TRIO™ MPC-145 SERIES

DUAL 3-AXIS MOTORIZED MICROMANIPULATOR SYSTEM

WITH SYNTHETIC FOURTH DIAGONAL AXIS

OPERATION MANUAL

REV. 2.62C (20191001) (FW V2.62)

TRIO MPC-100
X= 3000 Y= 3000
Z=22000 Speed 0
MANIPULATOR SELECT
HOME
WORK
SPEED
PULSE
RELATIVE
TRIO
TRIO

SUTTER INSTRUMENT®

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(The picture on the cover page shows a TRIO MPC-100 ROE/controller and two TRIO MP-845M micromanipulators (one right-handed and the other left-handed). The Sutter Instrument dPatch Headstage shown mounted on each micromanipulator are not included in the TRIO MPC-145 Series system.)

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CE EU Declaration of Conformity

Application of Council Directives:
2014/30/EU (EMC), 2014/35/EU (LVD), and 2011/65/EU (RoHS 2)

Manufacturer's Name:	Sutter Instrument Company
Manufacturer's Address:	One Digital Drive Novato, CA. 94949 USA Tel: +1 415 883 0128
Equipment Tested:	**TRIO MPC-100-based & TRIO MPC-145 Series** Dual 3-Axis Motorized Micromanipulator Series System
Model(s):	TRIO MPC-100-based or TRIO MPC-145 Series system consisting of **TRIO-MPC-100** (controller & ROE (Rotary Optical Encoder) for user control), with Power adapter (100-240 VAC to 24VDC) (same as, and tested as, a QUAD/E **TRIO-845-M Series & MP-285-M & based (3DMS & MP-78)** (motorized micromanipulator/stage electromechanicals),
Conforms to Standards:	EMC Emissions: EN 61326-1:2013, including: EN 55011: 2009 Group 1, Class A; EN 61000-3-2:2015, & EN 61000-3-3:2014 EMC Immunity: EN 61000-4-2:2009, EN 61000-4-3:2011, EN 61000-4-4:2012, EN 61000-4-5:2014, EN 61000-4-6:2014, EN 61000-4-8:2010, & EN 61000-4-11:2004 LVD (Safety): EN 61010-1:2010
Tested/Verified (as a QUAD system on which the TRIO series systems are based, and part on MPC-200 Series systems) by:	ITC Engineering Services, Inc 9959 Calaveras Road, PO Box 543 Sunol, CA 94586-0543 USA Tel. +1 925 862 2944 Fax: +1 925 862 9013 Email: itcemc@itcemc.com Web: www.itcemc.com Sutter Instrument
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Sutter Instrument Company hereby declares that the equipment specified above was tested and conforms to the EU Directives and Standards listed above, and further certifies conformation to the requirements of the European Union's Restriction on Hazardous Substances in Electronic Equipment Directive 2011/65/EU (RoHS 2).

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DISCLAIMER

The **TRIO MPC-145** series system consists of one or two electromechanical micromanipulator devices and one TRIO MPC-100 ROE (Rotary Optical Encoder) with integrated controller. The purpose of the system is for the manipulation at the micro level of micropipettes and probes used in conjunction with a microscope. No other use is recommended.

This instrument is designed for use in a laboratory environment. It is not intended nor should it be used in human experimentation or applied to humans in any way. This is not a medical device.

Unless otherwise indicated in this manual or by Sutter Instrument Technical Support for reconfiguration, do not open or attempt to repair the instrument.

Do not allow an unauthorized and/or untrained operative to use this device.

Any misuse will be the sole responsibility of the user/owner and Sutter Instrument Company assumes no implied or inferred liability for direct or consequential damages from this instrument if it is operated or used in any way other than for which it is designed.

SAFETY WARNINGS AND PRECAUTIONS

Electrical

- Operate the TRIO MPC-100 using 110 – 240 VAC., 50-60 Hz line voltage. This instrument is designed for use in a laboratory environment that has low electrical noise and mechanical vibration. Surge suppression is always recommended
- ⚠ NOTE: There are no user-replaceable fuses in the TRIO MPC-100 system.
- ⚠⚡ The TRIO MPC-100 system's power supply consists of an external AC to DC switching power adapter. If the external power adapter is damaged due to a mains over or under voltage, it must be replaced.
- ⚠⚡ GROUNDING/EARTHING: Proper grounding protects the ROE/controller electronics, reduces/eliminates electromagnetic interference, and improves the safety of the system operator. The ROE/controller provides a socket (labeled GROUND) that accepts a banana plug attached to a suitably gauged insulated wire, the other end of which (alligator clip) connects to a solid, proper ground.

Avoiding Electrical Shock and Fire-related Injury

- Always use the grounded power cord provided to connect the system's power adapter to a grounded/earthed mains outlet (3-prong). This is required to protect you from injury in the event that an electrical hazard occurs.
- Do not disassemble the system. Refer servicing to qualified personnel.
- ⚡ To prevent fire or shock hazard do not expose the unit to rain or moisture.

Electromagnetic Interference

To comply with FDA and CE/EU electromagnetic immunity and interference standards; and to reduce the electromagnetic coupling between this and other equipment in your lab always use the type and length of interconnect cables provided for interconnecting the electro-mechanical devices and ROE/controller (refer to Technical Specifications for more details).

Operational

Failure to comply with any of the following precautions may damage this device.

- This instrument is designed for operation in a laboratory environment (Pollution Degree I) that is free from mechanical vibrations, electrical noise and transients.
- ⚠DO NOT CONNECT OR DISCONNECT THE CABLES BETWEEN THE CONTROLLER AND THE MECHANICAL UNITS WHILE POWER IS ON.
  Please allow at least 20 seconds after turning the unit off before disconnecting the mechanical units. Failure to do so may result in damage to the electronics.
- Operate this instrument only according to the instructions included in this manual.
- Do not operate if there is any obvious damage to any part of the instrument.
- ⚠Do not operate this instrument near flammable materials. The use of any hazardous materials with this instrument is not recommended and, if undertaken, is done so at the users' own risk.
- ⚠Do not operate if there is any obvious damage to any part of the instrument. Do not attempt to operate the instrument with the MP-845 electromechanical manipulator shipping tape in place or severe motor damage may result. When transporting the mechanical manipulator, be sure to reinstall the shipping tape (using masking tape or equivalent only) to the original locations. Failure to do this may result in damage to the motors.
- ⚠Never touch any part of the micromanipulator electromechanical device while it is in operation and moving. Doing so can result in physical injury (e.g., fingers can be caught and pinched between the moving parts of the micromanipulator).
- ⚠If the TRIO MPC-100 system is used in a microinjection environment, please observe the following. As with most micromanipulation devices, sharp micropipettes can fly out of their holder unexpectedly. Always take precautions to prevent this from happening. Never loosen the micropipette holder chuck when the tubing is pressurized, and never point micropipette holders at yourself or others. Always wear safety glasses when using sharp glass micropipettes with pressure tubing.
- ⚠Take care to ensure no cables pass close to the MP-845 electromechanical micromanipulator within the spherical movement limits of all its axes combined.

Other

- Retain the original packaging for future transport of the instrument.
- Sutter Instrument reserves the right to change specifications without prior notice.
- Use of this instrument is for research purposes only.

Handling Micropipettes

⚠Failure to comply with any of the following precautions may result in injury to the users of this device as well as those working in the general area near the device.

- The micropipettes used with this instrument are very sharp and relatively fragile. Avoid contact with micropipette tips to prevent accidentally impaling oneself.
- Always dispose of micropipettes by placing them into a well-marked, spill-proof "sharps" container.

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1. INTRODUCTION

1.1 Structure of the TRIO MPC-145 Series Documentation Package

The TRIO MPC-145 series is a single or dual 3-axis motorized micromanipulator system comprised of the TRIO MPC-100 ROE/controller, a power adapter, and one or two MP-845 (aluminum) or MP-845S/M (stainless steel) stepper-motor-based electromechanical micromanipulators. This manual consists of five parts: This chapter, Introduction, which provides an overview and general description of the TRIO MPC-145 series system; Chapter 2, Installation, which describes how to install, set up, and configure all components of the system; Chapter 3, Operations, which describes how to operate the TRIO MPC-100 ROE/controller; Chapter 4, External Control, describes how to control the system by computer; Chapter 5, Maintenance, describes how to perform routine and other maintenance; and Chapter 6, Reconfiguration, describes the reconfiguration possibilities of the TRIO MPC-100 ROE/controller.

1.2 Components of the TRIO MPC-145 System

Carefully remove all components from the shipping container. In addition to this manual, the following should be included:

- TRIO MPC-100 ROE Rotary Optical Encoder input device with built-in controller and external power adapter.
- MP-845 electromechanical micromanipulator
- 25-pin DSUB cable (connects the ROE/controller to the micromanipulator).
- Power adapter
- Power adapter AC mains cable appropriate for your location
- Ground/Earth cable
- USB Cable

1.3 Components of the TRIO MPC-145-2 System

Same components as the TRIO MPC-145 system, with an additional MP-845 electromechanical manipulator and 25-pin DSUB cable.

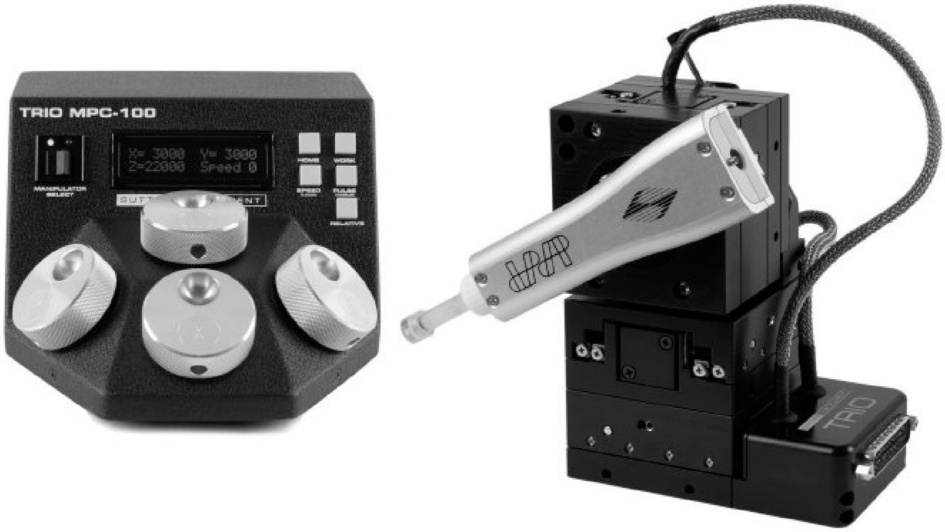
1.4 Components of the TRIO MPC-145S System

Same components as the TRIO MPC-145 system, with a stainless-steel MP-845S electromechanical manipulator.

1.5 Components of the TRIO MPC-145S-2 System

Same components as the TRIO MPC-145S system, with an additional MP-845S electromechanical manipulator and 25-pin DSUB cable.

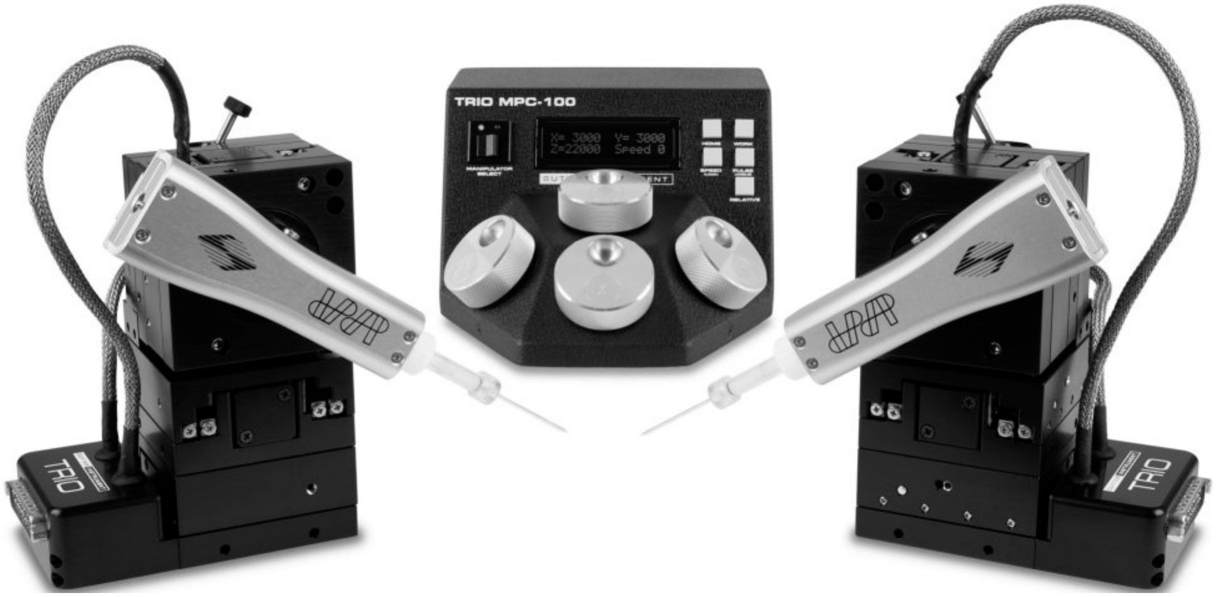
1.6 Overview



TRIO MPC-100 ROE/CONTROLLER

MP-845 SERIES ELECTROMECHANICAL MICROMANIPULATOR (E.G., A, RIGHT-HANDED)

Figure 1-1. The TRIO MPC-145 system



MP-845 SERIES ELECTROMECHANICAL MICROMANIPULATOR (E.G., B, LEFT-HANDED)

TRIO MPC-100 ROE/CONTROLLER

MP-845 SERIES ELECTROMECHANICAL MICROMANIPULATOR (E.G., A, RIGHT-HANDED)

Figure 1-2. The TRIO MPC-145-2 system

1.6.1 Features: TRIO MPC-100 Controller

- Controls one or two micromanipulators
- Three independent axes (X, Y, and Z) each with a virtual fourth axis (D) for coaxial pipette movement utilizing a tangent function factoring the holder's angle and the X and Z axes.
- Sub-micron 100nm resolution
- Digital display indicates coordinates in relative or absolute of active manipulator
- User-friendly, fanless compact controller with ROE preserves bench space
- Push button control of multiple functions – work, home, lock, pulse, relative mode, and angle set
- Robotic home- and work-position moves for easy automated pipette exchange
- Configuration DIP switches to select each axis' control knob rotation directionality
- USB interface for external computer control

1.6.2 Features: TRIO MP-845 3-Axis Micromanipulator Electromechanical

- Available in aluminum or thermally stable stainless steel (**TRIO MP-845S**)
- Mechanically robust construction for high stability
- Precision cross-roller bearings
- Three independent axes - 25 mm orthogonal travel in X, Y and Z
- Carries up to a kilogram
- Suited for *in vitro* and *in vivo* electrophysiological recording
- Universal mounting system for headstage or pipette holder

1.6.3 Description

Based on the original Sutter Instrument TRIO™ motorized 3-axis micromanipulator, the **TRIO MPC-100** expands the TRIO's capabilities by supporting up to two micromanipulators connected to a single ROE (Rotary Optical Encoder) and controller. A switch is provided on the front part of the controller for selecting which of the two manipulators is active for manual control. The X, Y, and Z axes provide 25mm range of motion (**MP-845** or **MP-845S**). D-axis movement virtually uses a tangent function of the chosen angle of the holder and simultaneously moving X and Z. The ROE controller has a digital display and keys for Home, Work, Pulse, Angle Set, Speed, Lock (Quiet) Mode, and Relative positioning. The compact, intuitive controller takes up minimal bench space, is fan-free, and easy to use.

While the axes provide X, Y, and Z orthogonal motion typical of most motorized manipulators, a synthetic diagonal axis is available with the **TRIO MPC-100** allowing one to move the electrode coaxially using X and Z at the exact desired angle of approach using a separate "D" control knob.

The **TRIO MPC-100's** ROE provides fine control of electrode position and the rate of rotation of ROE dials for each axis determines the speed of travel. The finest step size is less than 100nm. Five conveniently located buttons on the ROE provide control of all the basic functions you will need in normal operation (Work, Home, Speed/Lock, Relative, and Pulse/Angle).

Press and hold WORK (for 3 seconds) to quickly store a work position, tap HOME to move all axes to an initial location that is useful for changing electrodes, or press and hold the HOME button (for 3 seconds) to memorize a new HOME position.

When ready to record data, suppress the motor drive electronics by pressing and holding for 3 seconds the SPEED/LOCK button. In the LOCK mode, the display turns red and ROE input is locked out to avoid any accidental motion.

Pressing and holding the RELATIVE button for three seconds at any location causes the display coordinates to change to all zeroes. When activating relative mode, the display turns blue.

To return to viewing the absolute coordinates, tap the RELATIVE button to toggle back to absolute positioning mode.

Finally, tapping the PULSE button causes a 3μm advance in the diagonal. This rapid burst of forward motion can assist in sharp electrode cell penetration. Pressing and holding the PULSE button for 3 seconds allows for entering the angle to which the electrode/headstage is physically set so that X & Z coaxial (diagonal) movement is made at the correct angle.

All the electronics, except for a small power supply, are housed within the **TRIO MPC-100** ROE and no separate controller or computer is required.

External computer control of the **TRIO MPC-100** is possible via the USB connector mounted on the controller/ROE's rear panel. The controller's internal software is programmed with a defined set of commands allowing for a wide range of micromanipulator/stage movements as programmed in software residing in an external computer connected via USB.

Designed with maximum flexibility in mind, a DIP switch on the controller changes the directional movement of the ROE knobs to accommodate the preference of the user. A Y-axis lockout function (accessible by DIP switch) is also available, allowing X/Z-only axial movement during HOME and WORK repositioning. The TRIO comes standard with a universal mounting system suitable for the most popular headstages or pipette holders.

The new MP-845 micromanipulator features construction based on the TRIO-245, but with the addition of precision cross-roller bearings for even tighter tolerances, and a 25pin connector for future compatibility with our other controllers. The MP-845 is a highly stable 3-axis manipulator with 25 mm of travel on each axis. The TRIO MPC-100 controller gives the MP-845 a synthetic fourth axis that can be set in software to any angle between 0 and 90 degrees for diagonal movement. Based on a lead-screw design with a smaller overall size and footprint than most manipulators, the MP-845 is ideal for applications that require 2 pipettes in one setup or for setups where space is limited.

1.6.3.1 Stainless-Steel MP-845 (MP-845S)

The MP-845 manipulator is also available in stainless steel. The standard version of the **MP-845** has virtually no drift in its motor and bearing assemblies. The last remaining hurdle is that of thermal drift caused by the expansion and contraction of the aluminum body of the manipulator. By utilizing a stainless steel with very low coefficient of expansion, the **MP-845S** is simply the lowest drift manipulator available on the market. The added mass of the stainless-steel body has the additional benefit of dampening out vibration, giving the stainless **MP-845S** the silkiest movement of any manipulator.

Because low expansion stainless steels do have some ferric content, the stainless **MP-845S** is PVD coated in titanium nitride, giving it its distinctive gold color. This coating will ensure that the stainless trio will resist corrosion caused by exposure to salt solutions in a lab environment.

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2. INSTALLATION

When installing the TRIO MPC-100 system for the first time, it is recommended that the components of the system be installed in the following order: MP-845 electromechanical micromanipulator first, followed by the TRIO MPC-100/E ROE/Controller.

IMPORTANT

Once the TRIO MPC-145 series system has been unpacked, remove the shipping tape from the various locations on each MP-845 series electromechanical micromanipulator. The shipping tape must be removed before operating the TRIO MPC-100 system. If you need to transport the MP-845 series in the future, reapply 2 to 3-inch pieces of masking tape to the same locations. Once the tape has been removed, handle the MP-845 with care. The mechanisms can be damaged if any of the axes are inadvertently moved without the tape in place.

2.1 Mounting Instructions

The following sections describe how to mount the MP-845 manipulator to a stand using the mounting adapter plate, how to adjust the pipette angle and how to mount different headstages.

2.1.1 Mounting the MP-845 Series to the Stand or Platform

The MP-845 attaches to the mounting adapter plate using four M3.5x6 hex head locking screws.

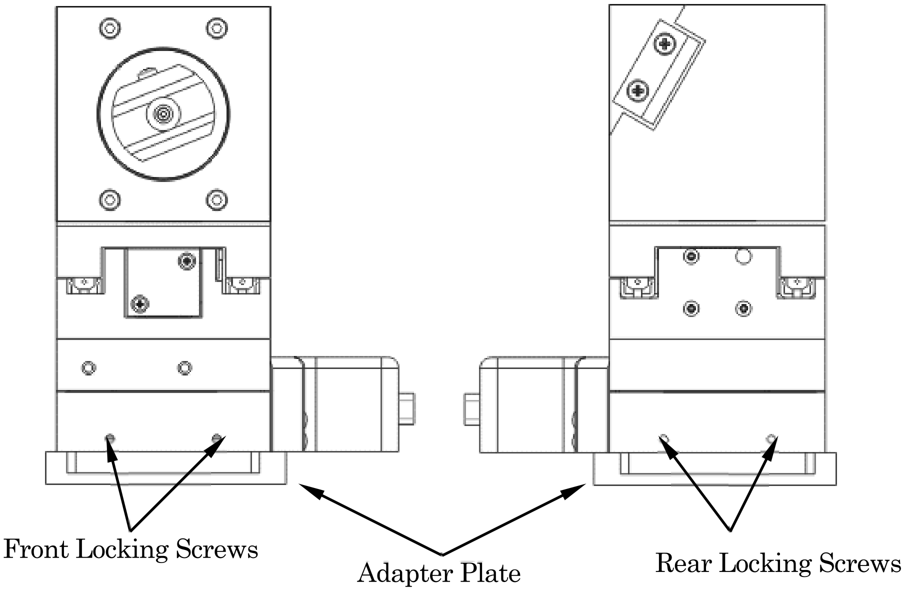


Figure 2-1. Side view of MP-845 showing mounting adapter plate and lock screws.

The MP-845 series is shipped with the adapter plate in place. It is attached using four tapered pegs, along with four locking screws.

To remove it, first loosen the four hex screws that secure the manipulator to the pegs in the adapter plate. The rear pair is in a similar location in the back of the manipulator. Once the locking screws are sufficiently loosened, lift the MP-845 upwards from the adapter plate.

Before attaching the adapter plate to the MP-845, you need to decide where to position the manipulator on your stand/platform. The stand can be any flat surface carrying ¼-20, 10-32, or M6 holes on one-inch centers (such as a Sutter Instrument MT-series stand or MD series platform).

Examine the space of the platform onto which installation is to take place. Attach the control cable to MP-845 and move the entire unit around on the platform until the precise desired position is determined. A small bag containing the necessary hardware to attach the MP-845 to the stand is included.

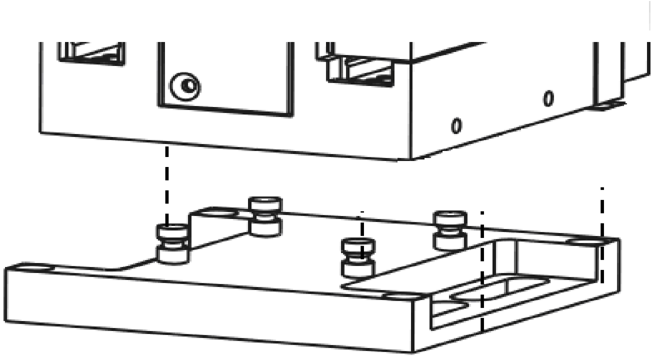


Figure 2-2. Mounting the MP-845 on the Adapter Plate

Once the plate is mounted, align the pegs on top of the plate with the holes in the manipulator, push the X-axis firmly onto the plate, and re-tighten the locking hex set screws.

2.2 Headstage Mounting

Sutter IPA headstage, Axon headstages 203B or CV-7, and the Heka EPC-10 headstage have an integral dovetail that fits directly into the rotary dovetail slide bracket on the MP-845. The dovetail slide bracket on the MP-845 also supports older Axon and Heka headstages when using the 4'' dovetail extension.

Rod-mounted headstages and micro tools are accommodated by the use of a rod clamp that fits into the dovetail (not shown). All the headstage adapters and mounting hardware are included with the manipulator and are shipped in a zip lock plastic bag.

2.3 Other Accessories

One or more accessories may have been ordered and received for mounting the MP-845 and/or modifying the headstage mount to the manipulator (i.e., rotating base, microscope stage mount, gantry, dovetail extension, etc.). Setup of these accessories is normally covered in documentation accompanying the accessory.

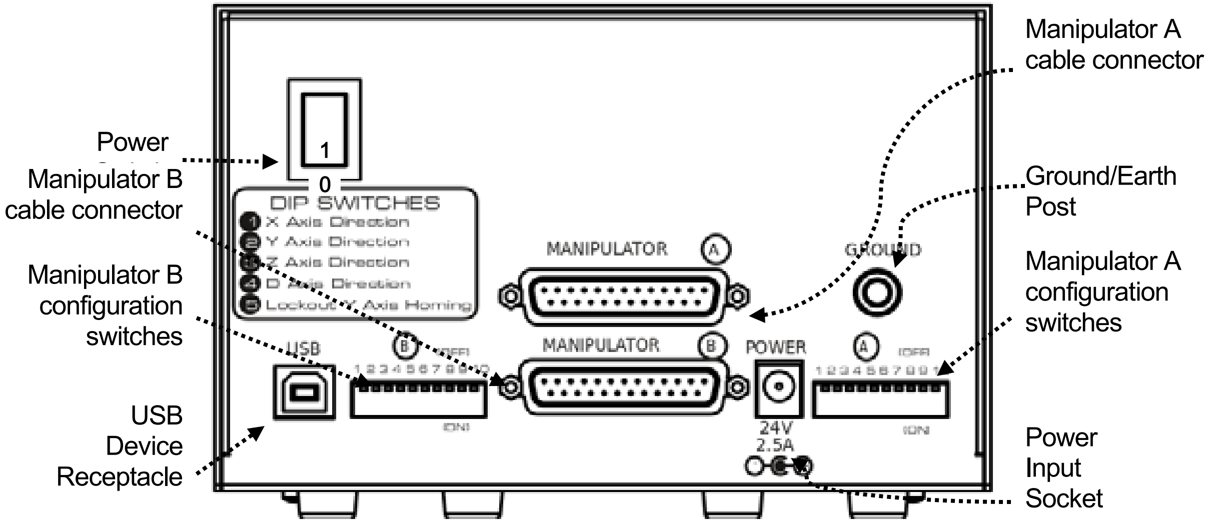
2.4 Electrical Connections and Initial Operating Instructions

Initially, you may want to simply connect the MP-845 micromanipulator and the ROE/Controller together and try some gross movements in order to get a feel for the controls and how to make simple movements. It is perfectly acceptable to set the manipulators in the middle of a bench top, make all electrical connections and then observe each unit's movement by eye.

⚠ **CAUTION: Unless the MP-845 micromanipulator electromechanical baseplate is firmly bolted down to a breadboard or solidly to a firm surface, the manipulator is likely to tip over when fully extending all of its axes, especially if it is loaded with a headstage that extends beyond the manipulator's current center of gravity.**

Upon deciding to directly install the TRIO MPC-100 system in your rig, it is useful to follow the initial setup procedure to learn how to move the units to allow easy access to the mounting screws.

1. With the power switch on the back of the ROE in the OFF (0) position, connect the power adapter's 24VDC cable to the POWER receptacle.


Power
Manipulator B cable connector
Manipulator B configuration switches
USB Device Receptacle
Manipulator A cable connector
Ground/Earth Post
Manipulator A configuration switches
Power Input Socket
1
0
DIP SWITCHES
1 X Axis Direction
2 Y Axis Direction
3 Z Axis Direction
4 D Axis Direction
5 Lockout Y Axis Homing
MANIPULATOR A
GROUND
USB
B (OFF) 1 2 3 4 5 6 7 8 9 10 (ON)
MANIPULATOR B
POWER
24V 2.5A
A (OFF) 1 2 3 4 5 6 7 8 9 10 (ON)

2. With the power OFF (rear panel switch in the "0" position), connect a well-grounded/earthed wire to the GROUND banana plug receptacle.
3. With the power OFF, connect the male end of the DB -25 cable to either MANIPULATOR connector on the ROE, the other end of which is connected to the MP-845, MP-845S, or MP-285M micromanipulator electromechanical or based stage. **(See cautionary note below.)**
4. Verify that the ten switches associated with the appropriate MANIPULATOR (A or B) on the rear of the ROE are set as desired.
5. Power up the system by moving the power switch on the rear of the ROE to the "1" position.

** ⚠ **CAUTION: NEVER CONNECT OR DISCONNECT THE ROE/CONTROLLER FROM EITHER ELECTROMECHANICAL MANIPULATOR/STAGE WHILE THE POWER IS ON!***

2.5 ROE/Controller Rear Panel Controls and Configuration

2.5.1 Power Switch

The power switch for the TRIO MPC-100 system is located on the rear panel of the ROE/controller. At power up, the microprocessor in the ROE/controller scans the attached equipment and configures the system accordingly.

CAUTION: When changing the configuration switches described in the following paragraphs, make sure that controller's power switch is turned off.

2.5.2 Configuration Switches

Each manipulator channel (A and B) has its own bank of configuration switches. Switch bank A affects only MANIPULATOR A, and switch bank B likewise for MANIPULATOR B.

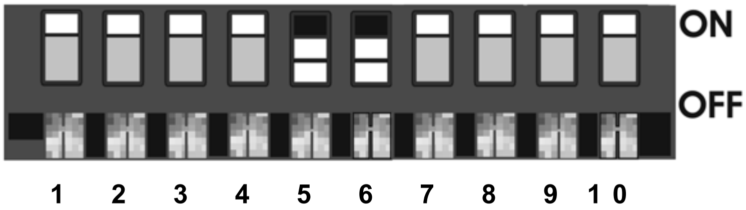


Figure 2-4. Configuration switches on rear of TRIO MPC-100 ROE/Controller unit (switch positions shown are factory defaults).

2.5.2.1 Switches 1, 2, 3 and 4

These switches set the directionality for each of the four axes.

Table 2-1. Configuration Switches 1 - 4: Configuring the direction of each axis.

Switch #	Definition	State	Setting	Position
1	**X-Axis Knob Directionality for Forward (+) Movement**	**Clockwise**	**OFF***	**UP***
		Counterclockwise	ON	DOWN
2	**Y-Axis Knob Directionality for Forward (+) Movement**	**Clockwise**	**OFF***	**UP***
		Counterclockwise	ON	DOWN
3	**Z-Axis Knob Directionality for Forward (+) Movement**	**Clockwise**	**OFF***	**UP***
		Counterclockwise	ON	DOWN
4	**D-Axis Knob Directionality for Forward (+) Movement**	**Clockwise**	**OFF***	**UP***
		Counterclockwise	ON	DOWN

**** Factory default (typical setting for right-hand-mounted manipulator).***

2.5.2.2 Switch 5: Y-Axis Lockout during Homing

Table 2-2. Configuration Switch 5: Configuring the Homing Y-Movement Lock Out.

Switch #	Definition	State	Setting	Position
5	**Y-Movement lock out during homing (pressing HOME or WORK)**	Enabled: Locked (no movement while X & Z are homing)	OFF	UP
		Disabled: Not locked (Y moves along with X & Z when homing)	**ON***	**DOWN***

**** Factory default (recommended normal operation setting)***

2.5.2.3 Switch 6: Calibration Homing on Power On

Table 2-3. Configuration Switch 6: Configuring the Sensor Test.

Switch #	Definition	State	Setting	Position
6	**Calibration Homing on Power On**	Disabled: No calibration occurs on power on. Power-off position is retained on power on	OFF	UP
		Enabled: Calibrates to 1,000 μm for all axes on power on. Power-off position is forgotten.	**ON***	**DOWN***

**** Factory default (recommended normal operation setting)***

2.5.2.4 Switches 7 & 8 Reserved

Switches 7 & 8 are reserved.

Table 2-4. Configuration Switches 7 & 8: Reserved.

Switch #	Definition	Setting	Position
7	**Reserved**	**OFF***	**UP***
8	**Reserved**	**OFF***	**UP***

**** Factory default (recommended normal operation setting).***

2.5.2.5 Switch 9 Electromechanical Device Compatibility

Table 2-5. Configuration Switch 9: Electromechanical device compatibility.

Switch #	Definition	State	Setting	Position
9	**Electromechanical device compatibility**	**MP-845[S]/M,** MP-245/M micromanipulators	**OFF***	**UP***
		MP-285/M micromanipulator; 3DMS & MT-78 stages; MOM & SOM objective movers	ON	DOWN

**** Factory default (recommended normal operation setting).***

2.5.2.6 *Switch 10 Linear/nonlinear manual movement*

Contact Sutter Instrument technical support for more information.

Table 2-6. Configuration Switch 10: Linear/nonlinear manual movement.

Switch #	Definition	Setting	Position
10	Linear/nonlinear manual movement	OFF*	UP*

**** Factory default (recommended normal operation setting).***

3. OPERATIONS

3.1 Main Controls and Indicators on the ROE/Controller

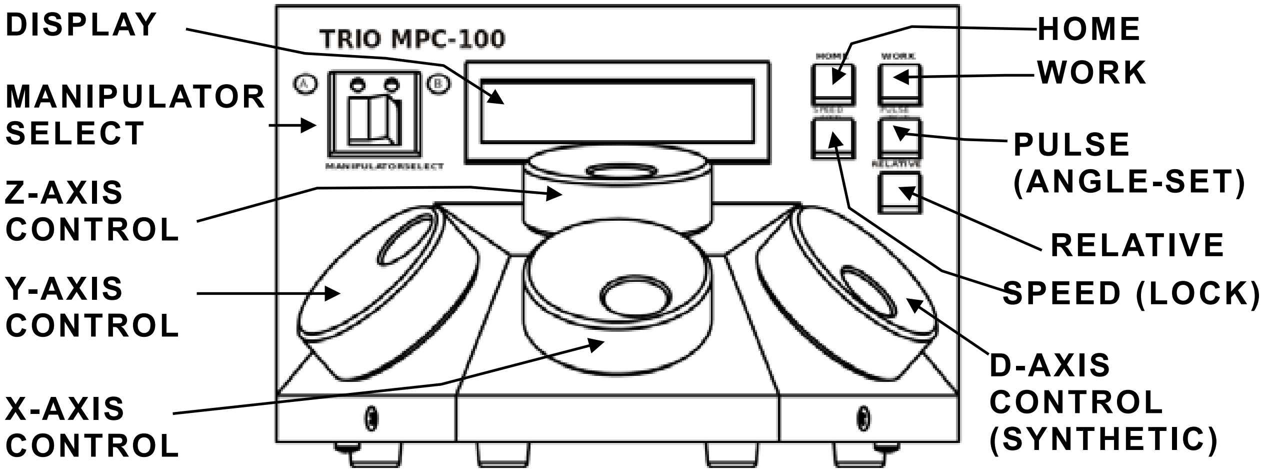
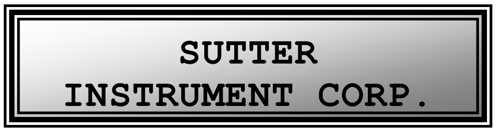

DISPLAY
MANIPULATOR SELECT
Z-AXIS CONTROL
Y-AXIS CONTROL
X-AXIS CONTROL
TRIO MPC-100
A
B
MANIPULATOR SELECT
HOME
WORK
SPEED
PULSE
RELATIVE
HOME
WORK
PULSE (ANGLE-SET)
RELATIVE
SPEED (LOCK)
D-AXIS CONTROL (SYNTHETIC)

Figure 3-1. Front view of the TRIO MPC-100 ROE/Controller

3.2 Display

3.2.1 Initial Startup

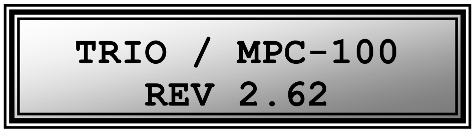


```
     SUTTER
INSTRUMENT CORP.
```

(Text in Green)

Figure 3-1. LCD Display showing startup screen.

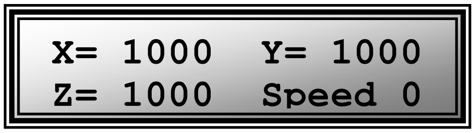
When starting the TRIO MPC-100 system for the first time or if the HOME position has not yet been defined (saved), the values of all four axes will be 1,000 micrometers (microns).



```
TRIO / MPC-100
   REV 2.62
```

(Text in Green)

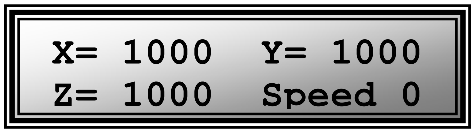
Figure 3-2. Startup screen



```
X= 1000  Y= 1000
Z= 1000  Speed 0
```

(Text in Green)

Figure 3-3. Device A factory default startup (Home) position after calibration



```
X= 1000  Y= 1000
Z= 1000  Speed 0
```

(Text in
Green)

Figure 3-4. Device B factory default startup (Home) position after calibration

3.3 Control Operations

3.3.1 Manipulator Select

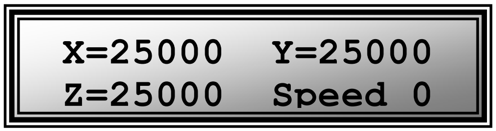
The MANIPULATOR select switch on the front of the TRIO MPC-100 ROE/controller is used to select which of two possible manipulators (or stages) is active for manual control using the axis control knobs and buttons or keys (HOME, WORK, etc.).

3.3.2 Maximum Positive Position Values:

Move the dial of an axis clockwise until its position value stops incrementing. The following table lists the maximum position value (in microns) for each axis.

Table 3-1. Maximum positive position value of each axis

Axis	**Maximum Position Value (in microns)**
X	25,000
Y	25,000
Z	25,000



```
X=25000  Y=25000
Z=25000  Speed 0
```

(Text in
Green)

Figure 3-5. Maximum positive values

3.3.3 Setting Position for HOME or WORK

To set position, hold down HOME or WORK button for 3 seconds until beep sounds.

3.3.4 Setting the Angle of the Pipette/Headstage Holder

To change the angle of the holder, first loosen the set screw at the top of the rotary dovetail bracket, rotate the holder to the desired angle, and then retighten the set screw.

Measure the angle of the holder. (Tip: Many smart phones have an app with a level that can assist the user.)

3.3.5 Operating the Virtual D Axis

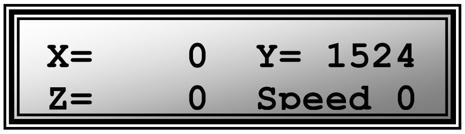
The TRIO MPC-100 consists of three physical axes, X, Y and Z. A tangent function utilizing X and Z axes and the angle of the holder has been implemented to create a virtual D axis. Use angles between 10° and 90° for best results.

Zero (0°) is set with the diagonal being parallel to the table and 90° is set with the diagonal being perpendicular to the table.

To set the angle measured above, on the ROE hold [PULSE]/ANGLE down for 3 seconds. The screen will be red until the display indicates in green: “Select the angle in use (0-90)”.

Use the D dial on the ROE to set the value of the angle. Once this value is dialed in, do not touch the ROE knob for 8-10 sec. The virtual D angle will now be set.

3.3.6 Moving to the Home Position

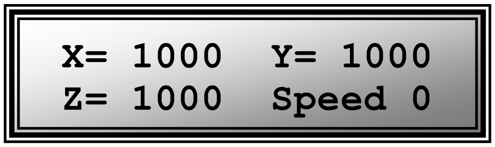


```
X=      0  Y= 1524
Z=      0  Speed 0
```

(Text in Red)

Figure 3-6. Moving to Home position (screen is amber while moving)

If the Home position has not yet been defined and saved, the Home position values for all axes will default to 1,000 microns, as shown in the following figure.

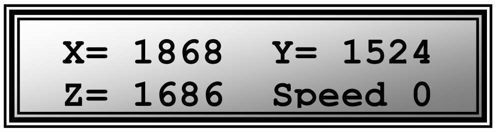


```
X= 1000  Y= 1000
Z= 1000  Speed 0
```

(Text in Green)

Figure 3-7. Factory default Home position

If the Home position has been previously defined (saved), pressing HOME will make a move to the defined home position (see example in the following figure).



```
X= 1868  Y= 1524
Z= 1686  Speed 0
```

(Text in Green)

Figure 3-8. Example Home position defined and saved

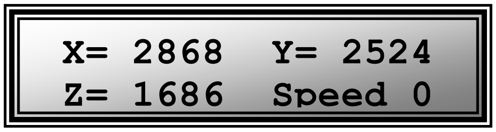
To move to the Home position, press HOME. If the current position before pressing HOME is greater than the Home position, the movement will be as follows:

NOTE: Movement to the Home position works only if X coordinates of the HOME position are less than the WORK position. HOME and WORK positions cannot be the same.

1. Movement begins by retracting the Z and X axes (at the angle currently set) away from the sample.
2. Movement then continues along the Y axis toward the Home position (towards the operator and away from the microscope).

NOTE: Step 2 occurs only if “Y-Lockout” is disabled. Otherwise, no movement along the Y-axis occurs.

3.3.7 Moving to the Work Position



```
X= 2868  Y= 2524
Z= 1686  Speed 0
```

(Text in
Green)

Figure 3-9. Example Work position

To move to the Work position, press the WORK button. If the current position before pressing WORK is less than the Work position, the movement will be as follows:

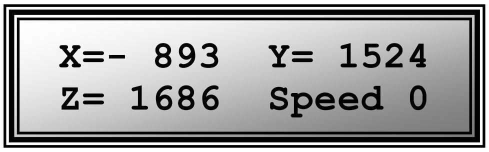
1. Movement travels along the Y-axis away from the operator and towards the microscope.
2. Movement is then made diagonally (according to angle setting) along the X and Z axes toward the sample.

NOTE: Step 1 occurs only if "Y-Lockout" is disabled. Otherwise, movement begins with Step 2.

3.3.8 Setting Absolute/Relative Coordinates Mode

The RELATIVE button toggles between Relative and Absolute coordinate systems. The default coordinate system on power up is Absolute, with the coordinates on the screen shown in green. To switch to relative coordinates, press the RELATIVE button once. To reset the current position to all zeroes, depress the RELATIVE button for 3 seconds or until a beep is heard, and then release the button. This resets the current position to all zeroes.

Press RELATIVE once (briefly for < 2 sec.)

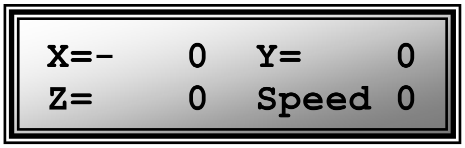


```
X=- 893  Y= 1524
Z= 1686  Speed 0
```

(Text in
Blue)

Figure 3-10. Relative mode

Depress RELATIVE for 3 sec. or until beep sounds

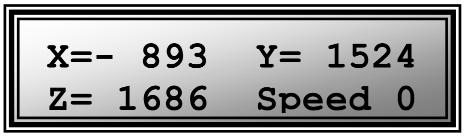


```
X=-    0  Y=     0
Z=     0  Speed 0
```

(Text in
Blue)

Figure 3-11. Relative mode

Pressing RELATIVE briefly while in Relative mode, returns displayed coordinates back to Absolute mode



```
X=- 893  Y= 1524
Z= 1686  Speed 0
```

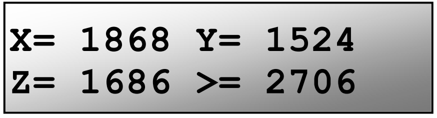
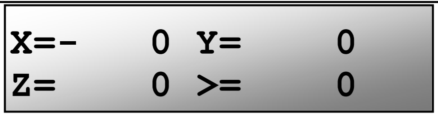
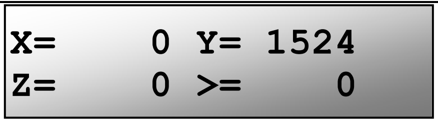
(Text in
Green)

Figure 3-12. Absolute mode

3.3.9 Mode Indications

The TRIO MPC-100 system has three modes of operation: Absolute coordinates, Relative coordinates, and Lock mode. The display turns color for each specific mode, as shown in the following table.

Table 3-2. Screen colors and modes

Screen Color	Mode	Example
Green	Absolute Coordinates	 X= 1868 Y= 1524 Z= 1686 >= 2706
Blue	Relative Coordinates	 X=- 0 Y= 0 Z= 0 >= 0
Red	Knobs disabled during move to Home or Work position, while in Lock mode.	 X= 0 Y= 1524 Z= 0 >= 0

3.3.10 Speed Control and ROE Knob Movements (SPEED)

The rate at which the ROE axis knobs move the manipulator can be adjusted with the SPEED button. Each press of the button cycles through four speeds: 0 (normal) through 3 (fastest).

3.3.11 Movement Knobs Disabling and Lock Mode ([SPEED]/LOCK)

Axis-movement knobs are disabled during movements to Home, Work, or while in Lock Mode (display is in red).

3.3.12 Pausing Home Movements (HOME (while moving to Home))

After Move to Home has been initiated, and while the move is in progress, pressing HOME a second time pauses the manipulator. Pressing HOME again resumes movement.

3.3.13 Pausing Work Movements (WORK (while moving to Work))

After Move to Work has been initiated, and while the move is in progress, pressing WORK a second time pauses the manipulator. Pressing WORK again resumes movement.

3.3.14 Pulse Mode and Virtual D-Axis Movement (PULSE)

Pulse mode advances the D axis in 2.85 μm steps. Each press of the PULSE button increments the Diagonal axis by one 2.85-μm step beyond the current position. This feature can be used to penetrate tough or resistant tissue.

3.4 Micropipette/Headstage Exchange

Mounted on the front of the Z-axis of the manipulator is the angle-control plate for the headstage mount.

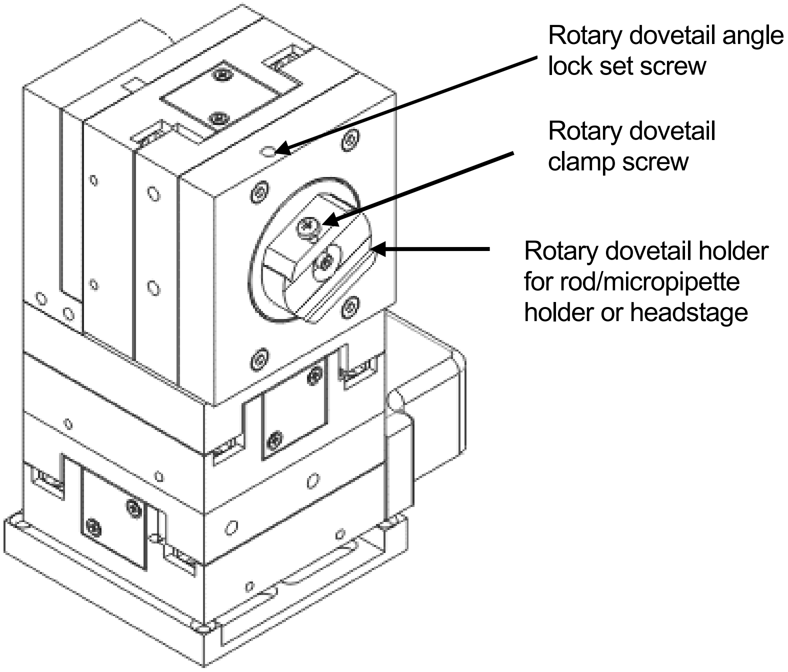

Rotary dovetail angle lock set screw
Rotary dovetail clamp screw
Rotary dovetail holder for rod/micropipette holder or headstage

Figure 3-13. Angled side view of MP-845 to change headstage mount

To change the headstage/micropipette, loosen the screw in the center of the rotary dovetail clamp. Slide the headstage upward out of the dovetail groove. Make any adjustments needed of the headstage, and then tighten down (but do not over tighten) the lock screw in the center of the holding bracket.

4. EXTERNAL CONTROL

4.1 General

Controlling the TRIO MPC-100 externally via computer is accomplished by sending commands over the USB interface between the computer and the USB connector on the rear panel of the TRIO MPC-100 controller/ROE. The USB device driver for Windows is downloadable from Sutter Instrument's web site (www.sutter.com). The TRIO MPC-100 requires Sutter Instrument's USB CDM (Combined Driver Model) Version 2.10.00 or higher. The CDM device driver consists of two device drivers: 1) USB device driver, and 2) VCP (Virtual COM Port) device driver. Install the USB device driver first, followed by the VCP device driver. The VCP device driver provides a serial RS-232 I/O interface between a Windows application and the TRIO MPC-100. Although the VCP device driver is optional, its installation is recommended even if it is not going to be used. Once installed, the VCP can be enabled or disabled.

The CDM device driver package provides two I/O methodologies over which communications with the controller over USB can be conducted: 1) USB Direct (D2XX mode), or 2) Serial RS-232 asynchronous via the VCP device driver (VCP mode). The first method requires that the VCP device driver not be installed, or if installed, that it be disabled. The second method requires that the VCP be installed and enabled.

Virtual COM Port (VCP) Serial Port Settings: The following table lists the required RS-232 serial settings for the COM port (COM3, COM5, etc.) generated by the installation or enabling of the VCP device driver.

Table 4-1. USB-VCP interface serial port settings.

Property	Setting
Data ("Baud") Rate (bits per second (bps))	57600
Data Bits	8
Stop Bits	1
Parity	None
Flow Control	None

The settings shown in the above table can be set in the device driver's properties (via the Device Manager if in Windows) and/or programmatically in your application.

4.2 Protocol and Handshaking

Command sequences do not have terminators. All commands return an ASCII CR (Carriage Return; 13 decimal, 0D hexadecimal) to indicate that the task associated with the command has completed. When the controller completes the task associated with a command, it sends ASCII CR back to the host computer indicating that it is ready to receive a new command. If a command returns data, the last byte returned is the task-completed indicator.

4.3 Command Sequence Formatting

Each command sequence consists of at least one byte, the first of which is the "command byte". Those commands that have parameters or arguments require a sequence of bytes that follow the command byte. No delimiters are used between command sequence arguments, and command sequence terminators are not used. Although most command bytes can be expressed as ASCII displayable/printable characters, the rest of a command sequence must generally be expressed as a sequence of unsigned byte values (0-255 decimal; 00 – FF hexadecimal, or 00000000 – 11111111 binary). Each byte in a command sequence transmitted to the controller must contain an unsigned binary value. Attempting to code command sequences as "strings" is not advisable. Any command data returned by the controller should be initially treated as a sequence of unsigned byte values upon reception. Groups of contiguous bytes can later be combined to form larger values, as appropriate (e.g., 2 bytes into 16-bit "word", or 4 bytes into a 32-bit "long" or "double word"). For the TRIO MPC-100, all axis position values (number of microsteps) are stored as "unsigned long" 32-bit positive-only values, and each is transmitted and received to and from the controller as four contiguous bytes.

4.4 Axis Position Command Parameters

All axis positional information is exchanged between the controller and the host computer in terms of microsteps. Conversion between microsteps and microns (micrometers) is the responsibility of the software running on the host computer (see *Microns/microsteps conversion* table for conversion factors).

Microsteps are stored as positive 32-bit values ("long" (or optionally, "signed long"), or "unsigned long" for C/C++; "I32" or "U32" for LabVIEW). "Unsigned" means the value is always positive; negative values are not allowed. The positive-only values can also be stored in signed type variables, in which case care must be taken to ensure that only positive values are exchanged with the controller.

The 32-bit value consists of four contiguous bytes, with a byte/bit-ordering format of Little Endian ("Intel") (most significant byte (MSB) in the first byte and least significant (LSB) in the last byte). If the platform on which your application is running is Little Endian, then no byte order reversal of axis position values is necessary. Examples of platforms using Little Endian formatting include any system using an Intel/AMD processor (including Microsoft Windows and Apple Mac OS X).

If the platform on which your application is running is Big Endian (e.g., Motorola PowerPC CPU), then these 32-bit position values must have their bytes reverse-ordered after receiving from, or before sending to, the controller. Examples of Big-Endian platforms include many non-Intel-based systems, LabVIEW (regardless of operating system & CPU), and Java (programming language/environment). MATLAB and Python (script programming language) are examples of environments that adapt to the system on which each is running, so Little-Endian enforcement may be needed if running on a Big-Endian system. Some processors (e.g., ARM) can be configured for specific endianess.

4.5 Microsteps and Microns (Micrometers)

All coordinates sent to and received from the controller are in microsteps. To convert between microsteps and microns (micrometers), use the following conversion factors (multipliers):

Table 4-2. Microns/microsteps conversion

TRIO MPC-100 Controller with Device	From/To Units	Conversion Factor (multiplier)
MP-845/M, MP-845S/M, or **MP-245/M*** micromanipulator	µsteps → µm	0.09375
	µm → µsteps	10.66666666667
MP-285/M micromanipulator; **3DMS** or **MT-78** stage; **MOM** or **SOM** objective mover	µsteps → µm	0.125
	µm → µsteps	8

** DB25 to DB26HD adapter required for MP-245/M.*

For accuracy in your application, type these conversion factors as “double” (avoid using the “float” type as it lacks precision with large values). When converting to microsteps, type the result as a 32-bit “long”, “signed long”, or “I32” integer. When converting to microns, type the result as “double” (64-bit double-precision floating-point values).

Table 4-3. Ranges (travel distances and bounds of each axis for compatible devices)

TRIO MPC-100 Controller with Device	Axis	Millimeters (mm)	Microns/-Micrometers (µm)	Microsteps (µsteps)
MP-845/M, MP-845S/M, or MP-245/M* micromanipulator	X, Y, & Z	0 – 25	0 – 25,000	0 – 266,667
MP-285/M micromanipulator; **3DMS** or **MT-78** stage; **MOM** or **SOM** objective mover	X, Y, & Z	0 – 25	0 – 25,000	0 – 200,000

** DB25 to DB26HD adapter required for MP-245/M (Manipulator Port A only).*

NOTE: Origin is a physical position of travel that defines the center of the absolute position coordinate system (i.e., absolute position 0).
Physical Positions: BOT (Beginning Of Travel), COT (Center Of Travel), & EOT (End Of Travel).
In the TRIO MP-145 Series, the Origin is fixed at BOT.

NOTE: Travel length of each axis is automatically determined by end-of-travel sensor.

4.6 Commands

4.6.1 Get Active Device & Firmware Version (‘K’) Command

This command is used to obtain the current-active device attached to the controller. The data returned is four bytes, the first of which is the device number (1 (MANIPULATOR A) or 2 (MANIPULATOR B), followed by the major version number, minor version number, and the completion indicator.

Table 4-4. Get Active Device & Firmware Version ('K') command.

Tx/-Delay /-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	75	4B	0100 1011	0075		**K**	Command
Rx	All	4	0	1 – 2	01 – 02	0000 0001 – 0000 0010		^A – ^B	<SOH> – <STX>	Currently-active device (1 – 2 (A – B)).
			1							Major version number (e.g., if ver. = 2.62, then byte = 2)
			2							Minor version number (e.g., if ver. = 2.62, then byte = 62)
			3	13	0D	0000 1101		^M	<CR>	Completion indicator

NOTE: The device number returned by the 'K' command indicates the active device for external commands only; it is completely independent of the manual A and B switch on the front of the MPC-100 ROE/controller.

4.6.2 Change Active Device ('I') Command

This command is used to change the currently-active device attached to the controller. One byte follows the command, consisting of a value of 1 (for Device A) or 2 (for Device B). Two bytes are returned: The first contains the device specified as confirmation, followed by the completion indicator.

Table 4-5. Change active device ('I') command.

Tx/-Delay /-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	2	0	73	49	0100 1001	0073		**I**	Command
			1	1-2	01 – 02	0000 0001 – 0000 0010	0001 – 0002	^A – ^B	<SOH> – <STX>	Manipulator to be made active (by value: 1(for A) or 2 (for B)
Rx	All	2	0	1-2	01 – 02	0000 0001 – 0000 0010		^A – ^B	<SOH> – <STX>	Manipulator value specified
			1	13	0D	0000 1101		^M	<CR>	Completion indicator

NOTE: The device number specified with the 'I' command is the active device for external commands only; it is completely independent of the manual A and B switch on the front of the MPC-100 ROE/controller.

4.6.3 Get Current Position and Angle ('c' or 'C') Command

This command is used to obtain the current position (X, Y, & Z coordinates) of the manipulator or stage and the current angle setting. The command sequence consists of one byte as shown in the following table. The data received consists of fourteen bytes containing X, Y, & Z position (32-bit) values in microsteps (4 bytes each), the angle in degrees (1 byte), and the completion indicator (1 byte).

Table 4-6. Get Current Position and Angle (‘c’ or ‘C’) command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	99 or 67	63 or 43	0110 0011 or 0100 0011	0099 or 0043		‘c’ or ‘C’	Command
Rx.	All		0 (4)							X pos. in µsteps
			4 (4)							Y pos. in µsteps
			8 (4)							Z pos. in µsteps
			12 (1)	0 – 90	00 – 5A	0000 0000 – 0101 1010			<NUL> – ‘z’	Angle in degrees
			13	13	0D	0000 1101		^M	<CR>	Completion indicator

NOTE: See Microns/microsteps conversion table for conversion from µsteps to µm (microns).

NOTE: All positions are in microsteps (µsteps): 32-bit (4 bytes) positive (unsigned) values, in Little Endian bit order (see Notes).

4.6.4 Move to Controller-Defined HOME Position (‘h’) Command

This command moves to the position saved by the controller’s HOME button. **X & Z** move first (angle determines order and simultaneity), and **Y** last.

Table 4-7. Move to controller-defined HOME position (‘h’) command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	104	68	0110 1000	0104		‘h’	Command
Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator

4.6.5 Move to Controller-Defined WORK Position (‘w’) Command

This command moves to the position saved by the controller’s WORK button. **Y** moves first, and **X & Z** last (angle determines order/simultaneity).

Table 4-8. Move to controller -defined WORK position (‘w’) command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx		1	0	119	77	0111 0111	0119		‘w’	Command
Rx		1	0	13	0D	0000 1101			<CR>	Completion indicator

4.6.6 Move to Specified “Home” Position (‘H’) Command

This command instructs the controller to move all 3 axes to specified position, moving **X & Z** (angle determines order/simultaneity), and **Y** last (see *Ranges* table).

Table 4-9. Move to specified "Home" position ('H') command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	13	0	72	48	0100 1000	0072		'H'	Command
			1 (4)							X µsteps
			5 (4)							Y µsteps
			9 (4)							Z µsteps
Rx	All	1	0	13	0D	0000 1101		^M	<CR>	Completion indicator

NOTE: All positions are in microsteps (µsteps): 32-bit (4 bytes) positive (unsigned) values, in Little Endian bit order (see Notes).

4.6.7 Move to Specified "Work" Position ('W') Command

This command instructs the controller to move all 3 axes to specified position, moving **Y** first, and **X & Z** last (angle determines order/simultaneity) (see *Ranges* table).

Table 4-10. Move to specified "Work" position ('W') command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	13	0	87	57	0101 0111	0087		'W'	Command
			1 (4)							X µsteps
			5 (4)							Y µsteps
			9 (4)							Z µsteps
Rx	All	1	0	13	0D	0000 1101		^M	<CR>	Completion indicator

NOTE: All positions are in microsteps (µsteps): 32-bit (4 bytes) positive (unsigned) values, in Little Endian bit order (see Notes).

4.6.8 Move in Straight Line to Specified Position at Specified Speed ('S') Command

This command instructs the controller to move all three axes simultaneously in a straight line to specified position (see *Ranges* table), at a specified speed (1 of 16 speeds). The command sequence consists of fourteen bytes.

Table 4-11. Straight-line move to specified position ('S') command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	14	0	83	53	0101 0011	0083		'S'	Command
			1 (1)	15 – 0	0F – 00	0000 1111 – 0000 0000	0015 – 0000	^O – ^@		Speed (15 – 0 (fastest through slowest))
			2 (4)							X µsteps
			6 (4)							Y µsteps
			10(4)							Z µsteps

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Rx	All	1	0	13	0D	0000 1101		^M	<CR>	Completion indicator

NOTE: All positions are in microsteps (μsteps): 32-bit (4 bytes) positive (unsigned) values, in Little Endian bit order (see Notes).

While all move commands cause movement to occur at a rate of 5,000 microns/second, the "Straight-Line Move 'S' command is specified with one of sixteen speeds. Actual speed for the can be determined with the following formula: (5000 / 16) * (sp +1), where 5,000 is the maximum speed in microns/second and "sp" is the speed level 0 (slowest) through 15 (fastest). For mm/second or microns/millisecond, multiply result by 0.001.

Table 4-12. Straight-Line Move 'S' Command Speeds.

Speed Setting (2nd Argument of 'S' Command Seq.)	mm/sec or μm/ms	μm/sec or nm/ms	nm/sec	in/sec or mil/ms	Percentage of Maximum
15	5.0000	5000.0	5000000	0.196850394	100.00%
14	4.6875	4687.5	4687500	0.184547244	93.75%
13	4.3750	4375.0	4375000	0.172244094	87.50%
12	4.0625	4062.5	4062500	0.159940945	81.25%
11	3.7500	3750.0	3750000	0.147637795	75.00%
10	3.4375	3437.5	3437500	0.135334646	68.75%
9	3.1250	3125.0	3125000	0.123031496	62.50%
8	2.8125	2812.5	2812500	0.110728346	56.25%
7	2.5000	2500.0	2500000	0.098425197	50.00%
6	2.1875	2187.5	2187500	0.086122047	43.75%
5	1.8750	1875.0	1875000	0.073818898	37.50%
4	1.5625	1562.5	1562500	0.061515748	31.25%
3	1.2500	1250.0	1250000	0.049212598	25.00%
2	0.9375	0937.5	937500	0.036909449	18.75%
1	0.6250	0625.0	625000	0.024606299	12.50%
0	0.3125	0312.5	312500	0.012303150	6.25%

4.6.9 Interrupt Straight-Line Move ('^C') Command

This command interrupts a move in progress (only for moves initiated by the "Straight-line" move ('S') command). The command sequence consists of one byte.

Table 4-13. Interrupt a straight-line move in progress ('^C') command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	3	03	0000 0011	0003	^C	<ETX>	Command
Rx		1	0	13	0D	0000 1101			<CR>	Completion indicator

4.6.10 Move to Specified X-Axis Position ('x' or 'X') Command

This command moves to a specified position for only the X-axis.

Table 4-14. Move to specified X-axis position ('x' or 'X') command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	5	0	120 or 90	78 or 5A	0111 1000 or 0101 1010	0120 or 0090		'x' or 'X'	Command
			1 (4)							X µsteps
Rx		1	0	13	0D	0000 1101			<CR>	Completion indicator

NOTE: All positions are in microsteps (µsteps): 32-bit (4 bytes) positive (unsigned) values, in Little Endian bit order (see Notes).

4.6.11 Move to Specified Y-Axis Position ('y' or 'Y') Command

This command moves to a specified position for only the Y-axis.

Table 4-15. Move to specified Y-axis position ('y' or 'Y') command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	5	0	121 or 91	79 or 5B	0111 1001 or 0101 1011	0121 or 0091		'y' or 'Y'	Command
			1 (4)							Y µsteps
Rx		1	0	13	0D	0000 1101			<CR>	Completion indicator

NOTE: All positions are in microsteps (µsteps): 32-bit (4 bytes) positive (unsigned) values, in Little Endian bit order (see Notes).

4.6.12 Move to Specified Z-Axis Position ('z' or 'Z') Command

This command moves to a specified position for only the Z-axis.

Table 4-16. Move to specified Z-axis position ('z') command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	5	0	122 or 92	7A or 5C	0111 1010 or 0101 1100	0122 or 0092		'z' or 'Z'	Command
			1 (4)							Z µsteps
Rx		1	0	13	0D	0000 1101			<CR>	Completion indicator

NOTE: All positions are in microsteps (µsteps): 32-bit (4 bytes) positive (unsigned) values, in Little Endian bit order (see Notes).

4.6.13 Setting the Angle ('A') Command

Sets the angle value, in degrees, to match the angle position of the rotary dovetail

Table 4-17. Set the angle ('A') command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	2	0	65	41	0100 0001	0065		'A'	Command
			1	0 – 90	00 – 5A	0000 0000 – 0101 1010	0000 – 0090		<NUL> – 'z'	Angle in degrees between 0 and 90. See *Angle Setting & Movement* note
Rx		1	0	13	0D	0000 1101			<CR>	Completion indicator

4.6.14 Recalibrate ('R') Command

Recalibrates the connected micromanipulator/stage to 1,000 microns in each axis.

Table 4-18. Recalibrate ('R') command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	82	52	0101 0010	0082		'R'	Command
Rx		1	0	13	0D	0000 1101			<CR>	Completion indicator

4.6.15 Notes

1. **Task-Complete Indicator:** All commands will send back to the computer the "Task-Complete Indicator" to signal the command and its associated function in controller is complete. The indicator consists of one (1) byte containing a value of 13 decimal (0D hexadecimal), and which represents an ASCII CR (Carriage Return).
2. **Intercommand Delay:** A short delay (usually around 2 ms) is recommended between commands (after sending a command sequence and before sending the next command).
3. **Clearing Send/Receive Buffers:** Clearing (purging) the transmit and receive buffers of the I/O port immediately before sending any command is recommended.
4. **Positions in Microsteps:** All positions sent to and received from the controller are in microsteps (μsteps). See *Microns/-microsteps conversion* table) for conversion between μsteps and microns (micrometers (μm)).
5. **Ranges and Bounds:** See *Ranges and Bounds* table for exact minimum and maximum values for each axis of each compatible device that can be connected. All move commands must include positive values only for positions – negative positions must never be specified. All positions are absolute as measured from the physical beginning of travel of a device's axis. In application programming, it is important that positional values be checked (>= 0 and <= max.) to ensure that a negative absolute position is never sent to the controller and that end of travel is not exceeded. All computational relative positioning must always resolve to accurate absolute positions.

6. **Absolute Positioning System Origin:** The Origin is set to a physical position of travel to define absolute position 0. The physical Origin position is fixed at beginning of travel (BOT). This means that all higher positions (towards end of travel (EOT)) are positive values; there are no lower positions and therefore no negative values are allowed.
7. **Absolute vs. Relative Positioning:** Current position ('c') and move commands always use absolute positions. All positions can be considered "relative" to the Origin (Position 0), but all are in fact absolute positions. Any position that's considered to be "relative" to the current position, whatever that might be, can be handled synthetically by external programming. However, care should be taken to ensure that all relative positions are accurately translated to correct absolute positions before initiating a move command.
8. **Position Value Typing:** All positions sent and received to and from the controller are in microsteps and consist of 32-bit integer values (four contiguous bytes). Position values can be either positive or negative, so type must be "signed". Although each positional value is transmitted to, or received from, the controller as a sequence of four (4) contiguous bytes, for computer application computational and storage purposes each should be typed as a signed integer ("long" or "signed long" in C/C++; "I32" in LabVIEW, etc.). Note that in Python, incorporating the optional NumPy package brings robust data typing like that used in C/C++ to your program, simplifying coding and adding positioning accuracy to the application.
9. **Position Value Bit Ordering:** All 32-bit position values transmitted to, and received from, the controller must be bit/byte-ordered in "Little Endian" format. This means that the least significant bit/byte is last (last to send and last to receive). Byte-order reversal may be required on some platforms. Microsoft Windows, Intel-based Apple Macintosh systems running Mac OS X, and most Intel/AMD processor-based Linux distributions handle byte storage in Little-Endian byte order so byte reordering is not necessary before converting to/from 32-bit "long" values. LabVIEW always handles "byte strings" in "Big Endian" byte order irrespective of operating system and CPU, requiring that the four bytes containing a microsteps value be reverse ordered before/after conversion to/from a multibyte type value (I32, U32, etc.). MATLAB automatically adjusts the endianess of multibyte storage entities to that of the system on which it is running, so explicit byte reordering is generally unnecessary unless the underlying platform is Big Endian. If your development platform does not have built-in Little/Big Endian conversion functions, bit reordering can be accomplished by first swapping positions of the two bytes in each 16-bit half of the 32-bit value, and then swap positions of the two halves. This method efficiently and quickly changes the bit ordering of any multibyte value between the two Endian formats (if Big Endian, it becomes Little Endian, and if Little Endian, it becomes then Big Endian).
10. **Travel Lengths and Durations:** "Move" commands might have short to long distances of travel. If not polling for return data, an appropriate delay should be inserted between the sending of the command sequence and reception of return data so that the next command is sent only after the move is complete. This delay can be auto calculated by determining the distance of travel (difference between current and target positions) and rate of travel. This delay is not needed if polling for return data. In either case, however, an appropriate timeout must be set for the reception of data so that the I/O does not time out before the move is made and/or the delay expires.
11. **Movement Speeds:** All move commands cause movement to occur at a rate of 5,000 microns/second, except for the "Straight-Line Move 'S' command which can be specified

with one of sixteen speeds. Actual speed for the "Straight-Line Move 'S' command can be determined with the following formula: (5000 / 16) * (sp +1), where 5,000 is the maximum speed in microns/second and "sp" is the speed level 0 (slowest) through 15 (fastest). For mm/second or microns/millisecond, multiply result by 0.001.

Table 4-19. Straight-Line Move 'S' Command Speeds.

Speed Setting	mm/sec or µm/ms	µm/sec or nm/ms	nm/sec	in/sec or mil/ms	% of Max.
15	5.0000	5000.0	5000000	0.196850394	100.00%
14	4.6875	4687.5	4687500	0.184547244	93.75%
13	4.3750	4375.0	4375000	0.172244094	87.50%
12	4.0625	4062.5	4062500	0.159940945	81.25%
11	3.7500	3750.0	3750000	0.147637795	75.00%
10	3.4375	3437.5	3437500	0.135334646	68.75%
9	3.1250	3125.0	3125000	0.123031496	62.50%
8	2.8125	2812.5	2812500	0.110728346	56.25%
7	2.5000	2500.0	2500000	0.098425197	50.00%
6	2.1875	2187.5	2187500	0.086122047	43.75%
5	1.8750	1875.0	1875000	0.073818898	37.50%
4	1.5625	1562.5	1562500	0.061515748	31.25%
3	1.2500	1250.0	1250000	0.049212598	25.00%
2	0.9375	0937.5	937500	0.036909449	18.75%
1	0.6250	0625.0	625000	0.024606299	12.50%

12. **Move Interruption and Concurrent Dual Manipulator Movements:** A command should be sent to the controller for a manipulator only after the task of any previous command for that same manipulator is complete (i.e., the task-completion terminator (CR) is returned associated with the manipulator). One exception is the "Interrupt Move" (^ C) command, which can be issued while an 'S' command-initiated move for a manipulator is still in progress. While a move is in progress for a manipulator (e.g., A), another move command sequence can be issued for the other manipulator (i.e., B).
13. **Angle Setting & Movement:** Although the set angle command allows for a range of 0° to 90°, the effective range that allows full movement is 1° to 89° (>0° and <90°). If 0° or 90°, Z or X axis fails to move, causing single- and multi-axis movement commands to fail. The ideal range for smooth movement is 10° to 80°. Factory default is 30°.

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5. MAINTENANCE

Routine cleaning of the TRIO MPC-100 system is required to prevent excessive dust accumulations. Wipe all exterior surfaces with a dry, soft, cotton cloth.

Periodically inspect all cables and connections to make sure that all connections are made well and that all connectors are well and evenly seated.

6. RECONFIGURATION

6.1 Changing the Rotary Knob Functions on the ROE/Controller

The axis motor assignment of each axis control knob on the ROE can be changed by opening the ROE/Controller cabinet as seen in the figure below and changing cables to appropriate connectors.

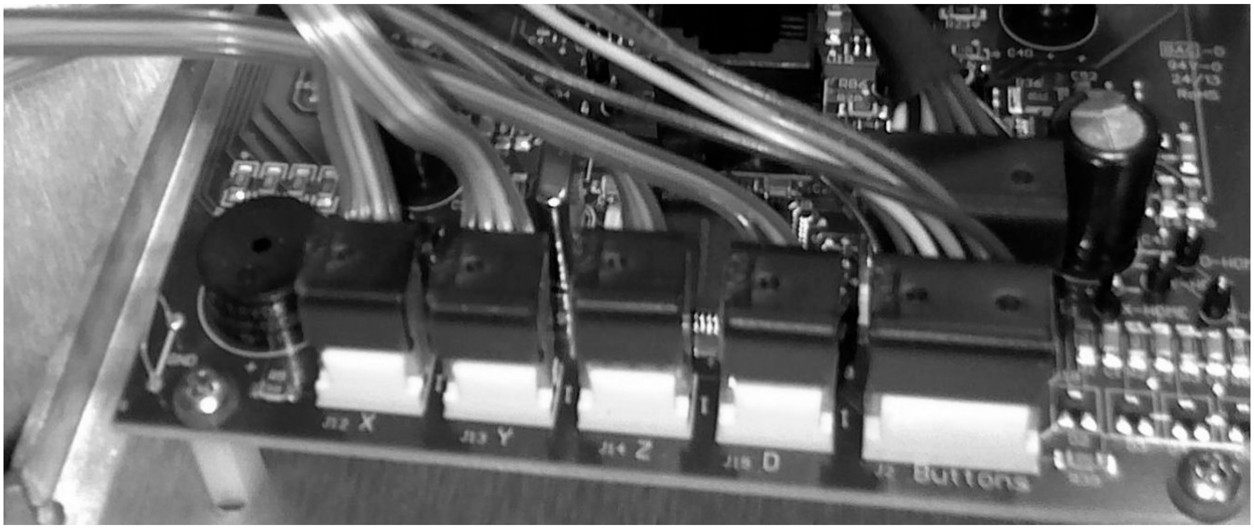

Figure 6-1. Locations of the axis connectors inside the ROE/Controller

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APPENDIX A. LIMITED WARRANTY

- Sutter Instrument Company, a division of Sutter Instrument Corporation, limits the warranty on this instrument to repair and replacement of defective components for two years from date of shipment, provided the instrument has been operated in accordance with the instructions outlined in this manual.
- Abuse, misuse, or unauthorized repairs will void this warranty.
- Warranty work will be performed only at the factory.
- The cost of shipment both ways is paid for by Sutter Instrument during the first three months this warranty is in effect, after which the cost is the responsibility of the customer.
- The limited warranty is as stated above and no implied or inferred liability for direct or consequential damages is intended.
- An extended warranty for up to three additional years can be purchased at the time of ordering, or until the original warranty expires. For pricing and other information, please contact Sutter Instrument.

APPENDIX B. ACCESSORIES

W621 150	Ground cable
285204	4-inch dovetail extension
285210	Mounting adapter plate
225RBI	Rotating base
221165	Z-axis vertical extension
BR-AW	Rod holding clamp for XenoWorks® injectors (for rod OD 2-4mm)
MP-ROD	Rod holder (for rod OD 6.25 mm or larger
MP-RISER-0.5	½-inch riser[*]
MP-RISER-1.0	1-inch riser[1]
MT-78-FS	Large fixed-stage platform
MT-78-FS/M6	Large fixed-stage platform with M6 tapped holes
MT-75	Standard gantry-stand 8.7 to 13.4 in (22.1 (22.098) to 33.9 (34.036) cm)
MT-75S	Short gantry-stand 6.7 to 9.6 in (16.9 (17.018) to 24.4 (24.384) cm)
MT-75T	Tall gantry-stand 10.7 to 15.4 in (27.2 (27.178) to 39.1 (39.116) cm)
MT-75XT	Extra tall gantry-stand 14.7 to 18.5 in (37.3 (37.338) to 47 (46.99) cm)

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[*] Risers can be combined to achieve desired height

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APPENDIX C. TECHNICAL SPECIFICATIONS

Travel	25mm on X, Y, and Z axes
Resolution	Minimal microstep size is 62.5 nanometers per microstep. Display has single micron resolution.
Speed	5 mm/sec.
Long Term Stability	< 1 micron/hour drive mechanism
Electrical:	
Power Adapter:	Meanwell GS60A24-P1J
Input (mains)	100 - 240 VAC, 50/60 Hz, 1.4A
Output (to controller)	24V DC, 2.5A, 60W Max. (see following table for cable specs)
System Power consumption	60-Watts maximum
Mains fuses	None replaceable (power protection built into the Power Adapter)
Cables	(Refer to the following tables for a description of all possible cables.)

Table C-1. TRIO MPC-100 cables and receptacles/connectors.

Controller Rear Panel Port Connector/-Receptacle	**Cable Connector Types**	**Connects to ...**	**Cable Type**	**Cable Max. Length**
Power Adapter 3-pin male connector	◄─3-pin power standard (female) | 3-pin male─► (Geographical region dependent)	**Mains power source.**	**10A, 250V, with safety ground plug**	**3 meters (approx. 10 feet)**
ROE/Controller Cabinet: MANIPULATOR A and MANIPULATOR B (25-Pin DSUB female receptacle)	◄─ DB-25 male | DB-25 female─► (Straight-through)	**MP-845/M, MP-845S/M, MP-245/M* or MP-285/M***	**Minimum of 26 awg stranded wire with 500 Volt.**	**3 meters (approx. 10 feet)**
Power Adapter	◄─(fixed) | ID 2.1 x OD 5.5 mm Barrel Plug (male)─►	**ROE/Controller Cabinet: POWER receptacle (center pin positive)**	**UL1185 18AWG**	**1.8 meters (approx. 6 feet)**
ROE/Controller Cabinet: GROUND (1-pin Banana-style female receptacle)	◄─Banana male | ─► Alligator clip (hooded)	**a ground/-earth source (user deter-mined)**		
ROE/Controller Cabinet: USB	◄─A | ─►B	**Computer USB port**		

** DB25 to DB26HD adapter required.*

*** Including 3DMS & MT-78 stages, MOM & SOM objective movers.*

Dimensions:

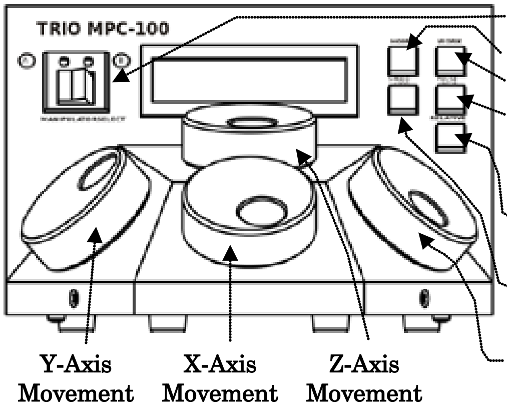
MPC-100 ROE/controller	**6.25 x 8 x 5.9 in | 15.9 x 20.3 x 14.986 cm**

Weight:

MPC-100 ROE/controller	**2.3 lbs. | 1.04 kg**
MP-845 micromanipulator	**3.5 lbs. | 1.6 kg**
MP-845S micromanipulator	**7.7 lbs. | 3.5 kg**

APPENDIX D. QUICK REFERENCE

D.1. Manual Operation


TRIO MPC-100
MANIPULATOR SELECT
Y-Axis Movement
X-Axis Movement
Z-Axis Movement

MANIPULATOR SELECT: Selects A or B manipulator.

HOME: Move to defined home position. Press again to pause/resume.

WORK: Move to defined work position. Press again to pause/resume.

PULSE (ANGLE SET): Advances diagonal axis in 2.85 μm steps. Hold 3-sec. for angle-set mode (active for 10 sec.) – use Knob D to change angle (0 – 90 degrees).

RELATIVE: Toggles between **Relative** and **Absolute** position moves. Hold 3-sec. for setting relative mode origin to current absolute position.

SPEED (LOCK): Cycles through Speed 0 (normal) through 3. Hold 3 sec. to enter lock (quiet) mode.

D-Axis Movement (Synthetic); select angle in degrees when in **ANGLE SET** mode.

Setting Home, Work, or Relative Mode Origin Position: To set position, hold down HOME, WORK, or RELATIVE button for 3 seconds until beep sounds.

Screen-color mode indications: Green = Absolute position; Blue = Relative position; Red = Movement in progress or in quiet (**LOCK**) mode; knobs disabled.

Movement Knobs Disabling and Lock (Quiet) Mode: Movement knobs are disabled during movement to Home, Work, external movement command, or while in Lock Mode.

Axis Movement Order: HOME: X & Z first, Y last. WORK: Y first. X & Z last.

X & Z movement precedence and simultaneity is determined by ANGLE setting: At 45°, movement is simultaneous; at <45°, Z has precedence; at >45°, X has precedence.

D.2. Configuration

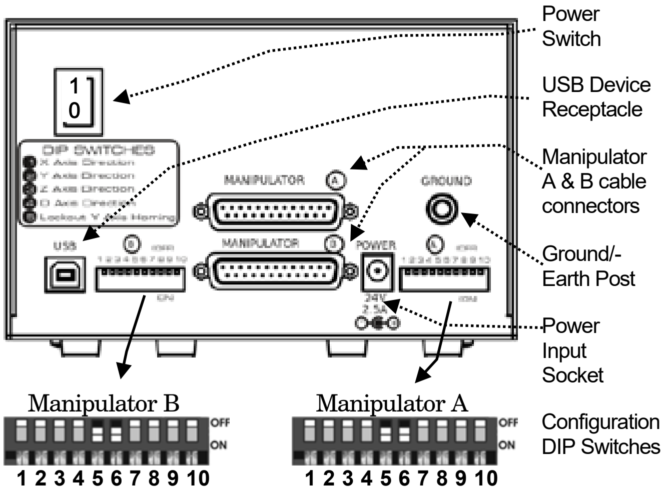

Power Switch
USB Device Receptacle
Manipulator A & B cable connectors
Ground/-Earth Post
Power Input Socket
Configuration DIP Switches
1
0
DIP SWITCHES
X Axis Direction
Y Axis Direction
Z Axis Direction
D Axis Direction
Lockout Y Axis Homing
USB
MANIPULATOR
A
B
GROUND
POWER
24V 2.5A
Manipulator B
Manipulator A
OFF
ON
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10

Table D-1. Configuration Switches 1 – 10

Sw #	Definition	State	Setting	Position
1	**X-Axis Knob Rotation for Forward (+) Movement**	**Clockwise**	**Off***	**Up***
		Counter	On	Down
2	**Y-Axis Knob Rotation for Forward (+) Movement**	**Clockwise**	**Off***	**Up***
		Counter	On	Down
3	**Z-Axis Knob Rotation for Forward (+) Movement**	**Clockwise**	**Off***	**Up***
		Counter	On	Down
4	**D-Axis Knob Rotation for Forward (+) Movement**	**Clockwise**	**Off***	**Up***
		Counter	On	Down
5	**Y Axis Lock Out for Homing**	Enabled	Off	Up
		Disabled	**On***	**Down***
6	**Calibration Homing on Power On ****	Disabled	Off	Up
		Enabled	**On***	**Down***
7	Reserved		**Off***	**Up***
8	Reserved		**Off***	**Up***
9	**Electromechanical device compatibility *****	**MP-x45[S]/M**	**Off***	**Up***
		MP-285/M	On	Down
10	**Linear/nonlinear manual movement ******		**Off***	**Up***

**** Normal operation (factory default).***

***** Switch 6 OFF (up) to retain axis positions on power-off.***

****** Switch 9 OFF (up) for MP-845[S]M & MP-245/M; ON (down) for MP-285/M & related devices (3DMS, MT-78, MOM/SOM objective movers).***

******* Contact Sutter Instrument tech. support for more information.***

D.3. External Control

Controlling the TRIO MPC-100 externally via computer is accomplished by sending commands over the USB interface between the computer and the USB connector on the rear panel of the TRIO MPC-100 controller/ROE. The USB device driver for Windows is downloadable from Sutter Instrument's web site (www.sutter.com). The TRIO MPC-100 requires Sutter Instrument's USB CDM (Combined Driver Model) Version 2.10.00 or higher. The CDM device driver consists of two device drivers: 1) USB device driver, and 2) VCP (Virtual COM Port) device driver. Install the USB device driver first, followed by the VCP device driver. The VCP device driver provides a serial RS-232 I/O interface between a Windows application and the TRIO MPC-100. Although the VCP device driver is optional, its installation is recommended even if it is not going to be used. Once installed, the VCP can be enabled or disabled.

The CDM device driver package provides two I/O methodologies over which communications with the controller over USB can be conducted: 1) USB Direct (D2XX mode), or 2) Serial RS-232 asynchronous via the VCP device driver (VCP mode). The first method requires that the VCP device driver not be installed, or if installed, that it be disabled. The second method requires that the VCP be installed and enabled.

Virtual COM Port (VCP) Serial Port Settings: The following table lists the required RS-232 serial settings for the COM port (COM3, COM5, etc.) generated by the installation or enabling of the VCP device driver.

Table D-2. USB-VCP interface serial port settings.

Property	Setting
Data ("Baud") Rate (bits per second (bps))	57600
Data Bits	8
Stop Bits	1
Parity	None
Flow Control	None

The settings shown in the above table can be set in the device driver's properties (via the Device Manager if in Windows) and/or programmatically in your application.

Protocol and Handshaking: Command sequences do not have terminators. All commands return an ASCII CR (Carriage Return; 13 decimal, 0D hexadecimal) to indicate that the task associated with the command has completed. When the controller completes the task associated with a command, it sends ASCII CR back to the host computer indicating that it is ready to receive a new command. If a command returns data, the last byte returned is the task-completed indicator.

Command Sequence Formatting: Each command sequence consists of at least one byte, the first of which is the "command byte". Those commands that have parameters or arguments require a sequence of bytes that follow the command byte. No delimiters are used between command sequence arguments, and command sequence terminators are not used. Although most command bytes can be expressed as ASCII displayable/printable characters, the rest of a command sequence must generally be expressed as a sequence of unsigned byte values (0-255 decimal; 00 – FF hexadecimal, or 00000000 – 11111111 binary). Each byte in a command sequence transmitted to the controller must contain an unsigned binary value. Attempting to code command sequences as "strings" is not advisable. Any command data returned by the controller should be initially treated as a sequence of unsigned byte values upon reception. Groups of contiguous bytes can later be combined to form larger values, as appropriate (e.g., 2 bytes into 16-bit "word", or 4 bytes into a 32-bit "long" or "double word"). For the TRIO MPC-100, all axis position values (number of microsteps) are stored as "unsigned long" 32-bit positive-only values, and each is transmitted and received to and from the controller as four contiguous bytes.

Axis Position Command Parameters: All axis positional information is exchanged between the controller and the host computer in terms of microsteps. Conversion between microsteps and microns (micrometers) is the responsibility of the software running on the host computer (see *Microns/microsteps conversion* table for conversion factors).

Microsteps are stored as positive 32-bit values ("long" (or optionally, "signed long"), or "unsigned long" for C/C++; "I32" or "U32" for LabVIEW). "Unsigned" means the value is always positive; negative values are not allowed. The positive-only values can also be stored in signed type variables, in which case care must be taken to ensure that only positive values are exchanged with the controller.

The 32-bit value consists of four contiguous bytes, with a byte/bit-ordering format of Little Endian ("Intel") (most significant byte (MSB) in the first byte and least significant (LSB) in the last byte). If the platform on which your application is running is

Little Endian, then no byte order reversal of axis position values is necessary. Examples of platforms using Little Endian formatting include any system using an Intel/AMD processor (including Microsoft Windows and Apple Mac OS X).

If the platform on which your application is running is Big Endian (e.g., Motorola PowerPC CPU), then these 32-bit position values must have their bytes reverse-ordered after receiving from, or before sending to, the controller. Examples of Big-Endian platforms include many non-Intel-based systems, LabVIEW (regardless of operating system & CPU), and Java (programming language/environment). MATLAB and Python (script programming language) are examples of environments that adapt to the system on which each is running, so Little-Endian enforcement may be needed if running on a Big-Endian system. Some processors (e.g., ARM) can be configured for specific endianess.

Microsteps and Microns (Micrometers): All coordinates sent to and received from the controller are in microsteps. To convert between microsteps and microns (micrometers), use the following conversion factors (multipliers):

Table D-3. Microns/microsteps conversion.

TRIO MPC-100 Controller with Device	From/To Units	Conversion Factor (multiplier)
MP-845/M, MP-845S/M, or **MP-245/M*** micromanipulator	μsteps → μm	0.09375
	μm → μsteps	10.66666666667
MP-285/M micromanipulator; **3DMS** or **MT-78** stage; **MOM** or **SOM** objective mover	μsteps → μm	0.125
	μm → μsteps	8

** DB25 to DB26HD adapter required for MP-245/M.*

For accuracy in your application, type these conversion factors as "double" (avoid using the "float" type as it lacks precision with large values). When converting to microsteps, type the result as a 32-bit "long", "signed long", or "I32" integer. When converting to microns, type the result as "double" (64-bit double-precision floating-point values).

Table D-4. Ranges and bounds.

Device	Axis	Len. (mm)	Origin	Microns (Micrometers (μm))	Microsteps (μsteps)
MP-845/M, MP-845S/M, or MP-245/M* micromanipulator	X, Y, Z	25	BOT	0 – 25,000	0 – 266,667
MP-285/M micromanipulator; **3DMS** or **MT-78** stage; **MOM** or **SOM** objective mover	X, Y, Z	25	BOT	0 – 25,000	0 – 200,000

** DB25 to DB26HD adapter required for MP-245/M.*

NOTE: Origin is a physical position of travel that defines the center of the absolute position coordinate system (i.e., absolute position 0).
Physical Positions: BOT (Beginning Of Travel), COT (Center Of Travel), & EOT (End Of Travel).
In the TRIO MPC-100, the Origin is fixed at BOT.

NOTE: Travel length of each axis is automatically determined by end-of-travel sensor.

Command Reference: The following table lists all the external-control commands for the TRIO MPC-100.

Table D-5. TRIO MPC-100 external control commands

Command	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
					Dec.	Hex.	Binary				
Get Active Device & Firmware Version (‘K’)	**Tx**	All	1	0	75	4B	0100 1011	0075		**K**	Command. Returns the currently active device, along with firmware version number.
	Rx	All	4	0	1 – 2	01 – 02	0000 0001 – 0000 0010		^A – ^B	<SOH> – <STX>	Currently-active device (1 – 2 (A – B)).
				1							Major version number (e.g., if ver. = 2.62, then byte = 2)
				2							Minor version number (e.g., if ver. = 2.62, then byte = 62)
				3	13	0D	0000 1101		^M	<CR>	Completion indicator
Change Active Device (‘I’)	**Tx**	All	2	0	73	49	0100 1001	0073		**I**	Command. Makes the specified device active, ensuring that all other commands are directed to that device.
				1	1-2	01 – 02	0000 0001 – 0000 0010	0001 – 0002	^A – ^B	<SOH> – <STX>	Manipulator to be made active (by value: 1(for A) or 2 (for B)
	Rx	All	2	0	1-2	01 – 02	0000 0001 – 0000 0010		^A – ^B	<SOH> – <STX>	Manipulator value specified
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
Get Current Position and Angle (‘c’ or ‘C’)	**Tx**	All	1	0	99 or 67	63 or 43	0110 0011 or 0100 0011	0099 or 0043		‘c’ or ‘C’	Command. Returns the current positions (µsteps) of X, Y, & Z axes and angle setting (degrees).
	Rx.	All	14		Three 4-byte (32-bit) values (current positions in µsteps of X, Y, & Z), + 1 byte for angle, & + 1 byte for completion indicator. See *Ranges* table for minimum and maximum values.						
				0 (4)							X pos. in µsteps
				4 (4)							Y pos. in µsteps
				8 (4)							Z pos. in µsteps
				12	0-90	00-5A	0000 0000 – 0101 1010			<NUL> – Z	Angle in degrees (0 – 90)
				13	13	0D	0000 1101		^M	<CR>	Completion indicator
Move to HOME Position (‘h’)	**Tx**	All	1	0	104	68	0110 1000	0104		‘h’	Command. Moves to the position saved by the controller’s HOME button. **X & Z** move first (angle determines order/simultaneity), and **Y** last.
	Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator
Move to WORK Position (‘w’)	**Tx**	All	1	0	119	77	0111 0111	0119		‘w’	Command. Moves to the position saved by the controller’s WORK button. **Y** moves first, and **X & Z** last (angle determines order/-simultaneity).
	Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator

Command	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
					Dec.	Hex.	Binary				
Move to Specified “Home” Position (‘H’)	**Tx**	All	13	0	72	48	0100 1000	0072		‘H’	Command. Move all 3 axes to specified position, moving **X & Z** (angle determines order/simultaneity), and **Y** last (see *Ranges* table).
				1 (4)							X μsteps
				5 (4)							Y μsteps
				9 (4)							Z μsteps
	Rx	All	1	0	13	0D	0000 1101		^M	<CR>	Completion indicator
Move to Specified “Work” Position (‘W’)	**Tx**	All	13	0	87	57	0101 0111	0087		‘W’	Command. Move all 3 axes to specified position, moving **Y** first, and **X & Z** last (angle determines order/simultaneity) (see *Ranges* table).
				1 (4)							X μsteps
				5 (4)							Y μsteps
				9 (4)							Z μsteps
	Rx	All	1	0	13	0D	0000 1101		^M	<CR>	Completion indicator
Move in Straight Line to Specified Position at Specified Speed (‘S’)	**Tx**	All	14	0	83	53	0101 0011	0083		‘S’	Command. Move all three axes simultaneously in a straight line to specified position (see *Ranges* table).
				1 (1)	15 – 0	0F – 00	0000 1111 – 0000 0000	0015 – 0000	^O – ^@		Speed (15 – 0 (fastest through slowest))
				2 (4)							X μsteps
				6 (4)							Y μsteps
				10(4)							Z μsteps
	Rx	All	1	0	13	0D	0000 1101		^M	<CR>	Completion indicator
Interrupt Straight-Line Move (^C)	**Tx**	All	1	0	3	03	0000 0011	0003	^C	<ETX>	Command. Interrupts a move in progress (only for moves initiated by the “Straight-line” move (‘S’) command).
	Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator
Move to specified X axis Position (‘x’ or ‘X’)	**Tx**	All	5	0	120 or 90	78 or 5A	0111 1000 or 0101 1010	0120 or 0090		‘x’ or ‘X’	Command. Move X axis to specified position (see *Ranges* table).
				1 (4)							X μsteps
	Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator
Move to specified Y axis Position (‘y’ or ‘Y’)	**Tx**	All	5	0	121 or 91	79 or 5B	0111 1001 or 0101 1011	0121 or 0091		‘y’ or ‘Y’	Command. Move Y axis to specified position (see *Ranges* table).
				1 (4)							Y μsteps
	Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator

Command	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
					Dec.	Hex.	Binary				
Move to specified Z axis Position ('z' or 'Z')	**Tx**	`All`	5	0	122 or 92	7A or 5C	0111 1010 or 0101 1100	0122 or 0092		'z' or 'Z'	Command. Move Z-axis to specified position (see *Ranges* table).
				1 (4)							Z μsteps
	Rx	`All`	1	0	13	0D	0000 1101			<CR>	Completion indicator
Enter Angle ('A')	**Tx**	`All`	2	0	65	41	0100 0001	0065		'A'	Command. Sets the angle value, in degrees, to match the angle position of the rotary dovetail.
				1	0 - 90	00 - 5A	0000 0000 - 0101 1010	0000 - 0090		<NUL> - 'z'	Angle in degrees between 0 and 90. See *Angle Setting & Movement* note
	Rx	`All`	1	0	13	0D	0000 1101			<CR>	Completion indicator
Recalibrate ('R')	**Tx**	2.6	1	0	82	52	0101 0010	0082		'R'	Command. Causes the currently active manipulator to recalibrate.
	Rx	2.6	1	0	13	0D	0000 1101			<CR>	Completion indicator
Query Moving State ('q' or 'Q')	**Tx**	2.6	1	0	81 or 113	51 or 71	1001 0001 or 0111 0001	0081 or 0113		'q' or 'Q'	Command. Reports the state of movement for each device.
	Rx	2.6	3	0	0	00	0000 0000		^@	<NUL>	Device 1: Not moving
					1	01	0000 0001		^A	<SOH>	Device 1: Movement in progress
				1	0	00	0000 0000		^@	<NUL>	Device 2: Not moving
					1	01	0000 0001		^A	<SOH>	Device 2: Movement in progress
				2	13	0D	0000 1101			<CR>	Completion indicator

NOTES:

1. **Task-Complete Indicator:** All commands will send back to the computer the "Task-Complete Indicator" to signal the command and its associated function in controller is complete. The indicator consists of one (1) byte containing a value of 13 decimal (0D hexadecimal), and which represents an ASCII CR (Carriage Return).
2. **Intercommand Delay:** A short delay (usually around 2 ms) is recommended between commands (after sending a command sequence and before sending the next command).
3. **Clearing Send/Receive Buffers:** Clearing (purging) the transmit and receive buffers of the I/O port immediately before sending any command is recommended.
4. **Positions in Microsteps:** All positions sent to and received from the controller are in microsteps (μsteps). See *Microns/-microsteps conversion* table) for conversion between μsteps and microns (micrometers (μm)).
5. **Ranges and Bounds:** See *Ranges and Bounds* table for exact minimum and maximum values for each axis of each compatible device that can be connected. All move commands must include positive values only for positions – negative positions must never be specified. All positions are absolute as measured from the physical beginning of travel of a device's axis. In application programming, it is important that positional values be checked (>= 0 and <= max.) to ensure that a negative absolute position is never sent to the controller and that end of travel is not exceeded. All computational relative positioning must always resolve to accurate absolute positions.
6. **Absolute Positioning System Origin:** The Origin is set to a physical position of travel to define absolute position 0. The physical Origin position is fixed at beginning of travel (BOT). This means that all higher positions (towards end of travel (EOT)) are positive values; there are no lower positions and therefore no negative values are allowed.
7. **Absolute vs. Relative Positioning:** Current position ('c') and move commands always use absolute positions. All positions can be considered "relative" to the Origin (Position 0), but all are in fact absolute positions. Any position that's considered to be "relative" to the current position, whatever that might be, can be handled synthetically by external programming. However, care should be taken to ensure that all relative positions are accurately translated to correct absolute positions before initiating a move command.
8. **Position Value Typing:** All positions sent and received to and from the controller are in microsteps and consist of 32-bit integer values (four contiguous bytes). Position values can be either positive or negative, so type must be "signed". Although each positional value is transmitted to, or received from, the controller as a sequence of four (4) contiguous bytes, for computer application computational and storage purposes each should be typed as a signed integer ("long" or "signed long" in C/C++; "I32" in LabVIEW, etc.). Note that in Python, incorporating the optional NumPy package brings robust data typing like that used in C/C++ to your program, simplifying coding and adding positioning accuracy to the application.

9. **Position Value Bit Ordering:** All 32-bit position values transmitted to, and received from, the controller must be bit/byte-ordered in "Little Endian" format. This means that the least significant bit/byte is last (last to send and last to receive). Byte-order reversal may be required on some platforms. Microsoft Windows, Intel-based Apple Macintosh systems running Mac OS X, and most Intel/AMD processor-based Linux distributions handle byte storage in Little-Endian byte order so byte reordering is not necessary before converting to/from 32-bit "long" values. LabVIEW always handles "byte strings" in "Big Endian" byte order irrespective of operating system and CPU, requiring that the four bytes containing a microsteps value be reverse ordered before/after conversion to/from a multibyte type value (I32, U32, etc.). MATLAB automatically adjusts the endianess of multibyte storage entities to that of the system on which it is running, so explicit byte reordering is generally unnecessary unless the underlying platform is Big Endian. If your development platform does not have built-in Little/Big Endian conversion functions, bit reordering can be accomplished by first swapping positions of the two bytes in each 16-bit half of the 32-bit value, and then swap positions of the two halves. This method efficiently and quickly changes the bit ordering of any multibyte value between the two Endian formats (if Big Endian, it becomes Little Endian, and if Little Endian, it becomes then Big Endian).
10. **Travel Lengths and Durations:** "Move" commands might have short to long distances of travel. If not polling for return data, an appropriate delay should be inserted between the sending of the command sequence and reception of return data so that the next command is sent only after the move is complete. This delay can be auto calculated by determining the distance of travel (difference between current and target positions) and rate of travel. This delay is not needed if polling for return data. In either case, however, an appropriate timeout must be set for the reception of data so that the I/O does not time out before the move is made and/or the delay expires.
11. **Movement Speeds:** All move commands cause movement to occur at a rate of 5,000 microns/second, except for the "Straight-Line Move 'S' command which can be specified with one of sixteen speeds. Actual speed for the "Straight-Line Move 'S' command can be determined with the following formula: (5000 / 16) * (sp +1), where 5,000 is the maximum speed in microns/second and "sp" is the speed level 0 (slowest) through 15 (fastest). For mm/second or microns/millisecond, multiply result by 0.001.

Table D-6. Straight-Line Move 'S' Command Speeds.

Speed Setting	mm/sec or µm/ms	µm/sec or nm/ms	nm/sec	in/sec or mil/ms	% of Max.
15	5.0000	5000.0	5000000	0.196850394	100.00%
14	4.6875	4687.5	4687500	0.184547244	93.75%
13	4.3750	4375.0	4375000	0.172244094	87.50%
12	4.0625	4062.5	4062500	0.159940945	81.25%
11	3.7500	3750.0	3750000	0.147637795	75.00%
10	3.4375	3437.5	3437500	0.135334646	68.75%
9	3.1250	3125.0	3125000	0.123031496	62.50%
8	2.8125	2812.5	2812500	0.110728346	56.25%
7	2.5000	2500.0	2500000	0.098425197	50.00%
6	2.1875	2187.5	2187500	0.086122047	43.75%
5	1.8750	1875.0	1875000	0.073818898	37.50%
4	1.5625	1562.5	1562500	0.061515748	31.25%
3	1.2500	1250.0	1250000	0.049212598	25.00%
2	0.9375	0937.5	937500	0.036909449	18.75%
1	0.6250	0625.0	625000	0.024606299	12.50%

12. **Move Interruption and Concurrent Dual Manipulator Movements:** A command should be sent to the controller for a manipulator only after the task of any previous command for that same manipulator is complete (i.e., the task-completion terminator (CR) is returned associated with the manipulator). One exception is the "Interrupt Move" (^C) command, which can be issued while an 'S' command-initiated move for a manipulator is still in progress. While a move is in progress for a manipulator (e.g., A), another move command sequence can be issued for the other manipulator (i.e., B).
13. **Angle Setting & Movement:** Although the set angle command allows for a range of 0° to 90°, the effective range that allows full movement is 1° to 89° (>0° and <90°). If 0° or 90°, Z or X axis fails to move, causing single- and multi-axis movement commands to fail. The ideal range for smooth movement is 10° to 80°. Factory default is 30°.

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