalty. For instance, a linear translation stage with a rotary encoder on the lead screw can easily achieve 1µm resolution with negligible backlash.

NOTE

For rotary stages, a rotary encoder measures the output angle directly. In this case, the encoder placed on the rotating platform has the same advantages and disadvantages of the linear scales.

5.6 Motors

There are many different types of electrical motors, each one being best suitable for certain kind of applications. The ESP301 supports two of the most popular types: *stepper motors* and *DC motors.*

Other technologies like interferometry or halography can be used but they are significantly more expansive and need more space.

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Another way to characterize motors is by the type of motion they provide. The most common ones are rotary but in some applications, linear motors are preferred.

5.6.1 Stepper Motors

The main characteristic of a stepper motor is that each motion cycle has a number of stable positions. This means that, if current is applied to one of its windings (called phases), the rotor will try to find one of these stable points and stay there. In order to make a motion, another phase must be energized which, in turn, will find a new stable point, thus making a small incremental move – a step.

Figure 5.31 shows the basics of a stepper motor. When the winding is energized, the magnetic flux will turn the rotor until the rotor and stator teeth line up. This true of the rotor core is made out of soft iron. Regardless of the current polarity, the stator will try to pull-in the closest rotor tooth.

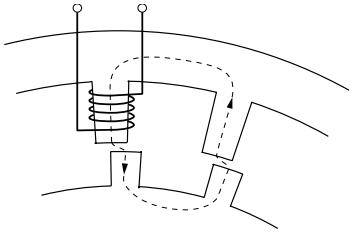


Figure 5.31: Stepper Motor Operation

But, if the rotor is a permanent magnet, depending on the current polarity, the stator will pull or push the rotor tooth. This is a major distinction between two different stepper motor technologies: variable reluctance and permanent magnet motors. The variable reluctance motors are usually small, low cost, large step angle stepper motors. The permanent magnet technology is used for larger, high precision motors.

The stepper motor advances to a new stable position by means of several stator phases that have the teeth slightly offset from each other. To illustrate this, **Figure 5.32** shows a stepper motor with four phases and, to make it easier to follow, it is drawn in a linear fashion (as a linear stepper motor).

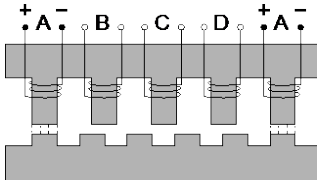


Figure 5.32: Four-Phase Stepper Motor

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The four phases, from A to D, are energized one at a time (phase A is shown twice). The rotor teeth line up with the first energized phase, A. If the current to phase A is turned off and B is energized next, the closest rotor tooth to phase B will be pulled in and the motor moves one step forward.

If, on the other hand, the next energized phase is D, the closest rotor tooth is in the opposite direction, thus making the motor to move in reverse.

Phase C cannot be energized immediately after A because it is exactly between two teeth, so the direction of movement is indeterminate.

To move in one direction, the current in the four phases must have the following timing diagram (**Figure 5.33**).

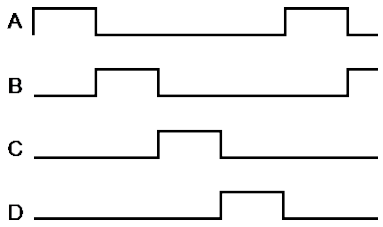


Figure 5.33: Phase Timing Diagram

One phase is energized after another, in a sequence. To advance one full rotor tooth the user needs to make a complete cycle of four steps. To make a full revolution, the user needs a number of steps four times the number of rotor teeth. These steps are called full steps. They are the largest motion increment the stepper motor can make. Running the motor in this mode is called full-stepping.

What happens if the user energizes two neighboring phases simultaneously (**Figure 5.34**).

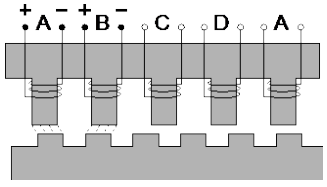


Figure 5.34: Energizing Two Phases Simultaneously

Both phases will pull equally on the motor will move the rotor only half of the full step. If the phases are always energized two at a time, the motor still makes full steps. But, if the user alternates one and two phases being activated simultaneously, the result is that the motor will move only half a step at a time. This method of driving a stepper motor is called half-stepping. The advantage is that we can get double the resolution from the same motor with very little effect on the

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driver's side. The timing diagram for half-stepping is shown in **Figure 5.35.**

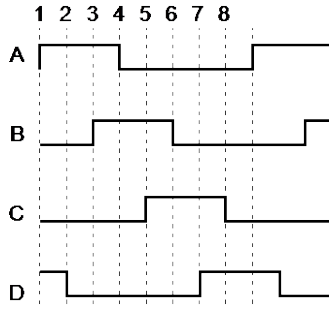


Figure 5.35: Timing Diagram, Half-Stepping Motor

Now, what happens if we energize the same two phases simultaneously but with different currents? For example, lets say that phase A has the full current and phase B only half. This means that phase A will pull the rotor tooth twice as strongly as B does. The rotor tooth will stop closer to A, somewhere between the full step and the half step positions (**Figure 5.36**).

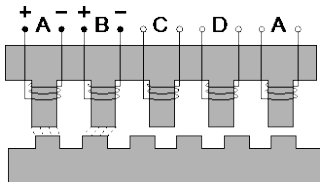


Figure 5.36: Energizing Two Phases with Different Intensities

The conclusion is that, varying the ratio between the currents of the two phases, the user can position the rotor anywhere between the two full step locations. To do so, the user needs to drive the motor with analog signals, similar to **Figure 5.37.**

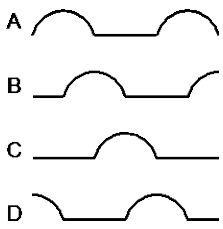


Figure 5.37: Timing Diagram, Continuous Motion (Ideal)

But a stepper motor should be stepping. The controller needs to move it in certain known increments. The solution is to take the halh-sine waves and digitize them so that for every step command, the currents change to some new pre-defined levels, causing the motor to advance one small step (**Figure 5.38**).

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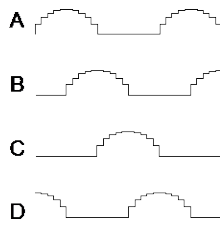


Figure 5.38: Timing Diagram, Mini-Stepping

This driving method is called mini-stepping or micro-stepping. For each step command, the motor will move only a fraction of the full-step. Motion steps are smaller so the motion resolution is increased and the motion ripple (noise) is decreased.

However, mini-stepping comes at a price. First, the driver electronics are significantly more complicated. Secondly, the holding torque or one step is reduced by the mini-stepping factor. In other words, for a x10 mini-stepping, it takes only 1/10 of the full-step holding torque to cause the motor to have a positioning error equivalent to one step (a mini-step).

To clarify a little what this means, lets take a look at the torque produced by a stepper motor. For simplicity, lets consider the case of a single phase being energized (**Figure 5.39**).

Once the closest rotor tooth has been pulled in, assuming that the user doesn't have any external load, the motor does not develop any torque. This is a stable point.

If external forces try to move the rotor (**Figure 5.40**), the magnetic flux will counter this effect. The more teeth misalignment exists, the larger the generated torque.

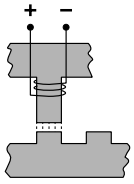


Figure 5.39: Single Phase Energization

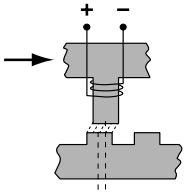


Figure 5.40: External Force Applied

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If the misalignment keeps increasing, at some point, the torque peaks and then starts diminishing again such that, when the stator is exactly between the rotor teeth, the torque becomes zero again (**Figure 5.41**).

This is an unstable point and any misalignment or external force will cause the motor to move one way or another. Jumping from one stable point to another is called missing steps, one of the most critiqued characteristics of stepper motors.

The torque diagram versus teeth misalignment is shown in **Figure 5.42.** The maximum torque is obtained at one quarter of the tooth spacing, which is equivalent to one full step.

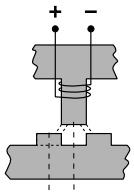


Figure 5.41: Unstable Point

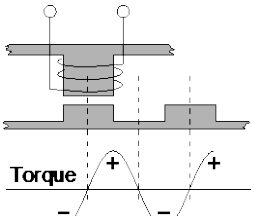


Figure 5.42: Torque and Tooth Alignment

This torque diagram is accurate even when the motor is driven with half-, mini-, or micro-steps. The maximum torque is still one full step away from the stable (desired) position.

5.6.1.1 Stepper Motor Types

To simplify the explanation, the examples above are based on a variable reluctance stepper motor. The main characteristic of these motors is that their rotors have no permanent magnets. The variable reluctance motors are easy and inexpensive to make but suffer from higher inefficiency and require a unipolar driver. They are used in low cost, low power applications.

Permanent magnet motors have each "tooth" made out of a permanent magnet, each one having alternate polarity. They are more efficient but the step size is very large due to the physical size of the pole "teeth". They are also being used in low cost and, in particular, miniature applications.

The most common type of stepper motor is the Hybrid stepper motor. It is the fine "teeth" and stepping angle of a variable reluctance motor

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and the efficiency of the permanent magnet motor. The rotor is made out of one or more stacks that consist of a pair of magnetically opposite polarized sections. These motors offer the best combination of efficiency and fine stepping angles and can be driven by both unipolar and bipolar drivers.

Advantages

Stepper motors are primarily intended to be used for low cost microprocessor controlled positioning applications. Due to some of their inherent characteristics, they are preferred in many industrial and laboratory applications. Some of their main advantages are:

- Low cost full-step, open loop implementation
- No servo tuning required
- Good position lock-in
- No encoder necessary
- Easy velocity control
- Retains some holding torque even with power off
- No wearing or arcing commutators
- Preferred for vacuum and explosive environments.

Disadvantages

Some of the main disadvantages of the stepper motors are:

- Could loose steps (synchronization) in open loop operation
- Requires current (dissipates energy) even at stop
- Generates higher heat levels than other types of motors
- Moves from one step to another are made with sudden motions
- Large velocity ripples, especially at low speeds, causing noise and possible resonances
- Load torque must be significantly lower than the motor holding torque to prevent stalling and missing steps
- Limited high speed.

5.6.2 DC Motors

A DC motor is similar to a permanent magnet stepper motor with an added internal phase commutator (**Figure 5.43**).

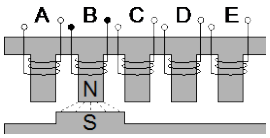


Figure 5.43: DC Motor

Applying current to phase B pulls in the rotor pole. If, as soon as the pole gets there, the current is switched to the next phase C, the rotor will not stop but continue moving to the next target.

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Repeating the current switching process will keep the motor moving continuously. The only way to stop a DC motor is not to apply any current to its windings. Due to the permanent magnets, reversing the current polarity will cause the motor to move in the opposite direction.

Of course, there is a lot more to the DC motor theory but this description gives the user a general idea on how they work.

A few other characteristics to keep in mind are:

- For a constant load, the velocity is approximately proportional to the voltage applied to the motor
- For accurate positioning, DC motors need a position feed-back device.
- Constant current generates approximately constant torque
- If DC motors are tuned externally (manually, etc.) they act as generators.

Advantages

DC motors are preferred in many applications for the following reasons:

- Smooth, ripple-free motion at any speed
- High torque per volume
- No risk of loosing position (in a closed loop)
- Higher power efficiency than stepper motors
- No current requirement at stop
- Higher speeds can be obtained than with other types of motors.

Disadvantages

Some of the DC motor's disadvantages are:

- Requires a position feedback encoder and servo loop controller
- Requires servo loop tuning
- Commutator may wear out in time
- Not suitable for high vacuum application due to the commutator arcing
- Hardware and setup are more costly than for an open loop stepper motor (full stepping).

5.7 Drivers

Motor divers must not be overlooked when judging a motion control system. They represent an important part of the loop that in many cases could increase or reduce the overall performance.

The ESP301 is an integrated controller and driver. The controller part is common for any configuration but the driver section must have the

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correct hardware for each motor driven. The driver hardware is one driver card per axis that installs easily in the rear of the controller. Each card has an end-plate with the 25 pin D-Sub motor connector and an identifying label. Always make sure that the motor specified on the driver card label matches the label on the motion device.

There are important advantages to having an integrated controller/driver. Besides reducing space and cost, integration also offers tighter coordination between the two units so that the controller can more easily monitor and control the driver's operation.

Driver types and techniques vary widely. In the following paragraphs, we will discuss only those implemented in the ESP301.

5.7.1 Stepper Motor Drivers

Driving a stepper motor may look simple at first place. For a motor with four phases, the most widely used type, the user will need only four switches (transistors), controlled directly by a CPU (**Figure 5.44**).

This driver works fine for simple, low performance applications. But, if high speeds are required, having to switch the current fast in inductive loads becomes a problem. When voltage is applied to a winding, the current (and thus the torque) approaches its normal value exponentially (**Figure 5.45**).

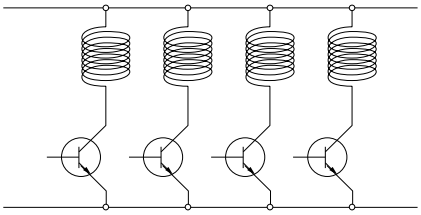


Figure 5.44: Simple Stepper Motor Driver

When the pulse rate is flat, the current does not have time to reach the desired value before it is turned off and the total torque generated is only a fraction of the nominal one (**Figure 5.46**).

How fast the current reaches its nominal value depends on three factors: the winding's inductance, resistance and the voltage applied to it.

The inductance cannot be reduced. But the voltage can be temporarily increased to bring the current to its desired level faster. The most widely used technique is a high voltage chopper.

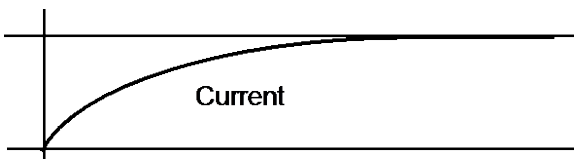


Figure 5.45: Current Build-up in Phase

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When the pulse rate is fast, the current does not have time to reach the desired value before it is turned off and the total torque generated is only a fraction of the nominal one (**Figure 5.46**).

How fast the current reaches its nominal value depends on three factors: the winding's inductance, resistance and the voltage applied.

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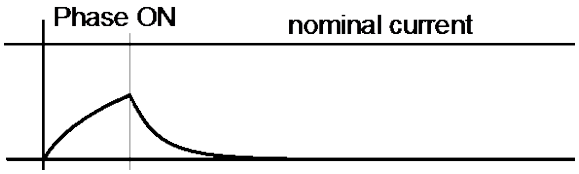


Figure 5.46: Effect of a Short ON Time on Current

If, for instance, a stepper motor requiring only 3V to reach the nominal current is connected momentarily to 30V, it will reach the same current on only 1/10 of the time (**Figure 5.47**).

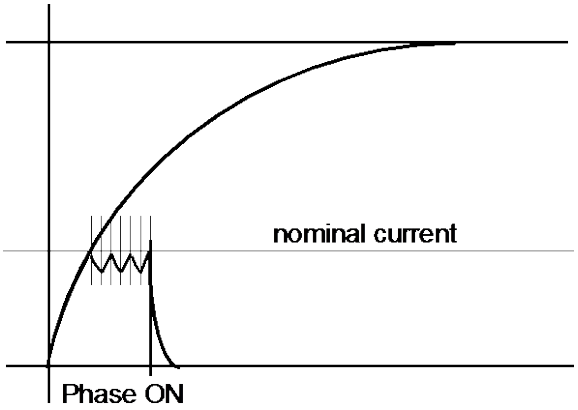


Figure 5.47: Motor Pulse with High Voltage Chopper

Once the desired current value is reached, a chopper circuit activates to keep the current close to the nominal value.

5.7.2 Unipolar – Bipolar Drivers

In the examples described in Section 5.7.1: Stepper Motor Drivers, each phase has its own commutator (transistor) to control the current that flows through it. Having one end permanently connected to the power source, the current will flow through each phase always in the same direction. For this reason, these types of drivers are called **Unipolar.**

On the other hand, **Figure 5.48** shows a **Bipolar** Driver built in a dual H-bridge configuration. The name "H-Bridge" comes from the

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topology of the transistors controlling one load (coil). In this case, by turning on diagonally transistors (1-4 or 2-3), the current could be made to flow either way through the coil. This means that the driver can control not just the intensity of the magnetic field generated by the stator, but also its polarity. Implicitly, the only stepper motors that can be used with such a driver are the ones with polarized rotors, the Permanent Magnet, and the Hybrid types.

The question that arises from the driver configuration is how to connect a four phase stepper motor to a driver that drives only two coils. This could be accomplished in three different ways, each one with its own advantages and disadvantages:

1. Use only two adjacent phases (e.g., phase #1 and #2).
   - **Advantage** – simplicity
   - **Disadvantage** – lower efficiency since only half the windings are being used.
2. Connect the two opposing phases (1-3 and 2-4) in series.
   - **Advantage** – the motor does not require more than the nominal current.
   - **Disadvantage** – the driver will see twice the nominal motor inductance that will reduce the motor's torque performance at higher speeds.
3. Connect the two opposing phases (1-3 and 2-4) in parallel.
   - **Advantage** – the motor inductance does not increase, allowing it to perform well at higher speeds.
   - **Disadvantage** – requires the driver to supply twice the motor's nominal current.

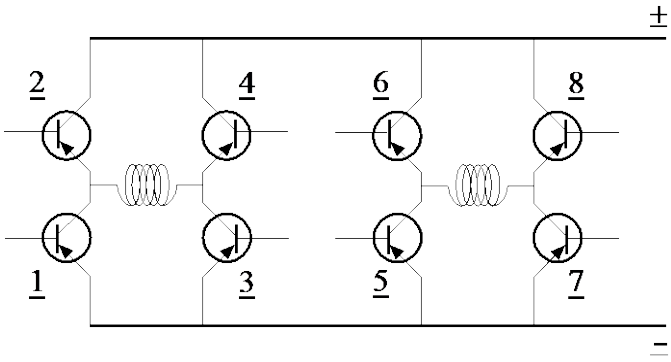


Figure 5.48: Dual H-Bridge Driver

5.7.3 DC Motor Drivers

There are three major categories of DC motor drivers. The simplest one is a voltage amplifier (**Figure 5.49**).

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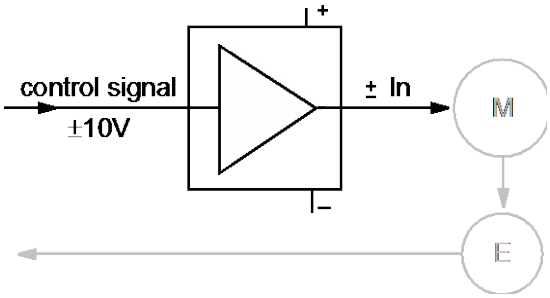


Figure 5.49: DC Motor Voltage Amplifier

The driver amplifies the standard ±10 V control signal to cover the motor's nominal voltage range while also supplying the motor's nominal current.

This type of driver is used mostly in low cost applications where following error is not a great concern. The controller does all the work in trying to minimize the following error but load variations make this task very difficult.

The second type of DC motor driver is the current driver, also called a torque driver (**Figure 5.50**).

In this case, the control signal voltage defines the motor current. The driver constantly measures the motor current and always keeps it proportional to the input voltage. This type of driver is usually preferred over the previous one in digital control loops, offering a stiffer response and thus reduces the dynamic following error.

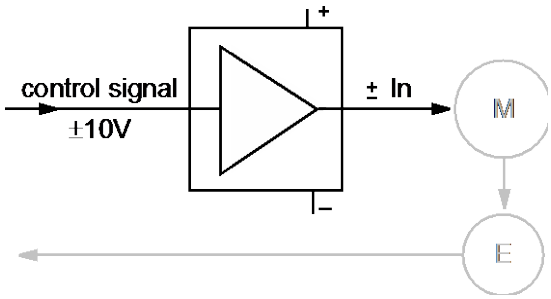


Figure 5.50: DC Motor Current Driver

But, when the highest possible performance is required, the best choice is always the velocity feedback driver. This type of driver requires a tachometer, an expensive and sometimes difficult to add device (**Figure 5.51**).

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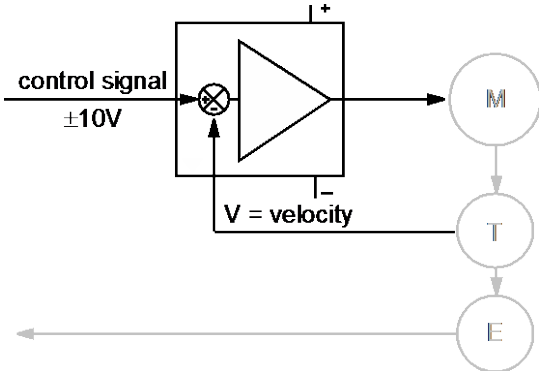


Figure 5.51: DC Motor Velocity Feedback Driver

The tachometer, connected to the motor's rotor, outputs a voltage directly proportional with the motor velocity. The circuit compares this voltage with the control signal and drives the motor so that the two are always equal. This creates a second closed loop, a velocity loop. Motions performed with such a driver are very smooth at high and low speeds and has a similar dynamic following error.

General purpose velocity feedback drivers have usually two adjustments: tachometer gain and compensation (**Figure 5.52**).

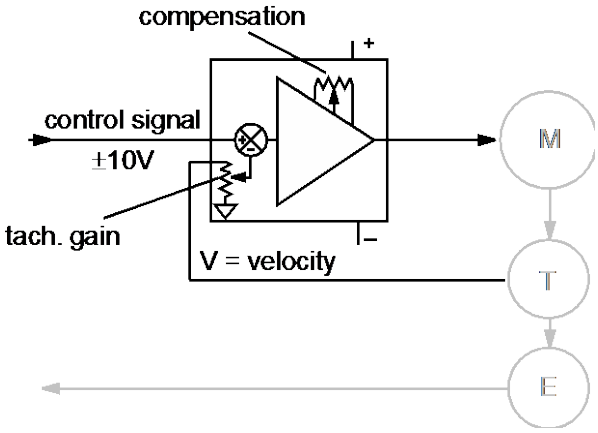


Figure 5.52: DC Motor Tachometer Gain and Compensation

The tachometer gain is used to set the ratio between the control voltage and the velocity. The compensation adjustment reduces the bandwidth of the amplifier to avoid oscillations of the closed loop.

5.7.3.1 PWM Drivers

Even though linear amplifiers are simpler and cleaner (do not generate noise), their low efficiency makes them impractical to be used with medium and larger motors. The most common types of DC drivers use some kind of PWM (**P**ulse-**W**idth **M**odulation) techniques to control the current and/or voltage applied to the motor. This allows for a more efficient and compact driver design.

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Section 6 – Servo Tuning

6.1 Tuning Principles

The ESP301 controller uses a PID servo loop with feed-forward. Servo tuning sets the **Kp, Ki,** and **Kd,** and feed-forward parameters of the digital PID algorithm, also called the PID filter.

Tuning PID parameters requires a reasonable amount of closed-loop system understanding. First review the Control Loops paragraph in the Motion Control Tutorial Section. If needed, consult additional servo control theory books.

Start the tuning process using the default values supplied with the stage. These values are usually very conservative, favoring safe and oscillation-free operation. To achieve the best dynamic performance possible, the system must be tuned for the specific application. Load, acceleration, stage orientation, and performance requirements all affect how the servo loop should be tuned.

6.2 Tuning Procedures

Servo tuning is usually performed to achieve better motion performance (such as reducing the following error statically and/or dynamically) or because the system is malfunctioning (oscillating and/or shutting off due to excessive following error).

Acceleration plays a significant role in the magnitudes of the following error and overshoot, especially at start and stop. Rapid velocity changes represent very high acceleration, causing large following errors and overshoot. Use the smallest acceleration the application can tolerate to reduce overshoot and make tuning the PID filter easier.

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NOTE

In the following descriptions, it is assumed that a software utility is being used to capture the response of the servo loop during a motion step command, and to visualize the results.

6.2.1 Hardware and Software Requirements

Hardware Requirements

Tuning is best accomplished when the system response can be measured. This can be done with external monitoring devices but can introduce errors.

The ESP301 controller avoids this problem by providing an internal *tune* capability. When *tune* mode is activated, the controller records a number of different parameters. The parameters can include real instantaneous position, desired position, desired velocity, desired acceleration, DAC output value, etc.

The sample interval can be set to one servo cycle (400 µs) or any multiple of it and the total number of samples can be up to 1000 points.

This is a powerful feature that the user can take advantage of to get maximum performance out of the motion system.

Software Requirements

Users can write their own application(s) or use the ESP-tune-exe Windows utility.

Please refer to the description of ASCII command, "**DC**", to setup data acquisition.

6.2.2 Correcting Axis Oscillation

There are three parameters that can cause oscillation. The most likely to induce oscillation is **Ki,** followed by **Kp** and **Kd.** Start by setting **Ki** to zero and reducing **Kp** and **Kd** by 50%.

If oscillation does not stop, reduce **Kp** again.

When the axis stops oscillating, system response is probably very soft. The following error may be quite large during motion and non-zero at stop. Continue tuning the PID with the procedures described in the next paragraph.

6.2.3 Correcting Following Error

If the system is stable and the user wants to improve performance, start with the current PID parameters. The goal is to reduce following error during motion and to eliminate it at stop.

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Guidelines for further tuning (based on performance starting point and desired outcome) are provided in the following paragraphs.

Following Error Too Large

This is the case of a soft PID loop caused by low values for **Kp** and **Kd.** It is especially common after performing the procedures described in paragraph 6.2.2.

First increase **Kp** by a factor of 1.5 to 2. Repeat this operation while monitoring the following error until it starts to exhibit excessive ringing characteristics (more than 3 cycles after stop). To reduce ringing, add some damping by increasing the **Kd** parameter.

Increase it by a factor of 2 while monitoring the following error. As **Kd** is increased, overshoot and ringing will decrease almost to zero.

NOTE

Remember that if acceleration is set too high, overshoot cannot be completely eliminated with Kd.

If **Kd** is further increased, at some point oscillation will reappear, usually at a higher frequency. Avoid this by keeping **Kd** at a high enough value, but not so high as to re-introduce oscillation.

Increase **Kp** successively by approximately 20% until signs of excessive ringing appear again.

Alternately increase **Kd** and **Kp** until **Kd** cannot eliminate overshoot and ringing at stop. This indicates **Kp** is larger than its optional value and should be reduced. At this point, the PID loop is very tight.

Ultimately, optimal values for **Kp** and **Kd** depend on the stiffness of the loop and how much ringing the application can tolerate.

NOTE

The tighter the loop, the greater the risk of instability and oscillation when load conditions change.

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Errors At Stop (Not In Position)

If you are satisfied with the dynamic response of the PID loop but the stage does not always stop accurately, modify the integral gain factor **Ki.** As described in the Motion Control Tutorial section, the **Ki** factor of the PID works to reduce following error to near zero. Unfortunately it can also contribute to oscillation and overshoot. Change this parameter carefully, and if possible, in conjunction with **Kd.**

Start with the integral limit (**IL**) set to a high value and **Ki** value at least two orders of magnitude smaller than **Kp.** Increase its value by 50% at a time and monitor overshoot and final position at stop.

If intolerable overshoot develops, increase the **Kd** factor. Continue increasing **Ki, IL** and **Kd** alternatively until an acceptable loop response is obtained. If oscillation develops, immediately reduce **Ki** and **IL.**

Remember that any finite value for **Ki** will eventually reduce the error at stop. It is simply a matter of how much time is acceptable for the application. In most cases it is preferable to wait a few extra milliseconds to get to the stop in position rather than have overshoot or run the risk of oscillations.

Following Error During Motion

This is caused by a **Ki,** and **IL** value that is too low. Follow the procedures in the previous paragraph, keeping in mind that it is desirable to increase the integral gain factor as little as possible.

6.2.4 Points to Remember

- Use the Windows-based "ESP_tune.exe" utility to change PID parameters and to visualize the effect. Compare the results and parameters used with the previous iteration.
- The ESP301 controller uses a servo loop based on the PID with velocity and acceleration feed-forward algorithm.
- Use the lowest acceleration the application can tolerate. Lower acceleration generates less overshoot.
- Use the default values provided with the system for all standard motion devices as a starting point.
- Use the minimum value for **Ki,** and **IL** that gives acceptable performance. The integral gain factor can cause overshoot and oscillations.

A summary of servo parameter functions is listed in **Table 6.2.1.**

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Parameter	Function	Value Set Too Low	Value Set Too High
Kp	Determines stiffness of servo loop.	Servo loop too soft with high following errors	Servo loop too tight and/or causing oscillation
Kd	Main damping factor, used to eliminate oscillation	Uncompensated oscillation caused by other parameters being high	Higher-frequency oscillation and/or audible noise in the motor caused by large ripple in the motor voltage
Ki	Reduces following error during long motions and at stop	Stage does not reach or stay at the desired stop position	Oscillations at lower frequency and higher amplitude
Vff	Reduces following error during the constant velocity phase of a motion	Negative following error during the constant velocity phase of a motion. Stage lags the desired trajectory.	Positive following error during the constant velocity phase of a motion. Stage is ahead of the desired trajectory.
Aff	Reduces following error during the acceleration and deceleration phases of a motion	Negative following error during the acceleration phase of a motion. Stage lags the desired trajectory.	Position following error during the acceleration phase of a motion. Stage is ahead of the desired trajectory.

Table 6.1: Servo Parameter Functions

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Appendix A – Error Messages

The ESP301 controller has an elaborate command interpreter and system monitor. Every command is analyzed for syntax and correct format after it is received. The result of the analysis is stored in an output buffer in plain English. During moves and while idle, system inputs are monitored and any change is reported to the user via the output buffer. To read the contents of the output buffer, send the command **TB** (tell buffer).

For more compact error messages, use the **TE** command. The ESP301 controller response to this command is a one byte; binary coded error number, e.g., 33.

For the sake of convenience, error messages are divided into two categories – non-axis specific error messages and axis specific error messages. Below is a list of all possible ESP301 controller error messages that are not axis specific:

0 NO ERROR DETECTED
No errors exist in the output buffer.

1 PCI COMMUNICATION TIME-OUT
A communication transfer was initiated through PCI bus interface and was never completed.

2 Reserved for future use

3 Reserved for future use

4 EMERGENCY SOP ACTIVATED
An emergency stop was executed because the motion controller received a '#' character or "STOP ALL AXES" button was pressed.

5 Reserved for future use

6 COMMAND DOES NOT EXIST
The issued command does not exist. Check the Command Syntax.

7 PARAMETER OUT OF RANGE
The specified parameter is out of range. Refer to the description of issued command for valid parameter range.

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8 CABLE INTERLOCK ERROR
The 100-pin cable between motion controller board and driver is disconnected.

9 AXIS NUMBER OUT OF RANGE
The specified axis number is out of range. Refer to the description of issued command for valid axis number range.

10 Reserved for future use

11 Reserved for future use

12 Reserved for future use

13 GROUP NUMBER MISSING
Group number is not specified. The issued command requires a valid group number. Refer to the description of issued command for valid group number range.

14 GROUP NUMBER OUT OF RANGE
The specified group number is out of range. Refer to the description of issued command for valid group number range.

15 GROUP NUMBER NOT ASSIGNED
The specified group has not been assigned. Refer to the description of **HN** command to create a new group with this group number.

16 GROUP NUMBER ALREADY ASSIGNED
The specified group number has already been assigned. Refer to the description of **HB** command to query the list of group numbers already assigned.

17 GROUP AXIS OUT OF RANGE
At least one of the axis numbers specified to be a member of this group is out of range. Refer to the description of **HN** command for valid range of axis numbers that can be assigned to a group.

18 GROUP AXIS ALREADY ASSIGNED
At least one of the axis numbers specified to be a member of this group is already a member of a different group.

19 GROUP AXIS DUPLICATED
At least one of the axis numbers is specified to be a member of this group more than once.

20 DATA ACQUISITION IS BUSY
Data acquisition is not yet complete.

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21 DATA ACQUISITION SETUP ERROR
An error occurred during data acquisition setup. Ensure that data acquisition is disabled and all parameters are within valid range before issuing the command. Refer to the command description for valid range of parameters.

22 DATA ACQUISITION NOT ENABLED
Data acquisition is not yet enabled.

23 SERVO CYCLE (400 µS) TICK FAILURE
There was a failure to increment the servo tick in the Interrupt Service Routine (ISR) that manages motion control.

24 Reserved for future use

25 DOWNLOAD IN PROGRESS
Firmware download is in progress.

26 STORED PROGRAM NOT STARTED
An attempt was made to execute a stored program and the program could not be started.

27 COMMAND NOT ALLOWED
The issued command is not valid in the context in which it was issued.

28 STORED PROGRAM FLASH AREA FULL
The flash area reserved for stored programs is full.

29 GROUP PARAMETER MISSING
At least one parameter is missing. Refer to the description of issued command for valid number of parameters.

30 GROUP PARAMETER OUT OF RANGE
The specified group parameters is out of range. Refer to the description of issued command for valid range of parameter.

31 GROUP MAXIMUM VELOCITY EXCEEDED
The specified group velocity exceeds the minimum of the maximum velocities of members of this group. Refer to the description of **HV** command for more details.

32 GROUP MAXIMUM ACCELERATION EXCEEDED
The specified group acceleration exceeds the minimum of the maximum acceleration of members of this group. Refer to the description of **HA** command for more details.

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33 GROUP MAXIMUM DECELERATION EXCEEDED
The specified group deceleration exceeds the minimum of the maximum decelerations of members of this group. Refer to the description of **HD** command for more details.

34 GROUP MOVE NOT ALLOWED DURING MOTION
Cannot make a coordinated move when one of the members of the group is being "homed".

35 PROGRAM NOT FOUND
The issued command could not be executed because the stored program requested is not available.

36 Reserved for future use

37 AXIS NUMBER MISSING
Axis number not specified. The issued command requires a valid axis number. Refer to the description of issued command for valid axis number range.

38 COMMAND PARAMETER MISSING
At least one parameter associated with this command is missing. Refer to the description of issued command for valid number of parameters.

39 PROGRAM LABEL NOT FOUND
The issued command could not be executed because the requested label within a stored program is not available.

40 LAST COMMAND CANNOT BE REPEATED
An attempt was made to repeat the last (previous) commanded by just sending a carriage return. This feature is not allowed for commands that carry strings in addition to the two-letter ASCII mnemonic. Issue the last command again.

41 MAX NUMBER OF LABELS PER PROGRAM EXCEEDED
The number of labels used in the stored program exceeds the allowed value.

Below is a list of all possible error messages that are axis specific. Here, "x" represents the axis number.

x00 MOTOR TYPE NOT DEFINED
A valid motor type was not defined for the requested axis. Refer to the description of **QM** command to define a motor type.

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x01 PARAMETER OUT OF RANGE
The specified parameter is out of range. Refer to the description of issued command for valid parameter range.

x02 AMPLIFIER FAULT DETECTED
There was an amplifier fault condition.

x03 FOLLOWING ERROR THRESHOLD EXCEEDED
The real position of specified axis was lagging the desired position by more encoder counts than specified with the **FE** command. Refer to the description of **ZF** command to configure the motion controller tasks upon encountering a following error.

x04 POSITIVE HARDWARE LIMIT DETECTED
The motion controller sensed a high level at its positive travel limit input. Refer to the description of **ZH** command to configure the motion controller tasks upon encountering a hardware limit.

x05 NEGATIVE HARDWARE LIMIT DETECTED
The motion controller sensed a high level at its negative travel limit input. Refer to the description of **ZH** command to configure the motion controller tasks upon encountering a hardware limit.

x06 POSITIVE SOFTWARE LIMIT DETECTED
The motion controller sensed that the axis has reached positive software travel limit. Refer to the description of **SR** command to specify the desired positive software travel limit. Also, refer to thew description of **ZS** command to configure the motion controller tasks upon encountering a software limit.

x07 NEGATIVE SOFTWARE LIMIT DETECTED
The motion controller sensed that the axis has reached negative software travel limit. Refer to the description of **SL** command to specify the desired negative software travel limit. Also, refer to the description of **ZS** command to configure the motion controller tasks upon encountering a software limit.

x08 MOTOR / STAGE NOT CONNECTED
The specified axis is not connected to the driver.

x09 FEEDBACK SIGNAL FAULT DETECTED
There was a feedback signal fault condition. Ensure that the encoder feedback is relatively noise free.

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x10 MAXIMUM VELOCITY EXCEEDED
The specified axis velocity exceeds maximum velocity allowed for the axis. Refer to the description of **VU** command or set maximum velocity for the axis.

x11 MAXIMUM ACCELERATION EXCEEDED
The specified axis acceleration exceeds maximum acceleration allowed for the axis. Refer to the description of **AU** command to query or set maximum acceleration or deceleration for the axis.

x12 Reserved for future use

x13 MOTOR NOT ENABLED
A command was issued to move an axis that was not powered ON. Refer to the description of **MO** and **MF** commands to turn the power to an axis ON or OFF respectively.

x14 Reserved for future use

x15 MAXIMUM JERK EXCEEDED
The specified axis jerk exceeds maximum jerk allowed for the axis. Refer to the description of **JK** command for valid jerk range.

x16 MAXIMUM DAC OFFSET EXCEEDED
The specified axis DAC offset exceeds maximum value allowed for the axis. Refer to the description of issued command for valid range.

x17 ESP CRITICAL SETTINGS ARE PROTECTED
An attempt was made to modify parameters that are specific to smart stages or "Unidriver".

x18 ESP STAGE DEVICE ERROR
An error occurred while reading a smart stage.

x19 ESP STAGE DATA INVALID
Smart stage data is invalid.

x20 HOMING ABORTED
Axis home search was aborted. This message is obtained when home search was not completed either due to an axis not being enabled or due to the occurrence of a fault condition. Refer to the description of **OR** command for information related to locating the home position of an axis.

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x21 MOTOR CURRENT NOT DEFINED
Maximum current for the motor is not specified. Refer to the description of **QI** command to query or set the maximum motor current for an axis.

x22 UNIDRIVE COMMUNICATIONS ERROR
There was no communication between motion controller and the Unidriver.

x23 UNIDRIVE NOT DETECTED
Unidrive could not be detected by the motion controller.

x24 SPEED OUT OF RANGE
The specified home search speed is out of range. Refer to the description of **OH** command for valid home search speed range.

x25 INVALID TRAJECTORY MASTER AXIS
The specified trajectory mode in not valid for a master axis. Refer to the description if **TJ** command to specify a valid trajectory mode for a master axis.

x26 PARAMETER CHARGE NOT ALLOWED
The specified parameter cannot be changed while the axis is in motion. Wait until the axis motion is complete, and issue this command again. Refer to the description of **MD** command to determine if motion is done.

x27 INVALID TRAJECTORY MODE FOR HOMING
The specified trajectory mode is not valid for locating the home position of the axis. Refer to the description of **TJ** command to specify a valid trajectory mode for locating the home position of this axis.

x28 INVALID ENCODER STEP RATIO
The specified full step resolution is invalid. Refer to the description of **FR** command for valid range of full step resolution.

x29 DIGITAL I/O INTERLOCK DETECTED
A DIO interlock was asserted.

x30 COMMAND NOT ALLOWED DURING HOMING
The command issued was not executed because locating the home position of this axis is in progress. Refer to the description of the issued command for further details.

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x31 COMMAND NOT ALLOWED DUE TO GROUP ASSIGNMENT

The specified command was not executed because this axis is member of a group. Refer to the description of issued command for further details.

x32 INVALID TRAJECTORY MODE FOR MOVING

The specified trajectory mode is invalid to make absolute or relative moves. Refer to the description of **PA** and **PR** commands for valid trajectory modes to initiate motion.

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Appendix B – Trouble-Shooting / Maintenance

There are no user-serviceable parts or user adjustments to be made to the ESP301 controller/driver.



Procedures are to be performed only by qualified service personnel. Qualified service personnel should be aware of the shock hazards involved when instrument covers are removed and should observe the following precautions before proceeding.

- **Turn off power switch and unplug the unit from its power source**
- **Disconnect cables if their function is not understood**
- **Remove jewelry from hands and wrist**
- **Expect hazardous voltages to be present in any unknown circuits.**



CAUTION

Verify proper alignment before inserting connectors.

Refer to Appendix H, Factory Service, for information about repair or other hardware corrective action.

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B.1 Trouble-Shooting Guide

A list of the most common problems and their corrective actions is provided in **Table B.1.** Use it as a reference but remember that a perceived error is open to an operator error or has some other simple solution.

PROBLEM	CAUSE	CORRECTIVE ACTION
Display does not come on.	Power switch is turned off.	Turn on the main power switch located on the front panel.
	No electrical power	Verify with an adequate tester or another electrical device (lamp, etc.) that power is present in the outlet. If not, contact an electrician to correct the problem.
	Power cord not plugged in.	Plug the power cord in the appropriate outlet. Observe all caution notes and procedures described in the System Setup section.
Error message or physically present stage is declared unconnected.	Bad connection.	Turn power off and verify the motion device connection.
	Bad component/ step/ cable	Turn power off and swap the motor cable with another axis (if cables are identical) to locate the problem. Contact Newport for cable replacement or motion device service.
	Safety control connector on the rear of the ESP301 is missing.	Plug connector in. If the connector was lost, you can either build one as shown in System Setup in Appendix C.1.8, or call Newport for a replacement.
Red LED above STOP ALL button remains on.	Power button on the display does not appear when motor power button is pressed.	Verify that the motion device is connected.
Motor can not be turned on.		

Table B.1: Trouble-Shooting Guide Descriptions

PROBLEM	CAUSE	CORRECTIVE ACTION
Excessive following error.	Wrong setup, load specification exceeded.	Verify that all setup parameters correspond to the actual motion device installed.
		Verify that the load specifications for the motion device are not being exceeded.

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Axis does not move.	Incorrect connection.	Verify that the motion device is connected to the correct driver card, as specified by the labels.
	Incorrect parameters.	Verify that the motion device is connected to the correct driver card, as specified by the labels.
System performance below	Incorrect connection.	Verify that the motion device is connected to the correct driver card, as specified by the labels.
	Incorrect parameters.	Verify that all relevant parameters (PID, velocity, etc.) are set properly.
Move command not executed.	Software travel limit	The software limit (See **SL** command) if the specified direction was reached. If limits are set correctly, do not try to move past them.
	Incorrect parameters	Verify that all relevant parameters (PID, velocity, etc.) are set
Home search not completed.	Faulty origin or index signals.	Carefully observe and record the motion sequence by watching manual knob rotation, if available. With the information collected, call Newport for assistance.
	Wrong line terminator.	Make sure that the computer and the controller use the same line terminator.
	No remote communication, wrong communication port.	Verify that the controller is set to communicate on the right port, RS-232 or IEEE488.
	Wrong communication parameters.	Verify that all communication parameters match between the computer and the controller.

Table B.1: Trouble-Shooting Guide Descriptions (Continued)

NOTE

Many problems are detected by the controller and reported on the display and/or in the error register. Consult Appendix A, Error Messages, for a complete list and description.

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B.2 Cleaning

Clean the exterior metallic surfaces of the ESP301 with water and a clean, lint-free cloth. Clean external cable surfaces with alcohol, using a clean, lint-free cloth.



WARNING

Power-down all equipment before cleaning.



CAUTION

Do not expose connectors, fans, LEDs, or switches to alcohol or water.

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Appendix C – Connector Pin Assignments

C.1 ESP301 Rear Panel

C.1.1 GPIO Connector (37-Pin D-Sub)

This connector is dedicated to the digital I/O ports. All I/O are pulled up to +5V DC with 4.7KΩ resistors. Maximum sink or source current is 32 mA (bits). Connector pin-outs are listed in **Table C.1,** and functionally described in the following paragraphs.

C.1.2 Signal Descriptions (Digital I/O, 37-Pin, JP4 Connector)

+5V, 100mA (maximum)
+5V supply

+15V, 25mA (maximum)
+15V supply

Digital I/O
The digital I/O can be programmed to be either input or output (in 8-bit blocks) via software.

DGND
Digital Ground used for all digital signals.

Pin #	Description
1	+15V, 25mA
2	+15V, 25mA
3	+5V, 100mA
4	Digital Input/Output 1
5	Digital Input/Output 2
6	Digital Input/Output 3
7	Digital Input/Output 4
8	Digital Input/Output 5
9	Digital Input/Output 6
10	Digital Input/Output 7
11	Digital Input/Output 8
12	Digital Input/Output 9
13	Digital Input/Output 10
14	Digital Input/Output 11
15	Digital Input/Output 12

Table C.1: Digital Connector Pin-Outs

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Pin #	Description
16	Digital Input/Output 13
17	Digital Input/Output 14
18	Digital Input/Output 15
19	Digital Input/Output 16
20	DGND
21	DGND
22	DGND
23	DGND
24	DGND
25	DGND
26	DGND
27	DGND
28	DGND
29	DGND
30	DGND
31	DGND
32	DGND
33	DGND
34	DGND
35	DGND
36	DGND
37	DGND

Table C.1: Digital Connector Pin-Outs (Continued)

C.1.3 Motor Driver Card (25-Pin) I/O Connector

This connector interfaces an ESP301 driver card to motorized stages. Cabling to the connector is provided with the applicable stage. Connector pin-outs are listed in **Table C.2.**

Pins	2 Phase Stepper Motor	DC Motor
1	Stepper Phase 1	Tachometer (+)
2	Stepper Phase 1	Tachometer (+)
3	Stepper Phase 2	Tachometer (-)
4	Stepper Phase 2	Tachometer (-)
5	Stepper Phase 3	DC Motor Phase (+)
6	Stepper Phase 3	DC Motor Phase (+)
7	Stepper Phase 4	DC Motor Phase (-)
8	Stepper Phase 4	DC Motor Phase (-)
9	Common Phase 3,4	N/C
10	N/C	N/C
11	Common Phase 1,2	N/C
12	N/C	N/C
13	Home Signal	Home Signal
14	Shield Ground	Shield Ground
15	Encoder Index (+)	Encoder Index (+)
16	Limit Ground	Limit Ground
17	Travel Limit (-) Input	Travel Limit (+) Input
18	Travel Limit (-) Input	Travel Limit (-) Input
19	Encoder Channel A (+)	Encoder Channel A (+)

Table C.2: Driver Card Connector Pin-Outs

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Pins	2 Phase Stepper Motor	DC Motor
20	Encoder Channel B (+)	Encoder Channel B (+)
21	Encoder Supply: +5V	Encoder Supply: +5V
22	Encoder Ground	Encoder Ground
23	Encoder Channel A (-)	Encoder Channel A (-)
24	Encoder Channel B (-)	Encoder Channel B (-)
25	Encoder Index (-)	Encoder Index (-)

Table C.2: Driver Card Connector Pin-Outs (Continued)

C.1.4 Signal Descriptions (Motor Driver Card, 25-Pin I/O Connector)

DC Motor Phase(+) Output

This output must be connected to the positive lead of the DC motor. The voltage seen at this pin is pulse-width modulated with a maximum amplitude of 48V DC.

DC Motor Phase(-) Output

This output must be connected to the negative lead of the DC motor. The voltage seen at this pin is pulse-width modulated with a maximum amplitude of 48V DC.

Stepper Motor Phase 1 Output

This output must be connected to Winding A+ lead of a two-phase stepper motor. The voltage seen at this pin is pulse-width modulated with a maximum amplitude of 48V DC.

Stepper Motor Phase 2 Output

This output must be connected to Winding A- lead of a two-phase stepper motor. The voltage seen at this pin is pulse-width modulated with a maximum amplitude of 48V DC.

Stepper Motor Phase 3 Output

This output must be connected to Winding B+ lead of a two-phase stepper motor. The voltage seen at this pin is pulse-width modulated with a maximum amplitude of 48V DC.

Stepper Motor Phase 4 Output

This output must be connected to Winding B- lead of a two-phase stepper motor. The voltage seen at this pin is pulse-width modulated with a maximum amplitude of 48V DC.

Common Phase 3,4

This output can be connected to the center tab of Winding B of a two-phase stepper motor. The voltage seen at this pin is pulse-width modulated with maximum amplitude of 48V DC.

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Common Phase 1,2

This output can be connected to the center tab of Winding B of a two-phase stepper motor. The voltage seen at this pin is pulse-width modulated with a maximum amplitude of 48V DC.

Travel Limit(+) Input

This input is pulled-up to +5V with a 4.7KΩ resistor by the controller and represents the stage negative direction hardware travel limit. The active true state is user-configurable. (default is active HIGH).

Travel Limit(-) Input

This input is pulled-up to +5V with a 4.7KΩ resistor by the controller and represents the stage negative direction hardware travel limit. The active true state is user-configurable (default is active HIGH).

Encoder A(+) Input

The A(+) input is pulled-up to +5V with a 1KΩ resistor. The signal is buffered with a 26LS32 differential receiver. The A(+) encoder encoded signal originates from the stage position feedback circuitry and is used for position tracking.

Encoder A(-) Input

The A(-) input is pulled-up to +5V and pulled down to ground with 1KΩ resistors. This facilitates both single- and double-ended signal handling into a 26LS32 differential receiver. The A(-) encoder encoded signal originates from the stage position feedback circuitry and is used for position tracking.

Encoder B(+) Input

The B(+) input is pulled-up to +5V with a 1KΩ resistor. The signal is buffered with a 26LS32 differential receiver. The B(+) encoder encoded signal originates from the stage position feedback circuitry and is used for position tracking.

Encoder B(-) Input

The B(-) input is pulled-up to +5V and pulled down to ground with 1KΩ resistors. This facilitates both single- and double-ended signal handling into a 26LS32 differential receiver. The B(-) encoder encoded signal originates from the stage position feedback circuitry and is used for position tracking.

Encoder Ground

Ground reference for encoder feedback.

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Home Input

This input is pulled-up to +5V with a 1KΩ resistor by the controller. The Home signal originates from the stage and is used for homing the stage to a repeatable location.

Index(+) Input

The (+) Index input is pulled-up to +5V with a 1KΩ resistor by the controller and is buffered with a 26LS32 differential receiver. The (+) Index signal originates from the stage and is used for homing the stage to a repeatable location.

Index(-) Input

The (-) Index input is pulled-up to +5V and pulled down to ground with 1KΩ resistors by the controller. This facilitates both single- and double-ended signal handling into a 26LS32 differential receiver. The (-) Index signal originates from the stage and is used for homing the stage to a repeatable location.

Encoder Supply: +5V, 250mA (Maximum)

A +5V DC supply is available from the ESP301. This supply is provided for stage home, index, travel limit, and encoder feedback circuitry.

Limit Ground

Ground for stage travel limit signals. Limit ground is combined with digital ground at the controller side.

Shield Ground

Motor cable shield ground.

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C.1.5 IEEE488 Interface Connector (24 Pin)

The IEEE488 Interface Connector has a standard configuration, as shown in **Table C.3.**

Description	Pin #	Pin #	Description
DIO1	1	13	DIO5
DIO2	2	14	DIO6
DIO3	3	15	DIO7
DIO4	4	16	DIO8
EOI	5	17	REN
DAV	6	18	GND
NRFD	7	19	GND
NDAC	8	20	GND
IFC	9	21	GND
SRQ	10	22	GND
ATN	11	23	GND
SIELD	12	24	SIGNAL GND

Table C.3: IEEE488 Interface Connector

C.1.6 RS-232C Interface Connector (9-Pin D-Sub)

The RS-232C interface uses a 9-pin sub-F connector. The back panel connector pin-out is shown in **Figure C.1.**

Pin No. Description
1 ---------- DCD
2 ---------- TXD
3 ---------- RXD
4 ---------- DTR
5 ---------- GRD
6 ---------- DSR
7 ---------- RTS
8 ---------- CTS
9 ---------- RI

Figure C.1: RS-232C Connector Pin-Out

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C.1.7 RS-232C Interface Cable

Figure C.2 shows a simple straight through, pin-to-pin cable with 9 conductors that can be used to connect to a standard 9 pin RS232 host.

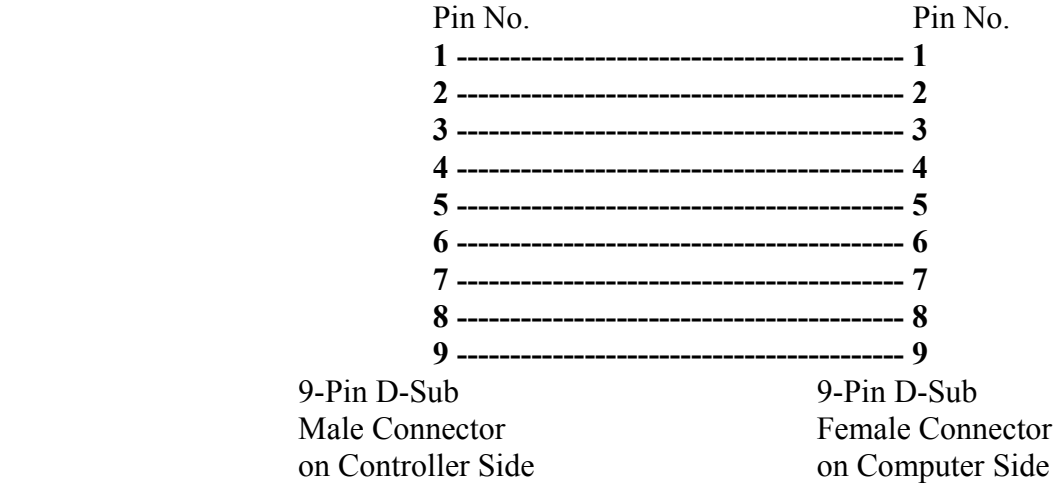


Figure C.2: Conductor, pin-to-pin RS-232C interface cable

C.1.8 USB Interface Connector (4-Pin Type B)

The RS-232C interface uses a 9-pin sub-F connector. The back panel connector pin-out is shown in **Figure C.3.**

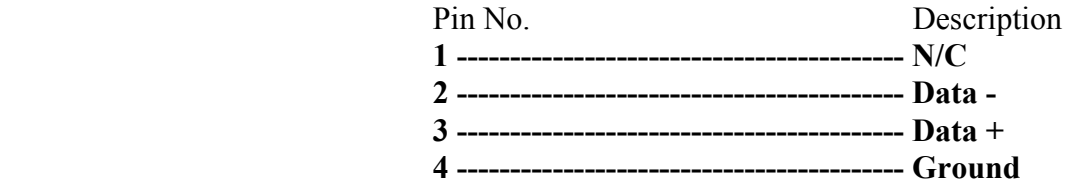


Figure C.3: RS-232C Connector Pin-Out

C.1.9 USB Interface Cable

Figure C.4 shows a simple straight through, pin-to-pin cable with 4 conductors that can be used to connect to a standard 4 pin USB Type A host. The ESP301 has a Type B USB connector.

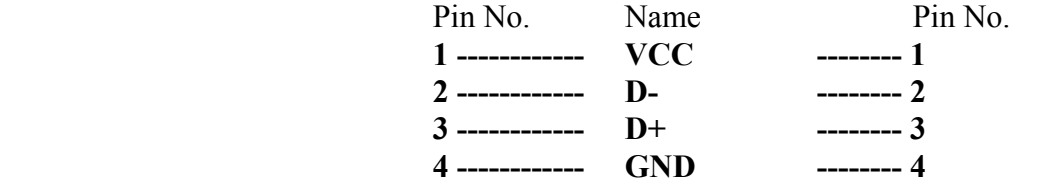


Figure C.4: Conductor, pin-to-pin USB interface cable

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C.1.10 Motor Interlock Connector (BNC)

This connector is provided for the wiring of one or more remote MOTOR ON/OFF. It will have the same effect as the front panel MOTOR ON/OFF button.

The switch has to be normally closed for operation. If more than one switch is installed, they should be connected in series. The minimum rating for the switches should be **50mA** at **5V.**

The ESP301 is supplied with a dust cap that automatically provides the proper connection for operation if no switch is connected

(See **Figure C.3**).

Pin #	Description
Center Pin	Input MOTOR ON/OFF must always be connected to the shell (GND) during normal controller operation. An open circuit is equivalent to pressing MOTOR ON/OFF on the front panel.
Connector Shield	Provides GND for switch

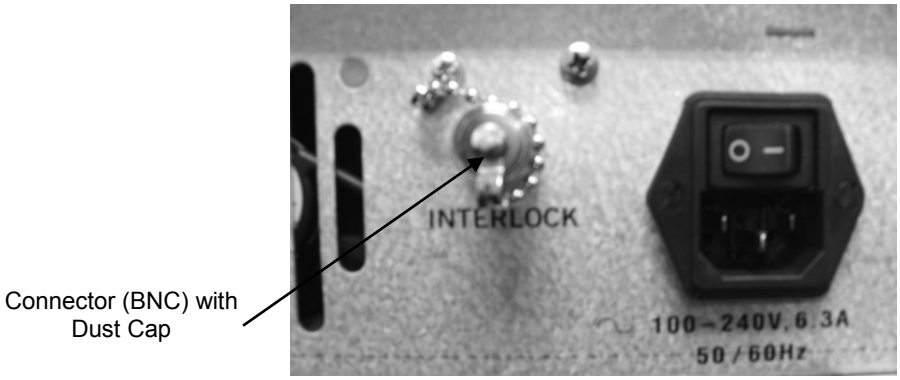


Figure C.3: Motor Interlock Connector (BNC) with dust cap

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Appendix D – Binary Conversion Table

Some of the status reporting commands return an ASCII character that must be converted to binary. To aid with the conversion process, the following table converts all character used and some other common ASCII symbols to decimal and binary. To also help in working with the I/O port related commands, the table is extended to a full byte, all 256 values.

Number (decimal)	ASCII Code	Binary Code
0	*Null*	00000000
1	*Soh*	00000001
2	*Stx*	00000010
3	*Etx*	00000011
4	*Eot*	00000100
5	*Enq*	00000101
6	*Ack*	00000110
7	*Bel*	00000111
8	*Bs*	00001000
9	*Tab*	00001001
10	*Lf*	00001010
11	*Vt*	00001011
12	*Ff*	00001100
13	*Cr*	00001101
14	*So*	00001110
15	*Si*	00001111
16	*Dle*	00010000
17	*Dc1*	00010001
18	*Dc2*	00010010
19	*Dc3*	00010011
20	*Dc4*	00010100
21	*Nak*	00010101
22	*Syn*	00010110
23	*Eth*	00010111
24	*Can*	00011000
25	*Em*	00011001
26	*Eof*	00011010
27	*Esc*	00011011
28	*Fs*	00011100
29	*Gs*	00011101
30	*Rs*	00011110

Table D.1: Binary Conversion Table (using decimal and ASCII codes)

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Number (decimal)	ASCII Code	Binary Code
31	*Us*	00011111
32	*Space*	00100000
33	**!**	00100001
34	**"**	00100010
35	**#**	00100011
36	**$**	00100100
37	**%**	00100101
38	**&**	00100110
39	**'**	00100111
40	**(**	00101000
41	**)**	00101001
42	*****	00101010
43	+	00101011
44	**,**	00101100
45	**-**	00101101
46	**.**	00101110
47	/	00101111
48	**0**	00110000
49	**1**	00110001
50	**2**	00110010
51	**3**	00110011
52	**4**	00110100
53	**5**	00110101
54	**6**	00110110
55	**7**	00110111
56	**8**	00111000
57	**9**	00111001
58	**:**	00111010
59	**;**	00111011
60	<	00111100
61	=	00111101
62	>	00111110
63	**?**	00111111
64	@	01000000
65	**A**	01000001
66	**B**	01000010
67	**C**	01000011
68	**D**	01000100
69	**E**	01000101
70	**F**	01000110
71	**G**	01000111
72	**H**	01001000
73	**I**	01001001
74	**J**	01001010
75	**K**	01001011
76	**L**	01001100
77	**M**	01001101
78	**N**	01001110
79	**O**	01001111

Table D.1: Binary Conversion Table (using decimal and ASCII Codes) (Continued)

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Number (decimal)	ASCII Code	Binary Code
80	**P**	01010000
81	**Q**	01010001
82	**R**	01010010
83	**S**	01010011
84	**T**	01010100
85	**U**	01010101
86	**V**	01010110
87	**W**	01010111
88	**X**	01011000
89	**Y**	01011001
90	**Z**	01011010
91	**[**	01011011
92	\	01011100
93	**]**	01011101
94	^	01011110
95	_	01011111
96	'	01100000
97	**A**	01100001
98	**B**	01100010
99	**C**	01100011
100	**D**	01100100
101	**E**	01100101
102	**F**	01100110
103	**G**	01100111
104	**H**	01101000
105	**I**	01101001
106	**J**	01101010
107	**K**	01101011
108	**L**	01101100
109	**M**	01101101
110	**N**	01101110
111	**O**	01101111
112	**P**	01110000
113	**Q**	01110001
114	**R**	01110010
115	**S**	01110011
116	**T**	01110100
117	**U**	01110101
118	**V**	01110110
119	**W**	01110111
120	**X**	01111000
121	**Y**	01111001
122	**Z**	01111010
123	{	01111011
124	|	01111100
125	}	01111101
126	~	01111110
127		01111111
128		10000000

Table D.1: Binary Conversion Table (using decimal and ASCII codes) (Continued)

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Number (decimal)	ASCII Code	Binary Code
129		10000001
130		10000010
131		10000011
132		10000100
133		10000101
134		10000110
135		10000111
136		10001000
137		10001001
138		10001010
139		10001011
140		10001100
141		10001101
142		10001110
143		10001111
144		10010000
145		10010001
146		10010010
147		10010011
148		10010100
149		10010101
150		10010110
151		10010111
152		10011000
153		10011001
154		10011010
155		10011011
156		10011100
157		10011101
158		10011110
159		10011111
160		10100000
161		10100001
162		10100010
163		10100011
164		10100100
165		10100101
166		10100110
167		10100111
168		10101000
169		10101001
170		10101010
171		10101011
172		10101100
173		10101101
174		10101110
175		10101111
176		10110000
177		10110001

Table D.1: Binary Conversion Table (Using decimal and ASCII codes) (Continued)

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Number (decimal)	ASCII Code	Binary Code
178		10110010
179		10110011
180		10110100
181		10110101
182		10110110
183		10110111
184		10111000
185		10111001
186		10111010
187		10111011
188		10111100
189		10111101
190		10111110
191		10111111
192		11000000
193		11000001
194		11000010
195		11000011
196		11000100
197		11000101
198		11000110
199		11000111
200		11001000
201		11001001
202		11001010
203		11001011
204		11001100
205		11001101
206		11001110
207		11001111
208		11010000
209		11010001
210		11010010
211		11010011
212		11010100
213		11010101
214		11010110
215		11010111
216		11011000
217		11011001
218		11011010
219		11011011
220		11011100
221		11011101
222		11011110
223		11011111
224		11100000
225		11100001
226		11100010

Table D.1: Binary Conversion Table (using decimal and ASCII codes) (Continued)

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Number (decimal)	ASCII Code	Binary Code
227		11100011
228		11100100
229		11100101
230		11100110
231		11100111
232		11101000
233		11101001
234		11101010
235		11101011
236		11101100
237		11101101
238		11101110
239		11101111
240		11110000
241		11110001
242		11110010
243		11110011
244		11110100
245		11110101
246		11110110
247		11110111
248		11111000
249		11111001
250		11111010
251		11111011
252		11111100
253		11111101
254		11111110
255		11111111

Table D.1: Binary Conversion Table (using decimal and ASCII codes) (Continued)

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Appendix E – System Upgrades

The modular design of the ESP301 makes it easy for qualified individuals to upgrade the unit in the field. Upgrade kits to add more axis, IEEE488 are available upon request. Call Newport support for details.

This section describes how to upgrade an ESP301 from 2 to 3 axes. Other axes upgrades can be performed accordingly.

WARNING

Opening or removing covers will expose you to hazardous voltages.

Refer all servicing internal to this controller enclosure to qualified service personnel who should observe the following precautions before proceeding:



- **Turn power OFF and unplug the unit from its power source**
- **Disconnect all cables**
- **Remove any jewelry from hands and wrists**
- **Use only insulated hand tools**
- **Maintain grounding by wearing a wrist strap attached to instrument chassis.**

CAUTION



The ESP contains static sensitive devices. Exercise appropriate caution when handling ESP301 boards, cables and other internal components.

CAUTION



Do not install anything into your ESP301 except items provided by Newport specifically for installation into the ESP301.

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E.1 Adding Axes

1. Turn the power off and unplug the power cord from the controller. Disconnect all cables from the controller.
2. Remove the 2 screws as shown below. See **Figure E.1,** which shows how to remove the cover.

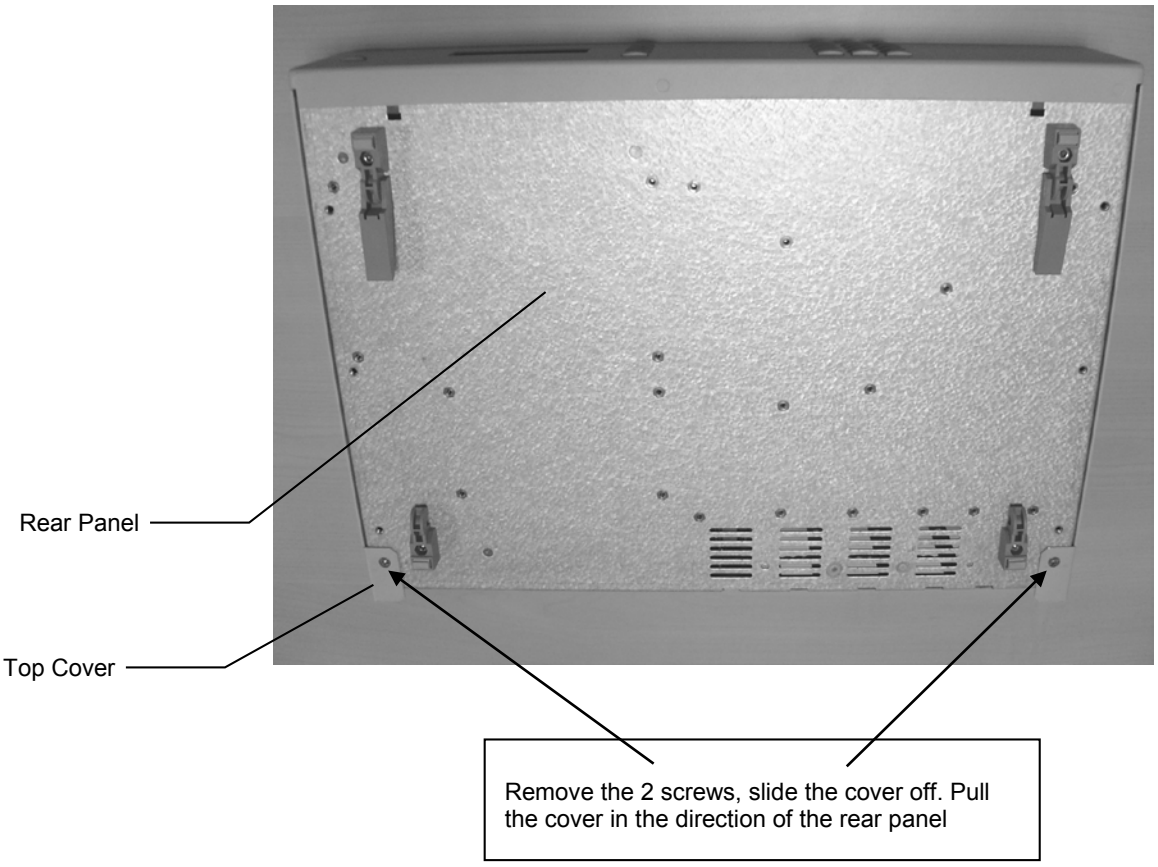


Figure E.1: Removal of the Top Cover

3. Carefully remove the top cover.
4. Insert the driver module for the respective axis. The connector of the driver module is keyed to prevent insertion with improper polarity. Make sure the keys line up properly before you try to insert the module (See **Figure E.2**).
5. Attach the driver panel to the rear panel of the unit with the two supplied screws.
6. Re-install the top cover.

The unit is now ready for use.

IEEE-488 Driver Module

Axis 1 Axis 2 Axis 3

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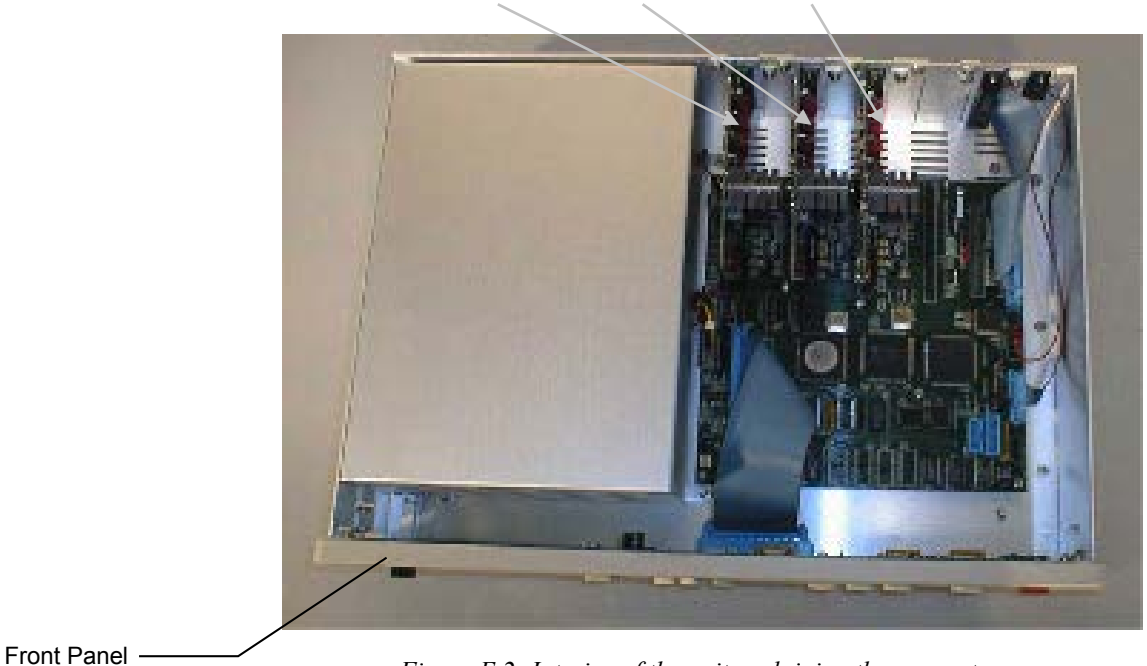


Figure E.2: Interior of the unit explaining the connectors

E.2 Adding IEEE488

1. Follow steps 1 – 3 adding axes.
2. Insert the IEEE-488 driver module in the connector. The connector of the module is keyed to prevent insertion with improper polarity. Make sure the keys line up properly before you try to insert the module.
3. Attach the IEEE-488 panel to the rear panel of the unit with the two supplied screws.
4. Re-install the top cover.

The unit is now ready for use.

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Appendix F – ESP Configuration Logic

Each time a stage or stages are disconnected/re-connected, or a system is powered down and then powered back up, the ESP301 controller card verifies the type of stage(s) present and re-configures its own flash memory if necessary (i.e., new stage). The controller card in the ESP301 system configuration, the stage motor and the current type are defined, the controller card will configure the specific axis. Specific ESP logic is shown in **Figure F.1.**



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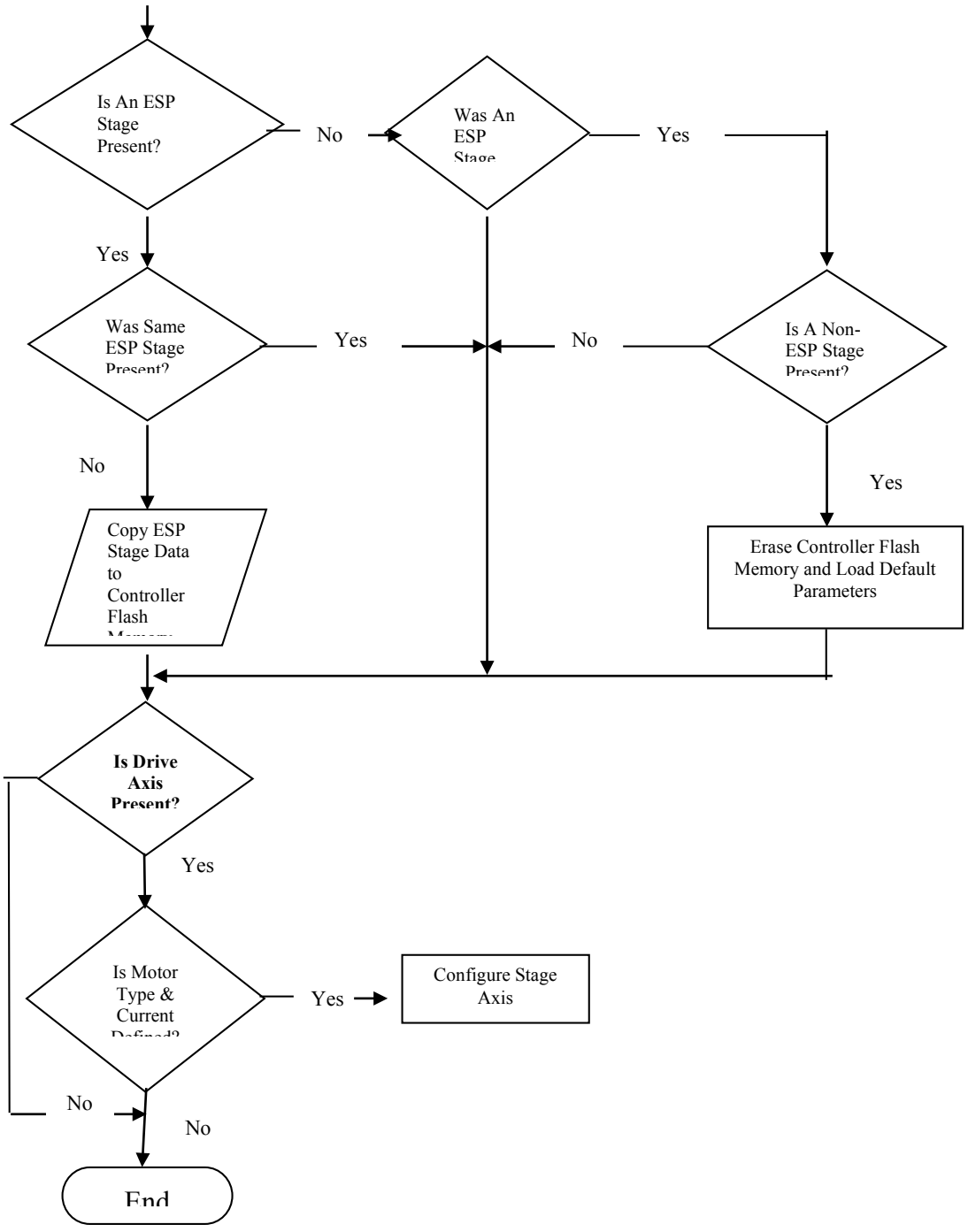


Figure F.1: Configuration Logic

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Appendix G – Programming Non-ESP Compatible Stages

Newport positioners, or stages, with integrated configuration memory devices are said to be "ESP Compatible". It is not necessary to manually enter individual stage parameters (E.G., motor current, maximum velocity, etc.) with an ESP compatible stage. All necessary configuration settings will be automatically loaded after system reset with ESP compatible positioners.

When a positioner is said to be ESP incompatible, all that really means is that it does not have the integrated memory device that allows for automatic configuration. Therefore, it will have to be configured manually – as is customary with all non-ESP controllers.

There are two (2) basic levels of positioner configuration. The first level assumes that the stage is Newport controller compatible. That is to say that hardware travel limits, encoder feedback counting, etc… are designed to operate with Newport controllers. In this case only a certain amount of commands are necessary to setup the axis before moving the stage. The second level is when a stage is not a standard Newport stage and various compatibility issues need to be addressed. This scenario requires additional command configurations.

The following are examples of how to configure an ESP controller axis for a standard Newport stage that is not equipped with the "ESP Compatible" memory device (i.e., level 1):

Example #1: DC Servo on axis 1

1qm1	//set motor type to DC servo
1qi0.15	//set motor maximum current to 0.15 amps
1qv30	//set motor voltage to 30 volts
1sn7	//set user units to degrees
1su0.005	//set resolution to 0.005 degrees
1vu15	//set maximum velocity to 15 deg/sec
1va7	//set working velocity to 7 deg/sec
1oh7	//set homing speed to 7 deg/sec
1jh7	//set jog high speed to 7 deg/sec
1jw1	//set jog low speed to 1 deg/sec
1au40	//set maximum acceleration to 40 deg/sec^2
1ac20	//set working acceleration to 20 deg/sec^2
1ag25	//set deceleration to 25 deg/sec^2

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```
1fe0.5      //set following error threshold to 0.5 deg
1kp600      //set PID proportional gain to 600
1kd600      //set PID derivative gain to 600
1ki350      //set PID integral gain to 350
1ks300      //set PID integral saturation gain to 300
1tj1        //set trajectory mode to trapezoidal
1qd         //update motor driver configuration
sm          //save configuration to non-volatile memory
```

Example #2: Stepper stage on axis 1

```
1qm3        //set motor type to commutated stepper
            (ESP301 only)
1qi 1       //set motor maximum current to 1 amp
1qv30       //set motor voltage to 30 volts
1sn2        //set user units to millimeters
1su0.001    //set resolution to 1 micron
1fr0.01     //set stepper motor full step resolution to 10 micron
1qs100      //set micro-stepping resolution to 100x
1vu20       //set maximum velocity to 20 mm/sec
1va10       //set working velocity to 10 mm/sec
1jh10       //set jog high velocity to 10 mm/sec
1jw1        //set jog low velocity to 1 mm/sec
1oh10       //set Homing velocity to 10 mm/sec
1au50       //set maximum acceleration to 50 mm/sec2
1 ac 50     //set acceleration to 30 mm/sec2
1ag30       //set deceleration to 30 mm/sec2
1fe1        //set following error threshold to 1 mm
1tj1        //set trajectory mode to trapezoidal
1qd         //update motor driver configuration
sm          //save configuration to non-volatile memory
```

The following commands should be reviewed for proper axis compatibility when connecting to a non-Newport stage – assuming that it is *electrically* compatible with the controller (1.e., level 2):

```
ZA          //set amplifier configuration
ZB          //set feedback configuration
ZH          //set hardware limit configuration
```


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Appendix H – Factory Service

This section contains information regarding factory service for the ESP301 motion controller. The user should not attempt any maintenance or service of the system or optional equipment beyond the procedures outlined in the Trouble-Shooting appendix of this manual. Any problem that cannot be resolved should be referred to Newport Corporation. For service, contact information is listed in **Table H-1** below.

Telephone	1-800-222-6440
Fax	1-949-253-1479
Email	service@newport.com
Web Page URL	www.newport.com/servicesupport/

Table H-1: Technical Customer Support Contacts

Contact Newport to obtain information about factory service. Telephone contact number(s) are provided on the Service Form (see next page). Please have the following information available:

- Equipment model number (ESP301)
- Equipment serial number (for the ESP301)
- Distribution revision number from a floppy disk
- Problem description (document using the Service Form, following page)

If the instrument is to be returned for repair, you will be given a Return Authorization Number that should be referenced in your shipping documentation. Complete a copy of the Service Form on the next page and include it with your shipment.

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Newport Corporation
U.S.A. Office: 800-222-6440
FAX: 949/253-1479

Name _____ **Return Authorization #_____**
(Please obtain RA# prior to return of item)

Company _____
(Please obtain RA # prior to return of item)

Address _____ _____Date _____

Country _____ Phone Number _____

P.O. Number _____ FAX Number _____

Item(s) Being Returned:

Model # _____ Serial # _____

Description _____

Reason for return of goods (please list any specific problems):

_____

_____

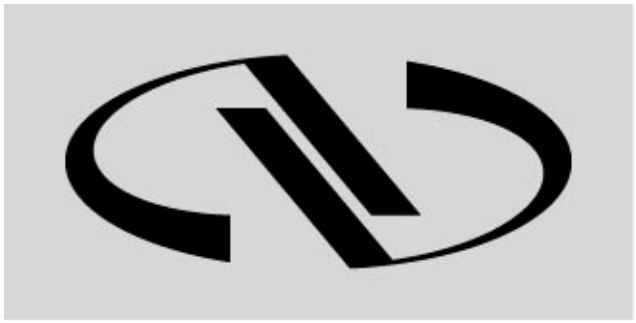
_____

_____

_____

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